Proceedings of 2022 International Conference on Information Resources Management

18-20 October 2022

Conference theme:

Thriving Amidst Disruptive Technologies

Hosted by:

Ontario Tech University

Editors:
Lech Janczewski
Jairo Gutierrez
Patrick Hung
Amarolinda Klein

ISBN 78-0-473-65864-9 ISSN: 2744-6220

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1. Welcome Message from the Conf-IRM 2022 Program Co-Chairs

The International Conference on Information Resources Management (Conf-IRM), an affiliated conference of the Association for Information Systems (AIS), is known to be an inclusive, collaborative, and friendly environment where colleagues from around the world meet each other to share research ideas as well as build personal relationships. Conf-IRM is a venue for developing emerging scholars from every region of the world. We take great pride in seeing scholars who began their journey at one of our conferences go on to excel in the many ways they have. This is the 15th year for the conference hosted by the Faculty of Business and Technology, Ontario Tech University, Oshawa, Ontario, Canada. It builds on the traditions of previous conferences held in Canada, the United Arab Emirates, Jamaica, South Korea, Austria, Brazil, Vietnam, Canada, South Africa, Chile, China, New Zealand, and the USA. While this year's conference will be in a hybrid format, we have endeavored to put together a substantive and meaningful program.

This year, each submission underwent an extensive evaluation process to yield the final list of 29 accepted papers. Each paper was evaluated carefully, with some papers receiving as many as three to four reviews. In addition, Conf-IRM 2022 is aligned with the Special Issue on "Thriving Amidst Disruptive Technologies" in ACM Distributed Ledger Technologies: Research and Practice.

We wish to express our sincere appreciation to all the people who have contributed to Conf-IRM 2022. Our foremost thanks go to the authors of the submitted papers for their valuable ideas and substantial efforts. Information resources management continues to grow as a critical technological area with exciting research directions and abundant research innovations, as is evident from the number of paper submissions and the resulting quality of the Conf-IRM 2022 program. We are also very grateful for the hard work of the program committee members and the external reviewers, who have helped ensure the quality of the Conf-IRM 2022 program. The review process would not have been so thorough and effective without them. Finally, we are grateful to the Conf-IRM Executive/International Co-Chairs for their continuous and strong support during the organization and program development of Conf-IRM 2022.

We hope you enjoy the stimulating Conf-IRM program and your stay in Ontario!

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3. Tracks & Track Chairs

Tracks	Chairs
1. Big Data, Data Analytics, and Business Intelligence	• Sumeet Gupta – Indian Institute of Management Raipur, India • Colin Conrad – Dalhousie University, Canada
2. Enterprise Systems and Knowledge Management	• Brian Detlor, McMaster University, Canada • Dorit Nevo, Rensselaer Polytechnic Institute, USA
3. Digital Transformation, Management, and Governance	• Barbara Krumay, Johannes Kepler University Linz, Austria • Vik Pant - University of Toronto and University of Ottawa, Canada
4. Information Security, Privacy, and Risk Management	• Matthew Nicolas Kreeger - Entrust, Cambridge, UK • Khalil El-Khatib - OntarioTech University, Oshawa, Canada
5. Digital Information Systems in the Public Sector, Healthcare, Telecommunications, Transport and Education	• Marie Anne Macadar, Federal University of Rio de Janeiro, Brazil • Makoto Nakayama, DePaul University, USA
6. Digital Business Platforms, Blockchain, Social Networking, and the Internet of Things	• Eduardo Henrique Diniz, FGV, Brazil • Martin Potančok, Prague University of Economics and Business, Czech Republic • Tomáš Bruckner, Prague University of Economics and Business, Czech Republic
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6. Conference papers

1. A Method to Visualize Patient Flow Using Virtual Reality and Serious Gaming Techniques

Michael Scott Orr
Ontario Tech University
Michael.Orr3@ontariotechu.net

Andrew Hogue
Ontario Tech University
andrew.hogue@ontariotechu.ca

Carolyn McGregor
Faculty of Business and IT, Ontario Tech University
Faculty of Engineering and IT, University of Technology Sydney
c.mcgregor@ieee.org

Abstract

This paper proposes a method to visualize Emergency Department patient flow data in a Virtual Reality (VR) Serious Game (SG) environment. Visualizing the patient flow data will allow patterns and trends that hospitals can use to reduce alternative level of care (ALC) days and increase the acute capacity of the hospital. The method proposes to use Unity to develop two VR visualisations of patient flow to a hospital ED such that hospital staff can determine which of the two visualizations will be the most usable, immersive, and playable. This paper also presents future work that will look at the whole system of a hospital using one years' worth of patient flow data to develop a usable, immersive and playable Virtual Environment (VE).

Keywords: Usability, Data Visualization, Serious Gaming, Big Data, Virtual Reality, Unity.

1. Introduction

One of the most important key performance indicators in the Emergency Department (ED) is wait-times. Wait-times are affected by patient flow in and out of ED. There is an expectation that patients will not be staying in ED for extended periods of time waiting for their next steps in their care journey. ED design typically expects a patient's length of stay to be between two to three hours. Between 2013 and 2014 the ED's across Canada saw 10 million visits consisting of approximately 23% under the age of 19, 59% between 19 to 64 and 21% greater than 64 (CIHI & NACRS, 2014). Of the over 64 age group, 14% required admission to the hospital and waited 10 to 12 hours for the decision to be admitted. Once the decision to admit the patient is made, the patient has typically waited between 25 to 27 hours for an inpatient bed to become available (CIHI & NACRS, 2014). When it is necessary for a patient to be admitted, there is an additional burden on the ED of 2.5 times more care required to continually care for the patient until the inpatient bed becomes available (Drummond, 2002). Wait-time in ED is one of the most important factors affecting ED patient flow and efficiency (Sinclair, 2007). There are several contributing factors that compound the waiting time of patients who need to be admitted including lack of appropriate beds, shortage of staff specifically nurses, increase in complexity, acuity, treatments, volumes, appropriate discharge care and facilities to handle patient care (Drummond, 2002). A key identified area that impacts ED patient flow and efficiency in Canada is the lack of inpatient beds. With only 2.52 acute beds per 1000 in 2019, Canada is ranked 31 out of 38 in Organization for Economic Co-Operation and Development (OECD) (OECD, 2013; Organization for Economic Co-Operation and

Development, 2019). Canada acute inpatient bed occupancy is fourth at 91.6% the highest in 2019 compared to other OECD countries (Organisation for Economic Cooperation and Development (OECD), 2021). Another contributing factor to the lack of inpatients beds and high occupancy are long wait-times for patients ready to be discharged to Alternative Levels of Care (ALC) beds such as long-term care, rehabilitation, assisted living or community care (Affleck et al., 2012). ALC patients are accounting for 20% of the inpatient beds and are known as “bed blockers” (Drummond, 2002). By better understanding and visualizing where and how patients move through and out of the hospital, hospitals can identify bottlenecks and “bed blockers” as they occur and deal with active mitigation.

This paper presents a method that proposes to visualize patient flow using virtual reality (VR) and serious gaming (SG) technology using ED as the test case. We propose the design for initial usability testing to determine the most effective VR environment to visualize patient flow. The focus of the paper will be to provide examples of developed VR scenes of patient flow that can be used to determine which scene would be the most useable, immersive and playable. Unity (www.Unity.com), a game engine development environment, is an effective tool to use to develop a VR SG. The paper will detail usability and playability considerations for developing a VR SG. Considering usability and playability will ensure an immersive VR SG environment for end users to explore patient flow into, through and out of an ED. The paper will provide a proposal of a VR SG developed using Unity that will determine the most effective way to visualize patient flow in a virtual environment (VE). The paper also details future work to expand the work to include the complete VE of the patient journey through the hospital as a whole system.

2. Literature Review

Several methods to visualize patient flow have been previously proposed including dashboards, models and simulations. Dashboards typically present information as a grouping of charts and gauges that can be used to assess patient flow metrics (Buttigieg et al., 2017). Models illustrating the process of patients on their care journey have been used to detail patient flow (Mohiuddin et al., 2017). Simulations provide a model of patient flow that visually details the paths patients could take based on past information mathematically modelled (Clissold et al., 2015).

Henderson and Mason (2000) developed a user-friendly interface to a visualization of ambulance data to show current ambulance performance used to redesign and develop new and more efficient ambulance services (Henderson & Mason, 2000). Wang et al. (2008) performed a controlled usability study using a visualisation of data rendered in LifeLines2 that provides an environment to allow visualisation of temporal EHR data from many data sources (Wang et al., 2008). They found that clinicians’ response time to sentinel electronic medical record (EMR) events improved by 61%. The interface was found to be usable and intuitive for clinicians (Wang et al., 2008).

Two dimensional (2D) dashboards, models and simulation abstract or model operational patient flow but require expertise to interpret or use the associated software. Developing a VE using VR and SG principles of patient flow to the hospital, through their patient care journey and final discharge to an appropriate location has the potential to provide a more immersive three-dimensional (3D) environment. Hospitals can then more closely monitor their hospital ED and ALC patient flow performance. The VE must be developed to enable the hospital to view the VE not as a “game”, but an easy-to-use tool to examine patient flow into the ED. In Tsoy (2019) a SG was found to provide sufficient utility in teaching patient flow in the ED to physicians, nurses and students (Tsoy et al., 2019).

Big Data (BD) has experienced a large growth of data in healthcare. Both structured and unstructured data has grown from 500 petabytes in 2012 to an expected 25,000 petabytes in 2020 which can be attributed to the implementation of EMR computer systems (Feldman et al., 2012). BD is determined by data volume, velocity, variety, veracity and value known as the 5v’s (Laney, 2001). Data volume are large volumes of both structured and unstructured data contained in an organization and can include transactional, real-time streaming or even image data (Laney, 2001). Velocity is how fast the data is generated and consumed by an organization (Laney, 2001). Variety are the various format and data systems that are used within an organization. Veracity is the quality and trust level that an organization has of the data captured and used (Fosso Wamba et al., 2015). Finally, value is how useful and relevant the data is to the organization (Chen et al., 2014; Fosso Wamba et al., 2015; Gantz & Reinsel, 2011; Hashem et al., 2015). One of the key BD sets available in hospitals that are part of EMR's are Admission Discharge and Transfer (ADT) computer systems which capture the transactional patient flow from hospital admission to discharge along with all the changes of location the patient travels on their care journey. In addition to ADT the Discharge Abstract Database (DAD) and National Ambulatory Care Reporting, are BD sets that are supplied by the hospital to the government.

The freely available Unity game engine can handle large amounts of data that can be graphically visualized to expose patterns and trends (Djorgovski, 2012). Unity can scale large data sets (100, 000 data points) on modest hardware requirements (Djorgovski, 2012; Drechsler & Soeken, 2013). Challenges with working in Unity are to ensure the visualisation presents high density data sets in a way a user can readily view the exposed patterns. Drechsler and Soeken (2013) suggest that visualisation provides for "true-to-reality" rendering of data that can create a virtual world based on the data set used that has an intuitive feel that the end user can extrapolate to the real world (Drechsler & Soeken, 2013). Unity manages the physics of the virtual world and provides 3D asset creation and management that allow for efficient structuring of data into an effective visualisation.

2.4 Virtual Reality (VR) Usability

There are two main concepts that are used in VR to rate usability which are immersion and presence. Immersion can be viewed as the ability of a VR system to provide a sensory experience equivalent to the real-world experience (Slater, 2003). Iaha et al. (2014) define immersion as displays that can produce the same degree of realism and "sensory fidelity" we would experience in the real-world. With increasing fidelity of VR applications, sensory input will increase the level of immersion and corresponding sense of presence (Bowman et al., 2007).

Presence is about combining sensory data with perceptual processing in an environment to create a sense of "being there" (Slater, 2003). If presence is obtained in VR the user reacts to stimuli as if they were physically present in a real-world environment (Slater, 2003). Sutcliffe et al. (2004) describes presence as how "real or natural the user's experience" is in a VR environment (Sutcliffe & Gault, 2004).

2.5 Serious Gaming Usability

Zyda (2005) defines a serious game (SG) as "a mental contest, played with a computer in accordance with specific rules that uses entertainment to further government or corporate training, education, health, public policy, and strategic communication objectives" (Zyda, 2005). SG primary focus is to aid in the learning of a specific topic or domain (Adamo-Villani et al., 2013). For SG to enhance immersion, the environment must provide sensory input that creates a sense of presence(Zyda, 2005). Zyda (2005) suggests that the VR environment should faithfully represent the real-world to ensure that the user has a sense of presence this is specifically important for training applications (Zyda, 2005).

SG has been used in healthcare specifically for training and patient treatments. Graafland et al. (2012) undertook a systematic review of SG used in healthcare and found 25 articles indicating that SG is an innovative approach to education and training of medical professions (Graafland et al., 2012). Serious games and VR that implements realistic and adaptive environments have been shown to be beneficial, motivational and usable in healthcare. SG and Unity can be leveraged to create dynamic scenes using an accurate physics model that closely mimics the real world.

2.6 Serious Gaming Playability

Usability focuses on game functionality where playability requires a holistic view of game component integration combined with user experience (Olsen et al., 2011). Both usability and playability must be balanced to ensure a positive user experience along with delivering educational value requires that the user be engaged during the design and development of VR and SG VE (Olsen et al., 2011).

To conclude, the literature review motivates the need to design assessment of the developed VE for both usability and playability. Conducting usability assessment will ensure an immersive experience that is acceptable to the user. Assessing playability will confirm that user experience is positive and valuable.

3. Method to Visualize Patient Flow Using VR

This paper proposes a method to visualize patient flow using a VR and SG to create a VE. This method is instantiated within a demonstration of a patient flow simulation developed in Unity. To construct the method, we first considered the translation of data elements to components within a VR SG environment and subsequently determined the depth of immersion required to ensure the VR SG is usable and playable by the target users (i.e., healthcare administration and operational personal).

3.1 From Dataset to Serious Game Structure

The significant components required for the simulation data set in this context are the entities of healthcare facilities, modes of transportation and patient genders. Each of the entities have attributes that are either variable and require representation in the VE dataset or are fixed and whose information can be sourced from knowledge about the entities. For example, gender information can be variable based on the simulation data and would be represented within the dataset, but the attributes of a healthcare facility relating to the number of floors and locations of wards and bed spaces can be obtained from other sources and would not be represented in the dataset other than room numbers (See Table 1). Structural data can be obtained from architectural diagrams and from recording actual space layouts that would be recognizable by the users when rendered in VR.

Data Item	Data Item	Data Item	Data Item	Data Item
Encounter #	Admit/Discharge Decision from Emerg	Time Mental Health crisis worker called	Ward - start of ALC time/day	ED entry (Y/N)
Gender	Patient leaves ED time	Time Metal Health Crisis worker arrived	Ward Discharge time/day	CTAS (1-5)
Triage Time	Time Tests Ordered from ED (Labs, DI, imaging)	Medical Assess & Consult Unit entry time/day	Ward exit time/day	Surge status by date
Time entering ED treatment area	Tests Results Completed Time	Medical Assess & Consult Unit exit time/day	Exit/Discharge from Hospital	Service patient is admitted to (on-service)
Ambulance arrival time	Time consult called by ED	ICU entry time/day	Reason RFD not disch. (if several incl. date of change)	ED physician name (can be given a code)
Ambulance offload time	Time consult arrives to ED	ICU exit time/day	Patient Transfers OUT (to other facility) exit time	Number of ED consults
First ED physician contact time	Consult Service Called	Ward entry time/day	Tranfer IN (from other facility) Entry time	Service of consult (s)
ED disposition time and date (decision to admit or not)	Time CCAC contacted by ED	Ward - start of NRFD status time/day	Patient Arrival Day of week	ED consult name (s) (can be given a code)
Admit criteria met (ED patient)?	Time CCAC concludes ED patient status	Ward - start of RFD status time/day	Patient Arrival time of day	Date time of each ambulance consideration call

Table 1: Patient flow data set

The VR SG can be developed using realistic architecture, geographical locations, elements, time and metrics. Architecture can be visualized that closely resembles a hospital which may show a virtual ED layout that mimics reality.

The VE can be constructed to closely resemble the geographical location of the hospital with roads and buildings that are spaced proportionally as compared to reality. Elements are visual items that are built in the VE which would include people, vehicles, signs or equipment that closely resembles reality. Time can be changed for display of past conditions based on the dataset to allow review of conditions that existed during a specific period of time. Time can be adjusted to either slow down or speed up the review of the dataset in VE to allow the end user to view trends and patterns that might not be seen using 2D methods. Metrics from the dataset can be incorporated in the VE to provide details based on time, elements, process or tasks along with potential for heatmap views. Incorporating the dataset in VE the end user can play and replay events and processes that occurred in the hospital over time, which then can be used to examine conditions that affect patient flow to, through the hospital and to a final location. By using a VR SG that faithfully represents an environment that is familiar and intuitive, the user will be able to see trends and patterns along with patient care bottlenecks over a period of time and specifically focus on ALC patients. Using the developed VR SG in a 3D VE will provide an optimum visual of a hospital that is easily relatable to the end user who can then see trends and patterns over time that may be more difficult to detect using 2D methods. By utilizing this approach, we feel the end user will engage with this environment as a mental contest towards optimization and in so doing we believe that this has great potential to support improved efficiencies and reduce errors.

3.2 Scene Development

The scene development will focus on evaluating each scene's immersion and usability to determine if the scene conveys enough information that the end user can determine patient flow to the hospital. To ensure that invested development time is not wasted on complete scene development which does not effectively provide the end user the experience and information required, scenes are limited to patients who are going to the hospital. Using a limited prototype is a means of storyboarding and rapid development that can be further built upon using an iterative method (Moreno-Ger et al., 2012).

The general requirement for all two scenes is to allow the user to explore the travel of patients from the sending to the receiving institution. A camera the user can control and move about the scene will allow the user to view patients visualized moving from the sending to the receiving institution. With the ability for the end user to move freely about the scene will help to immerse the user in the scene.

To start the patient from the sending institution, spawning code is developed so that the patient and arrival mode can be randomized to the required percentage and the frequency. Other patient attributes requiring a probability or other based distribution such as age, gender and method of arrival can also be implemented during this spawning process. The spawning of a patient could be customized for each sending institution.

4. Patient Flow Visualisation Demonstration Instantiation

For the purposes of the demonstration, the scenes visualize patient flow to the hospital (i.e., travelling from a starting location to a central hospital). The hospital scenario for the case study is based on a typical Group B Ontario Canada hospital having no fewer than 100 beds (Ontario Ministry of Health and Ministry of Long-Term Care, 2001). There are 52 hospitals that comprise of Group B out of a total of 151 public not-for-profit hospitals in Ontario and with the total hospitals serving over 15.1 million ED visits between 2019 and 2020 (Canadian Institute for Health Information, 2022) For this research a typical regional Ontario hospital with 400 beds and 90,000 annual ED visits will be used. The average time spent in the ED at a regional hospital for complex patients requiring more diagnoses and treatments was six hours and 9 out 10 complex patients spending 12.9 hours in ED (MOHLTC, n.d.). For minor or uncomplicated patients average time spent in ED was 1.9 hours and total time spent in ED (9 out of

10 patients) was 3.2 hours (MOHLTC, n.d.). By using a regional hospital as a test scenario allows for VR SG VE to demonstrate the potential benefits on a moderate size regional hospital.

4.1 Dataset

A typical regional hospital will have an extensive electronic data set contained in an EMR with the necessary patient movement information, a simulated dataset was used for this paper to demonstrate the effectiveness of visualizing patient flow for making decisions. Patient gender and mode of transportation (either by ambulance or other) was randomly generated to allow a simulation of patient traveling from the sending hospital to the regional hospital. Using randomly generated patients, the user can then focus on the immersion, usability and playability of each scene.

4.2 Scene Development

The first scene is a simplified rendering of sending hospitals to the regional hospital (See Figure 1). The simplified scene uses a cylinder object for the patient and color codes the gender and arrival mode. The scene does use building assets specifically hospitals to represent the sending institution and the regional hospital the receiving institution. The user can move about the scene and zoom in or out or pan around to observe the patient movement with the camera.

The second scene is semi-realistic which includes terrain, cars, ambulances and building assets (See Fig 2.). The building assets are more specific such that hospitals and long-term care facilities are different. The user can also move about the scene to observe the movement of the patient from the sending institution to the regional hospital. A white ambulance is shown which the color code for a male arriving by ambulance and a green ambulance would be a female. A blue car would be male, and a red car would be female for patients not arriving by ambulance.

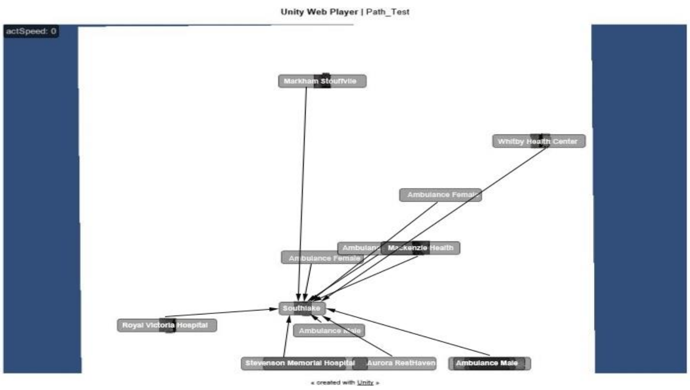

Figure 1: Simplified example developed in Unity

Figure 2: Semi-realistic example developed in Unity

To help the user identify the patient and where they came from as they move from the sending institution, the patient object was tagged with a text that floated along with patient as they moved to the regional hospital. Once the patient object arrived the patient object would be destroyed by the regional hospital object to minimize memory usage.

The proposed gender split was 50 percent male and 50 percent female with 30% arriving via ambulance. The sending institution comprised of long-term care facilities (LTC) and other hospitals. Closer LTC to the regional hospital had a higher percentage of patients sent to the regional hospital. Hospitals that were closer also had higher percentage of patients sent to the regional hospital but not as high as close LTC. The data was estimated to provide sufficient numbers that will allow the user to gauge the effectiveness of the immersion and usability.

5.0 Future Work

While this paper detailed using a VR SG to show patient flow to the ED the future work will include extending the VR SG to include the hospital as a whole system of the complete patient journey from admission to discharge and their final destination (Brailsford et al., 2019;). Developing a VE using VR and SG will require the VE to be sufficiently immersive to give the user a sense of presence (A. Sutcliffe & Gault, 2004). To ensure sufficient immersion and ultimately a sense of presence the VE will need to be sufficiently immersive along with playable as determined by the user. Playability is key in SG and require a more holistic integration of components and determination whether the user experience is positive or not (Olsen et al., 2011). The SG must be developed to ensure the SG is engaging, usable, playable and delivers educational value to the user (Olsen et al., 2011). The following are additional considerations for Future Work which will be detailed in a subsequent research and paper.

5.1 Big Data

As part of the extending to a whole system, a year's data set of ADT, DAD and NACRS will provide an even more effective view of patient flow that, when visualized, will enable the user to better extrapolate to the real world to find patterns, trends and complex workflow relationships more effectively (Drechsler & Soeken, 2013). Unity has been shown to handle large data sets that users can interact with in a VE (Donalek et al., 2014).

5.2 Virtual Reality

A realistic portrayal of a regional hospital catchment area including roads and buildings could be developed. The roads for the catchment area have been captured by using Open Street Maps (Figure 3 https://www.openstreetmap.org/#map=9/43.7522/-78.6676) which can produce an export that EasyRoads3d, a road development asset available to Unity, can import into Unity creating a realistic view of the road networks around regional hospital. The realistic scene could use high fidelity 3D objects and assets to provide a more immersive environment for the user. Additionally, the technology that is used to render the VR should allow visualization exploration based on how the end user will use the VE in a hospital setting (see Figure 4). A future study would look at what is the most effective visualization rendered to encapsulate a whole system patient flow in a VE.

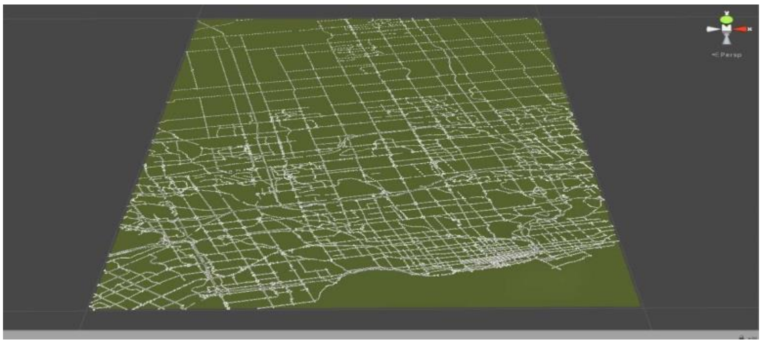

Figure 3: Open Street Map rendered in Unity

5.2 Usability and Playability Testing

The future VE will be designed and developed by engaging a hospital subject matter expert (SME) who is familiar with patient flow. The designed and developed VE will be tested against the 12 Heuristics proposed by Sutcliffe et. al (2004) that will evaluate usability and presence of the VE (A. Sutcliffe & Gault, 2004). The 12 Heuristics consist of natural engagement, compatibility with the user's task and domain, natural expression of action, close coordination of action and representation, realistic feedback, faithful viewpoints, navigation and orientation support, clear entry and exit points, consistent departures; support for learning, clear turn-taking and sense of presence (A. Sutcliffe & Gault, 2004). To test the usability of the SG component of the VE, the Serious Game Usability Evaluator (SeGUE) will be used, which evaluates 6 system elements and 11 user dimension criteria (Moreno-Ger et al., 2012). Additionally, during the design and development along with the usability testing, the playability of VE will also be evaluated using the 15 Playability Heuristics as described by Aker (2019)(Aker et al., 2019).

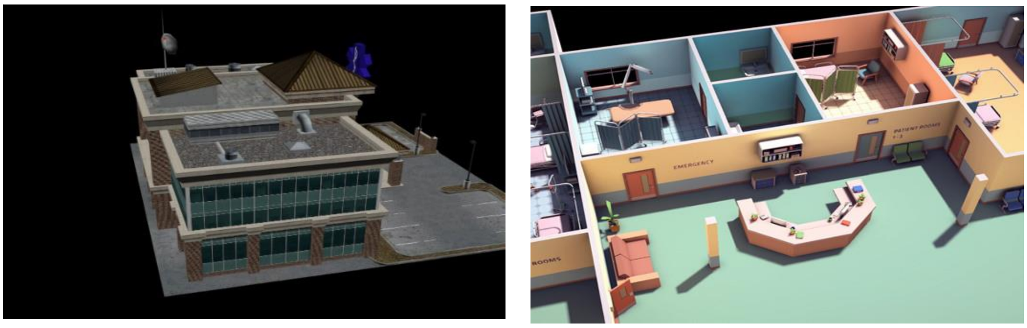

Figure 4: Examples of Unity hospital and patient ward assets

Once the developed VE is deemed to be usable and playable by the SME that collaborated on the design and development a more extensive usability study will be conducted to ensure the VE is usable and playable by a wider user group. The typical rule of thumb usability test is using a sample size of 5 to 8 users and is deemed to uncover 80% of the usability issues (NIELSEN, 2000; Virzi, 1992). The underlying assumption are the 5 to 8 users are experienced but in fact the participants experience in the usability test may vary (Faulkner, 2003). The future work will conduct a 4-user usability test to determine the number of usability issues one user can find. Based on the number of usability issues uncovered by one user a sufficiently powered sample size can be determined (Faulkner, 2003). By conducting a sufficiently powered sample the usability of the VE can be determined to ensure that the VE is usable and playable to view patient flow as a whole system in a hospital (Faulkner, 2003).

6. Conclusion

This paper has presented a method for VR simulation using SG to create a VE. We demonstrated how patient flow can be visualized using SG and VR through an emergency department case study. Using VR and SG has an opportunity to provide a new and novel method of visualizing complex healthcare operational data that would provide a user-friendly environment for healthcare administrators or operational users. This research used a limited development in Unity to test the applicability and depth of immersion, usability and playability required by end user and will ensure resources are efficiently used. The expectation is that one scene or a derivative of will be selected to develop a comprehensive scene that depicts patient flow from beginning to end and detail the bottlenecks, "bed blockers" and inefficiencies. Once the bottlenecks and inefficiencies are uncovered healthcare administration and operational personnel can address the bottlenecks and inefficiencies to improve the patient flow through and out of the hospital and reduce associated wait-times. The end goal will be to provide the patient with better and improved efficiency of care provision by examining the patient flow as a whole system. The work detailed in this paper will be the basis for the future development of a whole system developed VE that will be sufficiently immersive, usable and playable.

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2. A model to understand digital capabilities, shadow IT and individual performance in the context of remote work

Pietro Cunha Dolci
PPGA / UNISC
pcdolci@unisc.br

Antonio Carlos Gastaud Maçada
PPGA / EA / UFRGS
acgmacada@ea.ufrgs.br

Abstract

In recent years, remote work has grown enormously, as has the adoption of digital technologies and shadow IT. There has never been a situation where workers could choose to use their own devices and cloud-based applications. Due to the Covid-19 pandemic, large numbers of workers suddenly found themselves at home. Understanding how this shift to remote working has impacted digital resources, the use of shadow IT and individual performance is of great importance to academics and professionals. This study seeks to analyze the relationship between digital capabilities and shadow IT usage on the one hand and individual performance on the other in the context of remote working. To do so, a survey was carried out among a sample of 188 IT and non-IT executives from Brazil working remotely. The resulting data were analyzed using IBM-SPSS 24 exploratory analysis and PLS-SEM software to test the measurement and structural model. In the study we identified that shadow IT usage is positively related both to digital capabilities and individual performance. The main findings reveal that to understand the behavior of employees and how these systems are being used is essential for the individual performance of company employees to be maintained or even improved.

Key-words: Digital capabilities, Shadow IT usage, Individual performance, Remote working.

1. Introduction

Digital technologies have been penetrating all aspects of our lives, economy, living security and society, profoundly changing social productivity, human relationship, and production relations (Zhu, Dai & Wan, 2022). These technologies have brought many contributions, profound effects on organizational processes and opportunities for companies to improve their performance. Digital technologies can determine what kind of resources actors can provide as inputs and how these resources are transformed into and provided as outputs (Von Briel, Davidsson & Recker, 2018). The achievement of this transformation, according to Zhen et. al. (2021), is tricky and a complex task needing to establish digital organizational culture and digital capabilities. The concept of digital capabilities is still in its early stages of development and not present a uniform definition neither there are consolidated elements nor dimension. According to Zhu, Dai and Wan (2022) is the ability to integrate, allocate internal and external resources, and utilize the potential of digital technology.

According to Gartner (2021), global expenditure on Information Technology (IT) is expected to total US$ 4.2 trillion in 2021, equivalent to an increase of 8.6% compared to 2020. These investments will be directed towards digital transformation, cloud computing, mobile technologies and internet of things, which are capable of helping organizations in the search for greater performance and productivity of their employees at work and their relationship with their stakeholders. At the same time bringing implications for the potential use of alternative solutions and technologies, such as the use of shadow IT. Additionally, Gartner has estimated worldwide enterprise software spending at $600 billion in 2021, and forecasts spending to rise to $1 trillion by 2030, and specifically with SaaS (Software as a Service). KPMG & Beamy released a survey in early 2022 that 85% of applications should be managed by business units and individuals by 2031, which will represent greater engagement with IT and governance teams in managing the following risks: unplanned spending and waste; and compliance with unauthorized use of applications in controlled environments and remote work.

According to Dulipovici and Vieru (2016) the new IT management policy highlights the concern with the use of unauthorized Information Systems (IS) and Mobile Technologies (TM) in the business environment, called Shadow IT. Rentrop and Zimmermann (2012) define this as the adoption of systems developed by areas without the support of the IT department. These systems are implemented autonomously, without the organization's knowledge, therefore, these technologies are not included in the organization's IT service management (Zimmermann, Rentrop & Felden, 2014). Thus, Silic and Back (2014) revealed that organizations face enormous difficulties in controlling security risks because of unauthorized alternative technologies (shadow IT). From the users' point of view, the use of shadow IT associated with digital and IT capabilities allow overcoming the restrictions found in the IS of organizations and allow the work to be performed in a complete and effective way (Tallon et al., 2013).

According to Global Workplace Analytics (2021) during the pandemic, 95% of U.S. office workers worked from home three or more days a week. A full 82% said they wanted to continue working remotely at least weekly when the threat of the pandemic was over. Five million people in the US work at least 50% of their hours remotely, a number that has increased 173% over last year. During the initial phase of pandemic Microsoft reported a 500% increase in Microsoft Teams meetings, calls and conferences. Video conferencing software operator Zoom, meanwhile, added more users in the first six weeks of 2020 than it had in all of 2019, according to CNBC (2020). To Evangelakos (2020), as remote work sees extraordinary growth, however, shadow IT concerns grow in tandem for individual performance. To this author, never in history have we seen a situation where the temptation to use your own device, or use your preferred cloud-based consumer application, is so appealing to vast numbers of suddenly homebound workers. Even prior to Covid-19, shadow IT risks were underappreciated. Research from Gartner estimates that shadow IT represents up to 40% of overall IT spending in large enterprises (Evangelakos, 2020).

Thus, the research question of this study is how digital capabilities are related to shadow IT usage and individual performance in the context of remote working? To answer this question our study aims to analyze digital capabilities and shadow IT usage impacts on individual performance in the context of remote working.

2. Digital capabilities, shadow IT usage and individual performance

Digital capability is the ability to (1) integrate digital technology with organizational business process activities, (2) utilize the potential of digital technology and stimulate the utility of data resources and (3) allocate internal and external resources, enhance organizational practices, and drive organizational change driven by digital technology enablement and data resources (Zhu, Dai & Wan, 2022).

Digital capabilities have become important in the last decade for organizations to improve organizational responsiveness (Lavie, 2006). According to Tams et. al. (2014), with this responsiveness, firms can achieve greater performance and competitive advantage, even sustainable competitive advantage (Lavie, 2006). Moreover, to Pavlou and El Sawy (2011) sensing capability also is related with digital capabilities. To these authors sensing capability is defined as the ability to spot, interpret, and pursue opportunities in the environment.

Digital platforms and business models need well defined processes for digitization (Täuscher and Laudien, 2017). Digital capabilities are necessary to gain visibility into company's work processes and react to changes as quickly as possible. To Markus and Loebbecke (2013) to understand this change and the process of business is necessary an ecosystem orchestration. In this sense, in this study digital capabilities are understood (Table 1) by sensing capability (Pavlou & El Sawy, 2011), process digitization (Täuscher & Laudien, 2017), responsiveness (Tams et. al., 2014) and ecosystem orchestration (Markus & Loebbecke, 2013). All variables related to the dimension digital capabilities are at Table 1.

People and organizations increasingly want to use easy, fast, flexible, and ubiquitous access to software, platform, or infrastructure services from any device at low costs or even for free using internet (Haag, 2015). However, according to Haag e Eckhardt (2014), a challenge that occurs is that by taking advantage of the conveniences and benefits the services offered by public or private cloud services from third party providers are used independently of the IT department and without the approval of the organization sometimes. These authors define shadow IT usage as the voluntary usage of any IT resource violating injunctive IT norms at the workplace as reaction to perceived situational constraints with the intent to enhance the work performance, but not to harm the organization.

Mobile and cloud-based infrastructures enable users to take advantage of the flexible and convenient value propositions new IT services such as Dropbox, WhatsApp, or Google Docs propose, not only in private but also in work-life (Haag, Eckhardt, & Schwarz, 2019). These advantages enable collaboration among co-workers, customers, and partners, and thus, improve job performance. Moreover, it could be used as a collaborative tool, used for communication and to develop shared solutions (Rentrop and Zimmermann, 2012; Silic and Back, 2014).

According to Mallmann, Maçada and Oliveira (2018) another possibility of IT shadow usage is employees using at work equipment purchased (notebooks, servers, routers, printers, or other peripherals) directly from retail rather than being ordered through the official catalog of the IT department. It includes the use of applications in the employee’s personal devices at the workplace. Other Shadow IT usage is the software installed by employees to perform their work tasks, on the company’s computers (Mallmann, Maçada, & Oliveira, 2018). All variables related to the dimension Shadow IT Usage are at Table 1.

To Furstenau, Rothe and Sandner (2017), we must understand shadow IT usage as sociotechnical phenomena, which individuals are key for establishing a shadow system. Shadow systems can help employees to work around the restrictions of existing IT or organization processes (Alter, 2014). Workers tend to individualize systems based on business needs if they meet their individual requirements and social context conditions to adopt new or adapt existing IT (Furstenau, Rothe & Sandner, 2017). Thus, it is important to understand the individual performance related to Shadow IT.

The individual performance using informal systems can be measured in several ways, being related to productivity increase using informal systems at work, performing tasks faster using an informal system, exchanging information more effectively using an informal system, being able to solve problems faster using an informal system and controlling tasks using an informal system (Rentrop & Zimmermann, 2012; Silic & Back, 2014, Haag & Eckhardt, 2014). All variables related to the dimension individual performance are at Table 1.

3. Hypothesis development and proposed research model

As remote work has seen extraordinary growth in recent years, adoptions of digital technologies and the use of shadow IT grow together (Evangelakos, 2020). Never in history has there been a situation where the temptation to bring your own device, or use your preferred cloud-based consumer app, is so appealing to many workers suddenly stuck at home. Thus, in this context of remote work, digital capabilities (DC), the use of shadow IT (SITU) and individual performance (IP) have increased their importance for both academia and practice. It is important to understand the relationship and impacts of these variables. Based on these arguments and considerations, the research model proposed in Figure 1 was created. The formulation of the hypotheses is presented below.

Variable	Author(s) (year)
Digital capabilities	
Sensing	Pavlou & El Sawy (2011)
Process digitization	Täuscher & Laudien (2017)
Responsiveness	Tams, Grover & Thatcher (2014)
Ecosystem orchestration	Markus & Loebbecke (2013)
Shadow IT Usage	
Information sharing	Rentrop & Zimmermann (2012); Silic & Back (2014)
Communication	Rentrop & Zimmermann (2012); Silic & Back (2014)
Systems installation	Mallmann, Maçada & Oliveira (2018)
Use of own devices	Mallmann, Maçada & Oliveira (2018)
Solution development	Rentrop & Zimmermann (2012); Silic & Back (2014); Mallmann, Maçada & Oliveira (2018)
Individual performance	
Productivity increase	Rentrop & Zimmermann (2012); Silic & Back (2014); Haag & Eckhardt (2014)
Performing tasks faster	
Exchanging information more effectively	
Solve problems faster	
Control tasks	

Table 1: Dimensions and variables

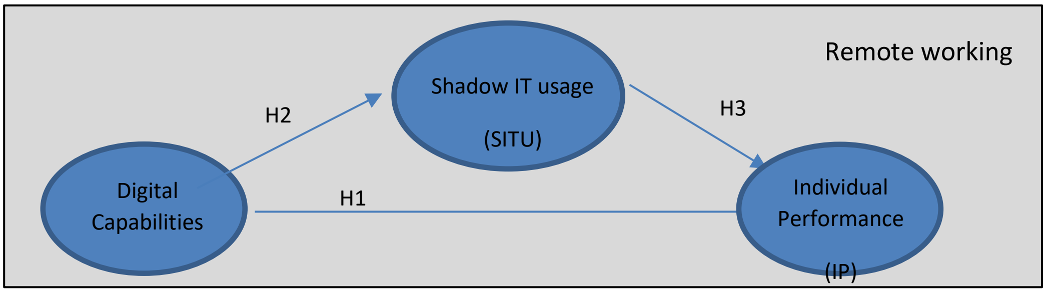

Figure 1: Research Model

(Source: Elaborated by authors.)

To Furstenau, Cleophas and Kliewer (2020) digital capabilities can improve performance by supporting complex decision-making processes. According to Tams et. al. (2014), organizations can achieve greater performance and competitive advantage, from digital capabilities enabled by different technologies. From this, we found a relationship between digital capabilities (DC) and individual performance (IP). Hence, we hypothesize that:

H1: Digital capabilities are positive related with individual performance

The company's digital capabilities (DC) are embedded in the people and relationships within the company, so their effectiveness depends on those people's interactions with available technologies (Tams et. al., 2014). More digitized the company or use digital solutions, employees have more tendency to provide their own technological solutions within organizations such as smartphones, tablets or cloud applications, within organizations, which have facilitated the adoption and use of technologies by the user, which are not authorized by the IT department (Goodwin, 2014). From this, we hypothesize that:

H2: Digital capabilities are positive related with shadow IT usage

Some research pointed out that Shadow IT usage could improve productivity and performance. Employees could use shadow IT to increase productivity, perform tasks faster, exchange information more effectively, solve problems faster and control their tasks (Rentrop & Zimmermann, 2012; Silic & Back, 2014; Haag & Eckhardt, 2014). Moreover, shadow IT usage enables the work to be carried out completely and efficiently (Tallon et. al., 2013) associated with individual performance. To Haag, Eckhardt and Bozoyan (2015) shadow system users were significantly more motivated and enthusiastic about coming up with new ideas for existing technology and processes to solve the most task in a better way. Similarly, Haag and Eckhardt (2014), Silic and Back (2014), Mallmann and Maçada (2017) point out in their research that the study of shadow IT, at an individual level, is related with individual performance. From this, we hypothesize that:

H3: Shadow IT usage is positive related with individual performance

4. Method

This is a descriptive and explanatory study (Pinsonneault & Kraemer, 1993). It is descriptive because we tried to find out opinions are occurring in a sample of population. It is explanatory because the instrument was to understand how and why the variables ought to be related. Also, we proposed cause and effect in the model not only assuming the existence of relations among variables but assumes directions.

This research was carried out using a survey. To operationalize the Survey collection, a questionnaire was prepared. The variables were operationalized using a seven-point Likert scale of agreement, aiming to measure the effects of the relationships between the variables studied. This questionnaire was developed with scales adapted from the literature and from interactions with experts. There is 3 dimensions and 19 items. The dimension Digital Capabilities is formed by Sensing (DC1 and DC2), Process digitization (DC3 and DC4), Responsiveness (DC5 and DC6), and Ecosystem orchestration (DC7 and DC8). The dimension Shadow IT Usage is composed by SITU 1, SITU2, SITU3, SITU4 and SITU5. Finally, the dimension Individual Performance is composed by IP1, IP2, IP3, IP4, IP5 and IP6. All the dimensions and variables are presented at Table 2.

Data collection was carried out during December 2020 to March 2021. Data collected from 188 IT and non-IT executives through an electronic questionnaire were analyzed. The largest group of participants in the survey are managers (13%), analysts (11%) and professors (11%), followed by directors (9%), business auxiliary (8%) and business assistants (6%). We received from different positions and functions such as, CTO, CEO, doctors, developers, consultants. The most of the responses are from employees working in a private company (63%), followed by public company (26%), self-employed (7%) and family business (3%). The respondents have between 31-43 years (37%), 18-30 years (33%), 44-60 years (26%) and 60 or more (3%) with on average 3.4 years in the company.

To simultaneously examine the dependence relationships between the variables studied, a structural equation modeling (SEM) were used (Hair & Hult, 2016). The minimum sample was calculated using the G*Power software, which is based on the dependent variable with the largest number of predictors.

To assess the validity and reliability of the sample, the procedures indicated in the literature for this type of research were followed. Convergent and discriminant validity analyzes were performed, exploratory and confirmatory factor analysis were also performed. Confirmatory factor analysis is important in the examination of structural equation modeling in the process of model refinement and research instrument (Koufteros, 1999).

Confirmatory Factor Analysis (CFA) is required as a refinement stage of the research model when verification is performed through structural equation modeling (Koufteros, 1999). The CFA was operationalized with the support of the PLS-SEM statistical software due to the saturation of the relationships between the variables (Hair & Hult, 2016). For the validation of the measurement model, at this stage, the individual validity of the factors was analyzed using Cronbach's Alpha and Composite Reliability (CR), which are more appropriate.

The convergent and discriminant validity of the constructs were also appreciated. The convergent validity was evaluated through the Average Variance Extracted (AVE – Average Variance Extracted). Fornell and Lacker's criterion is used, looking for values greater than 0.5, so that the model can converge to a satisfactory result (Fornell & Larcker, 1981). Discriminant validity was analyzed both by cross-loading analysis and by the Fornell and Larcker criterion. The models that make up this research were evaluated and tested using structural equation modeling techniques, with the help of IBM SPSS 24 and PLS-SEM software. The final phase of the research was developed from the evaluation of the quantitative stage and final analysis of the research with the crossing of inferences from the Survey results and the discussion of the proposed model.

5. Results

All constructs in this study are based on a reflective measurement model, as the items of each construct are associated and interchangeable (Hair & Hult, 2016). To evaluate the measurement model, the metrics proposed by Hair et. al. (2019) were used.

The first step in evaluating the model is to examine the loads of each item that make up the construct, which must be above 0.708 to indicate that the construct explains more than 50% of the item's variation, thus being able to attest to its reliability (Hair & Hult, 2016). Values below 0.708 were evaluated, the literature recommends that the item should be excluded if there is a significant increase in composite reliability, if not, it should be maintained (Hair, Ringle & Sarstedt, 2011). Items DC5, DC6, DC7 and SITU3 presented values of 0.525 and 0.581, respectively, and were excluded from the model because their exclusion increased the value of composite reliability. Items DC1, DC4 and SITU5 were kept in the model, as their exclusion would not lead to an increase in composite reliability (Hair et al., 2019). The other items have their loads above the established minimum parameter.

The second step was to assess internal consistency, using Cronbach's Alpha and Composite Reliability. The alpha must present values above 0.70, while the composite reliability must present values between 0.70 and 0.90, given that values above 0.95 indicate reliability problems (Diamantopoulos et al., 2012). Even though all values are between 0.70 and 0.90, it is noteworthy that the literature points to composite reliability as a more reliable criterion than Cronbach's alpha, as the items are weighted based on the individual loads of their respective constructs (Hair et al., 2019).

The third step was to analyze the convergent validity, which is the measure in which each construct converges to explain the variation of its items, using the Average Variance Extracted (AVE), which must present values above 0.50 to indicate that the construct explains at least 50% of the variation of its items (Hair et al., 2017). All constructs have convergent validity according to the established criteria. Table 2 presents the Descriptive analysis of each variable, Convergent Validity and Reliability Analysis.

The fourth step was to assess discriminant validity, which is the extent to which the construct is different from other constructs in the structural model. (Hair et al., 2019). Two criteria were used, as the HTMT is more reliable than the Fornell-Larcker criterion, which can generate inaccurate results in some cases, and which is widely used in studies that use the PLS-SEM as the only criterion to assess discriminant validity (Hair et al., 2019).

Construct	Variables		n	Mean	Standard deviation	Variance	Factor loading	AC	CR	AVE
Digital Capabilities	DC1	identify new opportunities for the development of my work	188	4,32	0,96	0,92	0.665	0.778	0.840	0.513
	DC2	interpret the information in the environment for the development of my work	188	4,27	0,89	0,78	0.769			
	DC3	gain visibility into my company's work processes	188	4,22	0,89	0,78	0.709			
	DC4	react to changes as quickly as possible	188	4,35	0,99	0,99	0.667			
	DC5	create strategies to improve my activities and the activities of my colleagues	excluded							
	DC6	respond quickly to the problems I encounter when performing my activities	excluded							
	DC7	acquire and exchange more information with co-workers	excluded							
	DC8	acquire and exchange more information with external stakeholders	188	4,13	1,06	1,13	0.747			
Shadow IT Usage	SITU1	I share work information using informal systems)	188	3,25	1,56	2,42	0.868	0.963	0.970	0.843
	SITU2	I communicate with my co-workers through informal systems	188	3,71	1,43	2,04	0.863			
	SITU3	I install informal systems on the company computer to carry out my work tasks	excluded							
	SITU4	I use my own devices to carry out my work tasks	188	3,63	1,54	2,37	0.735			
	SITU5	I develop technological solutions using informal systems to carry out my work tasks	188	2,80	1,47	2,16	0.678			
Individual Performance	IP1	My productivity increases by using informal systems in remote work	188	3,27	1,31	1,73	0.929	0.798	0.868	0.624
	IP2	I can accomplish my remote work tasks faster using an informal system	188	3,27	1,39	1,94	0.920			
	IP3	I exchange information with my colleagues more effectively using an informal system in remote work	188	3,51	1,48	2,18	0.891			
	IP4	I can solve problems in my work more quickly using an informal system	188	3,36	1,41	2,00	0.924			
	IP5	I better control the tasks in my work using an informal system	188	3,13	1,40	1,97	0.912			
	IP6	In general, the use of informal systems improves my performance in remote work	188	3,23	1,42	2,02	0.933			

Table 2: Descriptive analysis, Convergent Validity and Reliability Analysis.

Note: Cronbach's Alpha (AC), Composite Reliability (CR), Mean Variance Extracted (AVE)

The Fornell-Larcker criterion points out that to assess the discriminant validity it is necessary that the square root of the AVE of each construct must be greater than the estimated correlations between it and the other constructs (Fornell & Larcker, 1981). The heterotrait-monotrait ratio (HTMT) criterion indicates that the obtained values must be less than 0.85 for conceptually different constructs (Franke & Sarstedt, 2019). Both discriminant validity criteria are met. In order to evaluate the structural model, the hypothesis test of the model was performed, using the bootstrapping resampling technique, using 5000 samples, to ensure stability in the determination of standardized errors (Hair et al., 2019). In addition, the blindfolding function was used to assess the predictive relevance of the model.

The first step was to verify that there are no critical levels of collinearity between the proposed structural relationships, using the Variance Inflation Factor (VIF), which should present values below 3.3 (Diamantopoulos & Siguaw, 2006). The obtained results varied between 1.185 and 1.877, indicating that there were no collinearity problems. The second step was to analyze the Coefficient of Determination (R^2), which is a measure of the explained variance of the endogenous construct and is a measure of the explanatory power of the model (Hair, Ringle; Sarstedt, 2011). Values 0.26, 0.13 and 0.02 are considered substantial, moderate and weak in social and behavioral sciences (Cohen, 1988). The obtained R^2 values were 0.519 (IP) and 0.048 (SITU), both considered substantial.

The third step was to assess the predictive relevance of the model in the PLS through the Stone-Geisser value (Q^2), which must present values greater than 0, with values 0, 0, 25 and 0.50 representing low, medium and high predictive model relevance (Hair et al., 2019). The obtained Q^2 values were 0.431 (IP) and 0.027 (SITU), supporting the model's predictive relevance. Finally, the hypothesis test was performed for the relationships between the constructs, considering that for the hypotheses to be supported, the critical t values must be 1.96 ($p<0.05$) and 2.57 ($p<0.01$) (Hair et al., 2019). Additionally, the standardized root mean residual (SRMR) was analyzed as a measure to assess the model's fitting. The cutoff value of the SRMR is 0.08 for models that use the PLS-SEM (Henseler, Hubona & Ray, 2016). The SRMR value in this study was 0.069, so the model is a good fit. Table 3 presents the results of the model's hypothesis test.

Hypotheses	Path	VIF	Coefficient	Value *t* [a]	*p* value	Decision
H1	DC → IP	1.877	-0.219	0.157	0.876	Not supported
H2	DC → SITU	1.680	0.723	2.802*	0.005	Supported
H3	SITU → IP	1.575	0.013	16.244*	0.000	Supported

Table 3: Path Coefficient and Hypothesis Testing

Note. [a] t value for two-tailed test:* 2.57 ($p < 0.01$) **1.96 ($p < 0.05$) (HAIR et al., 2019).

Digital capabilities are positively related to Shadow IT usage ($\beta = 0.723$, $p < 0.005$), providing empirical support for hypothesis H2. H3 was also supported, showing that shadow IT usage is positively related to individual performance ($\beta = 0.013$, $p < 0.000$). H1 was not supported.

The main results indicate that for digital capacity to be related to individual performance, care must be taken with the use of shadow IT or informal systems. Sharing information using informal systems as well as communication (Rentrop & Zimmermann, 2012; Silic & Back, 2014) among colleagues proved to be very important for the relationship between digital capabilities and performance. In addition, the use of their own devices (Mallmann, Maçada & Oliveira, 2018) to carry out activities at work and the development of technological solutions were also evidenced in the research as relevant in this relationship. This demonstrates the importance of clear BOYD policies being extremely necessary for companies to understand the behavior of their employees that has influenced their performance. Another important point is the issue of information and systems security, especially in times of remote work. According to Abbas and Alghail (2021) the Shadow IT usage, mobile in this case, can lead to a security issue of the data privacy in organizations, that could disseminate inside the companies without the organization fully knowing. Thus, the need for clear policies for the use of their own systems and devices must be on the companies' agenda to avoid the problems caused by the potential use of informal systems. The research showed that prohibition is not the way but understanding more about the phenomenon and the behavior of employees to extract the best from them in relation to the use of technologies within the company.

It was identified in the research that individual performance improves with the use of informal systems. This type of system improves productivity in remote work, facilitates tasks to perform them faster, the exchange of information is more effective through this type of system, problem solving, and task control are also better with the use of informal systems (Rentrop & Zimmermann, 2012); Silic & Back, 2014); Haag & Eckhardt, 2014). Thus, as mentioned before, individual performance is positive influenced by Shadow IT use, the prohibition is not the best way, but the best understanding of the use of informal systems, such as Whatsapp, tools from Google Tools (Drive, Sheets, Docs, Forms,…) and in the cloud such as Dropbox. Understanding the behavior of employees and how these systems are being used is essential for the individual performance of company employees to be maintained or even improved. Understanding the digital capabilities of these employees, such as identifying new opportunities for the development of work, interpreting information from the environment, more visibility of work processes and reacting to changes as quickly as possible are the capabilities that should be observed and encouraged by companies. An important point that drew attention was that the acquisition and exchange of information with colleagues was not confirmed, but with external stakeholders it was. This shows that an important capability is more related to external actors than to co-workers, and that this can create a differential for employees and their companies.

6. Conclusion

The objective of the study “analyze digital capabilities and shadow IT usage impacts on individual performance in the context of remote working” was accomplished. Findings pointed to the importance of the study of digital capabilities, shadow IT and individual performance. The investment in digital capabilities and enabling system users to engage in this challenge could improve the management of these resources. Also, policies about the usage of Shadow IT could help companies to understand this phenomenon and improve the task performance by employees. The literature does not answer all the questions about the usage of shadow IT and if companies should turn off all the devices used without formal acceptance of the IT department. Our study proposes a model and validates the scale to advance in this discussion.

Other contribution is the instrument construction relating digital capability, shadow TI usage and individual performance. The instrument was created and validated with IT and non-IT Brazilian managers through an electronic questionnaire. We propose a model to understand and measure Digital capability by elements Sensing, Process digitization, Responsiveness and Ecosystem orchestration. Shadow IT usage was measured by Information sharing, Communication, Systems installation, Use of own devices and Solution development. We validated the dimension Individual performance that can be measured by productivity using informal systems at work, performing tasks faster using an informal system, exchanging information more effectively using an informal system, being able to solve problems faster using an informal system and controlling tasks using an informal system.

We can highlight that digital capacity could be related to individual performance, using shadow IT. The direct relationship was not supported. We found that use of information systems or shadow IT could help the daily activities and should be studied and understand by organizations. In the results we infer that companies should not prohibit the use of these systems without permission and validation of organization. Instead of, organizations should identify these systems and create new forms of use and formalize the use.

The academic contribution is to propose and validated an instrument to measure digital capability, shadow IT and individual performance. In the remote work this contribution could help researchers to understand these phenomena and advance in the field. The managerial contribution is to create a model to companies to understand how analyze digital capability, shadow IT and individual performance generate ways to improve productivity and interaction with technology. Other contribution is to show that individual performance is influenced by digital capacity by using shadow IT or informal systems. Thus, organizations should understand why and how employees use this type of system and create new forms to use these technologies or create policies and rules to use.

For future study we indicated a survey with a bigger sample in different contexts and industries. Another suggestion is applying a qualitative study based on instrument validated in this study to understand the phenomena in more detail. Researchers could explore the results to propose tools to create a link between digital capability and individual performance using shadow IT. Finally, from the results of this study, BYOD policy could be articulated and discussed in companies from digital capabilities view that influence individual performance by Shadow IT usage.

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3. A Viable Business Model for Innovations with Digital Healthcare Applications in Germany

Paul Alpar
University at Marburg
alpar@staff.uni-marburg.de

Andreas Rösch
smart medication eHealth Solutions GmbH,
aroesch@smart-medication.eu

David Schmoldt
smart medication eHealth Solutions GmbH,
dschmoldt@smart-medication.eu

Luisa De Witte
smart medication eHealth Solutions GmbH,
ldewitte@smart-medication.eu

Abstract

Germany established laws to quickly introduce digital innovations in healthcare by forcing statutory insurances to reimburse companies producing digital applications. This could enhance the well-being of patients. For example, an application in psychotherapy can cut the waiting time for a psychotherapist in Germany. However, such enhancements will reach the patients only if companies offering digital applications have a viable business model to survive. Our analysis of the business model of a company offering a recognized digital application shows that such business models are not easy to develop. The analysis is transferrable to other countries, if they establish similar laws.

First, we describe the legal framework for digital healthcare applications set up in Germany. We also describe the conditions that must be met for such an application to be recognized by the relevant body so that statutory insurances must pay for it. This is followed by a discussion of the reimbursement amount. Then, we develop the business model of a producer of a specific digital healthcare application. Although the possibility of reimbursement for accepted applications constitutes a competitive advantage, underestimating costs from the approval process and marketing may be dangerous. The same is true for relying on revenues from reimbursement.

Keywords: Healthcare digitalization, digital healthcare application, medical app, mobile application.

1. Introduction

We concentrate on digital healthcare applications on the web or mobile devices that must be reimbursed by statutory health insurances in Germany. Only 33 digital healthcare applications (as of August 2022) achieved such a status granted by the Federal Institute for Drugs and Medical Devices (Bundesinstitut für Arzneimittel und Medizinprodukte, abbreviated BfArM), which is an independent part of the German Ministry of Health. Such an app is called a DiGA, an abbreviation for “Digitale Gesundheitsanwendung” (digital healthcare application). A report of the association of statutory insurances for the time frame from Sept. 1, 2020 to Sept. 30, 2021 stated that DiGAs were reimbursed about 40,000 times (GKV 2022). However, by September 2021, companies submitted 89 applications to become a recognized DiGA, but four of them were declined acceptance while 42 applications were withdrawn (Vetters and Schaffelhofer 2021). More than 318,000 apps for healthcare and wellness existed all over the world already in 2017 (Aitken et al. 2017), but Germany is a pioneer in reimbursing healthcare applications. While Germany is often considered a laggard in digitalization among developed countries (see Thiel et al. 2018 for digitalization with a focus on the healthcare area), it will be followed in this case by other countries in the European Union (EU). The French President Macron stated not only that France will pass laws allowing DiGAs, but that France will simply replicate the German model (Lovel 2021). Experts suggest that the EU should pass appropriate laws for all of its members (EIT

Health 2021), but it is more likely that individual countries will do it by themselves. Thus, although our analysis must be specific to Germany where appropriate laws already exist, it is applicable to countries with a similar legal environment.

The acceptance by BfArM means that statutory healthcare insurances must reimburse DiGAs (i. e., pay for them to producers) which makes them different from other such applications. Consequently, the business model of firms producing DiGAs needs to account for this special status and the fact that DiGAs are considered medical products. On one hand, the reimbursement obligation is an advantage. On the other hand, the status is difficult to achieve and may include costs (e. g., to prove the beneficial effects of a DiGA on patients) which other digital applications do not carry. For example, some digital health applications follow the advertising-based business model while other digital health applications just support the medication made by the same producer.

In the following, we will first describe how to become a DiGA. Then we will discuss the reimbursement fees. On this basis, we will sketch the business model for an exemplary DiGA and then discuss its strengths and weaknesses. If the company producing the DiGA does not survive then patients will not be able to benefit from the DiGA (unless someone else buys and offers it in the future).

2. A reimbursable health application

There are three levels of law which establish DiGAs. First, the German parliament laid the foundation with a law called the “Digital Healthcare Act,” in original “Digitales Versorgungsgesetz (DVG),” effective since Dec. 19, 2019. The DiGA model has borrowed from another law (abbreviated AMNOG) which was passed in 2011 to regulate the introduction of innovative drugs. In the same time, DiGAs are only one aspect of digitalization of healthcare in Germany. Electronic patient records or electronic recipes are other examples in this area where Germany is definitely not a pioneer. The German Ministry of Health issued on the basis of DVG the “Digital Health Applications Ordinance (DiGAV),” a regulation on how to implement the law. This regulation has been recently updated so we also refer to planned changes below. Finally, BfArM published an administrative regulation that describes the so called fast-track procedure to become a DiGA. The accepted DiGAs are listed on the website of BfArM at https://diga.bfarm.de. The legal fundament of DiGAs is also shown in Fig. 1.

According to laws and regulations, following four conditions must be met by a digital health application to be recognized and listed by BfArM:

1. the fulfillment of requirements related to general security, functionality, and quality of the application,
2. an electronic application to BfArM,
3. proof of fulfillment of requirements related to data protection and data security, and
4. a proof of medical benefits for patients or patient-relevant structural and procedural improvements.

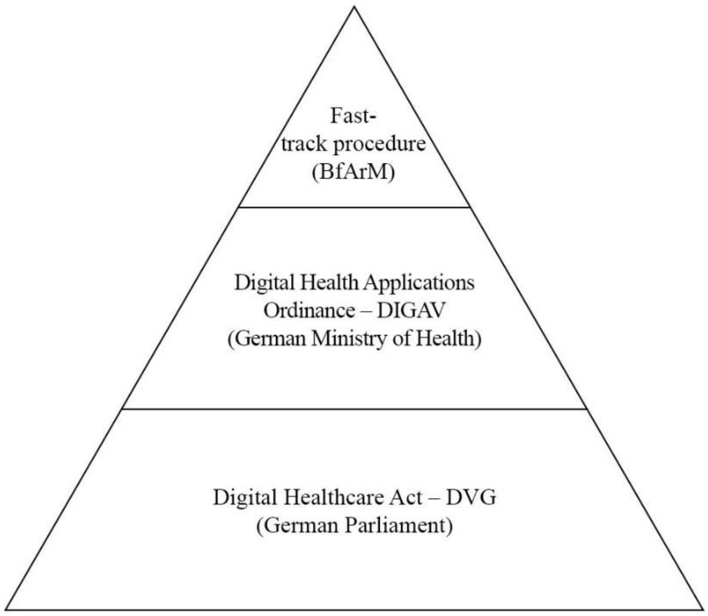

Fig. 1: Legal basis for digital health applications in Germany

The first condition is fulfilled if the health application receives the CE mark (which in French stands for "conformité européenne"). This means that the manufacturer or importer of a good affirms the good's conformity with European health, safety, and environmental protection standards. In this case, a body in the EU needs to be notified of the conformity and will check it according to the Medical Devices Regulation (MDR) from 2017 which must be applied since May 2021. The Medical Devices Directive (MDD) was in place before MDR. There are four risk-based classes of medical devices in the EU. It is only possible to become a DiGA with low-risk applications, i.e., class I or IIa. According to MDD, a device of a risk class IIa (or IIb or III) had to be checked by a notified body. The notified bodies also need to be accredited to be allowed to issue certificates according to MDR. There are only 27 bodies that received such certification from the EU as of Feb. 2022 (European Commission 2022). A recertification of devices (hardware or software) certified according to MDD will be needed by Mai 2024, so the certification of medical devices has become a serious bottleneck. If a medical device was of risk class I, only a self-declaration of conformity was needed according to MDD. Then, the producer of the application could put a CE on the device without having a number from a notified body.

So far, most of the DiGAs have been certified through a self-declaration as class I devices according to MDD. Only a few DiGAs have been certified according to MDR, all in class I. However, most class I medical devices must now be classified in the higher class IIa due to the new MDR, so self-declaration does not seem to be enough anymore. The MDR did not directly eliminate class I software. However, Rule 11 in Annex VIII MDR raises the question among all stakeholders as to what software still falls within class I at all. Many experts see an ambiguous wording in the text of the law, which leaves room for self-interpretation. After receiving the CE mark, the application can be submitted to BfArM.

The third condition "only" needs to be fulfilled by a statement of the producer and is not further checked by BfArM. Obviously, breaches against data protection can be costly in the EU so that producers should not state the fulfillment of this condition without proper proof. Benevolent hackers have shown recently that two of the DiGAs had serious "holes" which have been closed quickly (Larraondo 2022) but we do not really know whether other hackers discovered these problems, too. However, from April 1, 2022 all DiGA suppliers, even the producers of already listed DiGAs, must prove that they have an information security management in place according to ISO 27001. From January 1, 2023 the producers must have a certificate relating to data security from BSI (the Federal Office for Security in Information Technology in Germany).

Medical benefits (abbreviated mN in the documents) or improvements in patient-relevant structure and procedures (abbreviated pSVV in the documents), fourth condition, must be shown for all or only certain patients (BfArM 2020). The patients need to be exactly named (e.g., women above 40 years of age) for who positive effects are expected or the indications need to be stated according to ICD-10 (ICD-10 is the International Statistical Classification of Diseases and Related Health Problems). Such claims are usually proven through appropriate studies. At this point, it should be mentioned that manufacturers must specify the request for provisional or final inclusion in the directory. When applying for provisional inclusion, only study designs and explanatory information on how a medical benefit and/or pSVV will be demonstrated must be submitted, but the evidence itself can be provided within 12 months. The majority of DiGAs has only the status of provisional inclusion as of August 2022. BfArM even states in its guideline brochure which studies are acceptable (e.g., randomized control studies) and which not (e.g., descriptive studies are usually not enough). Several DiGAs that were developed before the relevant legislation was in place have been tested via randomized control studies (e. g., Berger et al. 2017).

Although DiGAs are also popularly called “app per prescription,” a patient can also request some DiGAs directly from his health insurance company without a prescription of a physician (about 11% of cases according to (GKV 2022)). In this case, the patient must prove a need for the application which he can do with a treatment or diagnosis of the relating illness made by a physician. The prescription can also be made through a telemedicine service provider. In any case, the patient sends the request or the prescription to his insurance which, then, sends an activation code to unlock the DiGA. The patient downloads the DiGA from an app store or uses it on the web.

The above conditions are required but they are not sufficient. A DiGA must also fulfill the needs of its stakeholders to be successful (Urbanek 2021). If physicians do not prescribe a DiGA because they do not know about it, they cannot test it themselves, they think that they are not appropriately reimbursed for its use, or they do not believe that it is beneficial to their patients, the DiGA will even not reach the patients.

In contrast to prescription drugs, medical devices such as DiGAs of classes I or IIa may be advertised not only to physicians, but also to medical laypersons, i. e., also to patients. However, advertising a DiGA must comply with the requirements of the German Drug Advertising Act (HWG) – it must not be misleading or deceptive. According to Section 12 HWG, a general ban on advertising also applies to mobile health products in connection with addictive diseases (with the exception of nicotine addiction), pathological complications of pregnancy, childbirth and the postpartum period, and in connection with notifiable diseases under the Infection Protection Act.

3. Reimbursement amount

A producer of a DiGA can, in principle, ask any amount to be reimbursed in the first year that the DiGA has been listed unless a specific agreement is made with insurances. However, the calculation must be explained to the insurances. There is also a revenue ceiling of 750,000€ (incl. value added tax) above which the price for a DiGA must be agreed upon. Otherwise, after a year, the price is determined by an agreement between The National Association of Statutory Health Insurance Funds (representing about 90% of the German population or about 73 million people) and various associations of producers of DiGAs. This agreement was reached through an intermediation between these two parties in two phases, with the last agreement version published on December 16, 2021. The agreement determines the highest price the producers of DiGAs can ask for. It is based on formulas which also depend on the number of DiGAs for the same use. Thus, the current competitive situation also plays a role in price determination. The current average reimbursement amount is about 444€ and it ranges from about 119€ to 743€ per quarter of a year. The price limit is not valid for applications addressing a disease with an “orphan status.”

In the time frame of the mentioned report, the most prescribed DiGA was the app against tinnitus, Kalmeda, which has been reimbursed 8,600 times (GKV 2022). This app can be reimbursed up to four times, so we do not know how many unique patients got a prescription for it. The physician who is the “spiritual father” of the app and the founder of the firm that produces it, estimates the development costs to be almost 1,000,000€ and the development time to be about six years (Mitternacht 2021).

Physicians also get reimbursed for writing a recipe for a DiGA, although this is not a big amount (2€ flat), on one hand. On the other hand, there may be other efforts (e. g., for the control of a DiGA therapy) that they can charge for. The regulation regarding additional charges for related services is often still missing so this can be a reason for physicians’ hesitance to prescribe DiGAs. In the case of the DiGA somnio (see below), prescribers can charge 7,12€ for follow-up controls. The prescription of a DiGA or follow-ups can also be conducted via video (telemedicine). In any case, prescriptions of a DiGA and follow-ups do not burden the physician's or psychotherapist's budget, which is usually capped for drugs or remedies.

4. Business model

In this section, we will draw a possible business model for a specific DiGA in the form and structure of a lean business model canvas (Maurya 2012). There is a criticism of the lean startup approach in general (Felin et al. 2020) but we apply the lean version since it is more suitable to the needs of an independent startup (Maurya 2012) which all DiGA producers are, so far. It also explicitly names the model’s competitive advantage (under “unfair advantage”), which we consider important for a business model to be defensible. Finally, the good performance of lean startups has been proven (Harms and Schwery 2020). We use the DiGA somnio (somnio 2022 and BfArM 2022) as an example in this section because different DiGAs may use different business models which may depend of who is financing their development and other criteria. We choose somnio because it is permanently listed in the DiGA directory of BfArM, meaning that the proof of medical benefit has already been provided. Also, it has been graded well by end-users in GooglePlay (4.2 stars out of 5 at 332 evaluations) and in the AppleStore (4.4 stars out of 5 at 370 evaluations). The developed canvas relates actually to the producer of somnio (mementor DE GmbH) but we use the name of the product because the company has only this product, at the moment, on the list of accepted DiGAs. The product name, somnio, is also much better known than the company behind it.

4.1 Problem

somnio is a medical app for the treatment of problems falling asleep and staying asleep, so-called non-organic insomnia. (IDC-10 code: F51.0). Primary insomnia has a prevalence of about 3% in the general German population (Wikipedia 2021). If non-organic sleep disorders with or without daytime sleepiness are considered independently of the criteria, the prevalence is up to one third of the total population. The general therapy suggestions for non-organic insomnia include psychotherapy and, if necessary, support with medication. Psychotherapy includes elements such as keeping a sleep diary, improving sleep hygiene, behavioral control measures, and also cognitive techniques. The number of specialists and psychotherapists, on the other hand, is far from enough to provide all patients willing to receive therapy with sufficient intensity and in a timely manner.

4.2 Solution

With the help of the app somnio, a cognitive behavioral therapy is implemented as a treatment method, according to the recommendations of the German Society for Sleep Research and Sleep Medicine (DGSM). In the center of the somnio app are functions for keeping a digital sleep diary, document sleep times and analyze progress. The goal is to understand and correctly classify sleep problems, deal with circling thoughts and musings, and learn relaxation techniques to fall asleep faster. Ultimately, sleep times should be optimized and the ability to perform and concentrate during the day should be increased.

4.3 Key Metrics

The most important key metric is the number of activation codes transmitted by health insurers that were ultimately used by patients to activate the somnio app, as only these can be billed. Self-payers are excluded, as these patients pay in advance, i.e. before activation. In addition, the number of prescriptions from physicians and psychotherapists billed to the health insurer (billing code 01470), the number of follow-up visits billed to the health insurer (billing code 01471) and the number of prescriptions from telemedicine providers are important metrics.

In addition, a metric of interest is the data shared by patients with medical staff via a patient-created access code. Patients can create an access code that is valid for 30 minutes. This code allows the physician to view the data documented in the somnio app in a web portal. This metric can be used to infer the level of interaction between patient and physician or psychotherapist and answer the question of whether patients are more likely to use the app on their own or with consultation with their physician or psychotherapist.

Note that all these metrics can differ because patients may get an activation code directly from their insurance, i. e., without a prescription. When they get the code, patients still may not use it and register in the DiGA (Urbanek 2021). Finally, even when they register within the DiGA they may not use it or not as often as they should.

4.4 Value Proposition

Patients who want to be seen by a specialist in sleep disorders and especially a psychotherapist must wait on average over 20 weeks in Germany (Onmeda 2022). They do not have a short-term access to an adequate therapy. somnio offers a complementary treatment option that helps to avoid bottlenecks in specialist care by allowing a larger number of patients to be treated. With the alternative of an app, patients can be cared for promptly with a therapy in line with current guidelines. It can also be a low-entry into a type of psychological treatment which may be postponed otherwise.

4.5 Unfair advantage

Recognition of BfArM and the consequent listing of a DiGA as reimbursable constitute an advantage. The effort is considerable both monetarily and in terms of time. In order to meet all the requirements for compliance with the MDR and to be listed permanently by BfArM require a proof of benefit through a randomized controlled trial, extensive know-how, investment capital, and time. It is also possible for companies to make direct reimbursement contracts with health insurances (Stüber 2020), but then a one-to-one contract needs to be made with each of the many insurances. If the health insurances are not covered by DiGA-laws (e.g., for privately insured patients or insurances outside of Germany), then the individual contracts lead both to a competitive advantage and additional revenues.

However, the advantage of a listed DiGA or individual contracts is not as strong as a patent for a drug because competitors can develop alternative products, bring them to approval, and establish them on the DiGA market. Analogies can be drawn with the market for generic drugs.

4.6 Channels

The most important sales channel for the app are undoubtedly physicians and psychotherapists who are familiar with somnio. Alternative prescription options are offered by telemedicine service providers. However, this form of prescription is still little used in Germany. Further support for distribution is achieved through the website of the manufacturer of somnio, the DiGA directory at BfArM, and recommendations from health insurance companies.

4.7 Customer Segments

somnio is suitable for patients 18 years of age and older who suffer from symptoms of insomnia with no underlying organic cause. The app can be prescribed by physicians and psychotherapists who treat patients with insomnia.

Privately insured patients should contact their health insurance company directly for cost coverage with a confirmation of the indication from a physician, psychotherapist or telemedicine service provider. After confirmation of cost coverage by the health insurance company, the activation code is obtained directly from somnio.

Patients who want to use the app but have no insurance (or whose insurance does not want to cover the costs) can pay by themselves. These patients also get the activation code directly from somnio.

4.8 Cost Structure

There are now suppliers of services for each step of DiGA development, certification, and registration with BfArM. The exact cost will depend, among others, on the service done in-house or bought. A physician with an idea but without programming skills (or without willingness to make such people part of his team) can hire another firm to develop the app. Usually, this firm will already be certified according to relevant standards (i.e. IEC 62304, ISO 13485) in order to prove the compliance requirements within the process of CE acquisition. If the app should (also) run on mobile phones, it should be programmed for iPhones and Android-devices.

Once the app works, there will be operation costs for the server on which the web version runs but also for the functioning of apps on mobile phones. Even if there is no web version, it makes sense to have a website devoted to the app. Maintenance cost will accrue when bugs need to be corrected or new versions of the digital application will be released.

New apps need a certification following MDR (while apps certified following MDD will need to be recertified according to MDR). A working app also needs to show improvements in the medical care as described above which is shown through appropriate studies (before or latest within 12 months after it has been accepted by BfArM).

Stakeholders (e.g., patients and physicians) should know about the app and how to use it so marketing costs will also accrue. Advertising in outlets for patients (e.g., widespread journals that are given for free in pharmacies) may be needed. Advertising in outlets geared towards physicians is also meaningful and there will be costs to explain the working of the app (through trials by physicians, demonstrations by sales representatives, or explanations of the app by other company employees).

All these steps create internal or external costs.

4.9 Revenue Streams

Publicly insured patients receive an activation code from their insurance based on a prescription from a physician, a psychotherapist, or a telemedicine service, or because the insurance allows the use of the app (see above). As long as the activation code is not used, no payment is made by the insurance company to the manufacturer of somnio.

For privately insured patients or self-pay patients, the activation code is purchased before use and billed immediately to the patient, regardless of whether the activation code is ever used.

Finally, somnio also generates revenues from patients who are insured by companies with which they have a special contract (be the insurances covered by DiGA-laws or not).

Since revenues of manufacturers are in the same time costs of insurances, insurances will try to lower their cost for DiGAs through negotiations and the process mentioned in section 3. This will lower the revenue per activation code in the business model. In the case of somnio, the listed price for the app went down from about 400€ (Stüber 2020) to 224,99€! Revenues from insurances with which individual contracts exist, may be good, but they require negotiation skills which may not be available in the startup team yet. The value of a “blanket” regulation like DiGA-laws is diminished if suppliers need many individual contracts to gain an acceptable level of revenues. Fig. 2 summarizes our view of the business model of somnio in a canvas.

5. Prescribed Digital Therapeutics in the U.S.A.

The U.S.A. healthcare market is not only the largest singular healthcare market in the world, but also a major leader in digital healthcare due to the broad base of high-tech companies, as well as the very high level of healthcare expertise and quality available. In the U.S.A. the Food and Drug Administration (FDA) is responsible for approving mobile medical applications (MMAs). Similar to the German DiGAs, there are so-called Prescription Digital Therapeutics (PDTx). PDTx are software-based therapeutic interventions prescribed by a healthcare provider. They are evidence-based therapies with proven clinical effectiveness that are approved by regulatory agencies (FDA) for the treatment of specific conditions. Already back in September 2017, Pear Therapeutic’s mobile application “reSET®” became the first PDTx to be approved by the FDA for use in patients with substance abuse disorder. Today, the number of approved PDTx stands at around 40.

FDA approval contains many parallels to the approval process in Germany. Likewise, PDTx undergo rigorous evaluation for safety and effectiveness in clinical trials with clinically-meaningful results published in peer-reviewed journals before approval is granted by FDA. The differences between a DiGA and a PDTx with regulatory approval lie in many details that can only be touched upon in this paper due to the abundance and complexity. One major difference, however, is the reimbursement by insurance companies. While in Germany after BfArM approval the health insurance provider (payer) are obliged to make the agreed payments to the DiGA manufacturers and healthcare providers, the reimbursement of PDTx depends on the respective payer. A prior authorization/claim has to be raised with the health insurance provider prior to prescription and needs to be approved by the payer before reimbursement is granted (Virtusa n.y.). For example, Aetna Inc. (Aetna n.y.), a health insurance owned by CVS Health Corporation, states that PDTs are experimental and investigational because in their opinion there is insufficient evidence in the published peer-reviewed literature to support their effectiveness. Aetna currently reimburses only 13 PDTs.

The success of PDTx depends on how well it is accepted by healthcare providers, which in turn depends on the willingness of payers to adequately reimburse for digital therapies. A survey conducted jointly by Pear Therapeutics and Avalere (Avalere 2021) found that only 40% of payers will cover PDTx in 2021, while 50% plan to do so in the next 18 months.

6. Implications

The average cost per app will go down for producers when an app is billed more often. This is especially true if other EU countries adopt the German model, thus creating a bigger market for producers. In economic terms, the producers will enjoy economies of scale. However, this will be also associated with new costs of translating the apps and perhaps adapting them to the local market. For example, only four out of currently listed 33 DiGAs have a French version (with somnio being one of them).

If a company has several products (e.g., as GET.ON GmbH or GAIA AG do), then they also enjoy economies of scope because they know the approval process and, if apps are in the same specialization, their representative can discuss more than one product with a physician or psychotherapist who are supposed to prescribe the DiGA.

Unfortunately, it is not enough to develop a good DiGA (and have it listed by BfArM). Physicians also need to prescribe it. Physicians will not prescribe a DiGA if they do not know about it. If they know about it, they should be able to investigate it without asking for activation codes (Mittermeier 2022). If they cannot examine it by themselves or they do not have the time for it, they must believe that it is beneficial based on the studies done with it. If a DiGA is listed by BfArM temporarily but no studies have been executed yet, the physicians probably will not prescribe it. Finally, physicians will recommend an application to their patients if this is also beneficial to them in some way (Alpar and Driebe 2021). It is helpful in this context that prescribing a DiGA is budget-neutral for physicians who otherwise receive a fixed budget from statutory insurances for prescribing medication.

Alternatively, patients can demand the activation code for a DiGA from their insurances based on previously diagnosed problems. If patients do not get a cue from their physician, they will ask their insurance for the code only if they perceive the application to be beneficial. This is especially true, if the application can or should be used more than one quarter.

Another threat to the above business model comes from the financing of the firm. If big pharmaceutical or other big companies “discover” the market (see, for example, the takeover of MySugr by Roche (Schade and Scherkamp 2017)), they may participate with stronger financial support and business models that support other activities where revenues from DiGAs are less important. The regulations on the reimbursement of DiGAs explicitly advocate establishing alternative apps in each indication group and thereby advocate price competition among companies. If a DiGA supports the use of a drug with high revenues, for example, then the revenues from the DiGA itself are not important. If a buy-out by a big company takes place, this may make the founders of an app wealthy (and/or the early investors), but the above business model will not work. Many DiGAs, like somnio, are currently financed by relatively small venture funds and (local) business angels (Stüber 2020) who may not have or do not want to spend enough capital to finance the growth of DiGA producers.

To summarize our analysis, the business model of a DiGA can be quite vulnerable on the cost dimension (the approval process and marketing) and the revenues dimension (strong insurances may wish to lower their costs). This may drive some startups out of the business, lower the competition in the healthcare market, and slow down the desired process of innovation with digital applications.

Problem	Solution	Unique Value Proposition	Unfair Advantage	Customer Segments
▪ disorders of falling asleep and sleeping through the night (insomnia)	▪ understand and correctly classify sleep problems ▪ deal with circling thoughts and ruminations ▪ learn relaxation techniques to fall asleep faster ▪ optimize sleep times ▪ increase the ability to perform and concentrate during the day ▪ use a digital sleep diary to document sleep times and analyze their progress	▪ quick access to therapy following professional guidelines	▪ certification following MDR ▪ listing by BfArM ▪ contracts with insurances	▪ patients 18 years of age and older who are experiencing symptoms of insomnia
Key Metrics		**Channels**		
▪ # activation codes ▪ # app used ▪ # prescriptions ▪ # prescriptions via telemedicine ▪ data shared with medical staff		▪ physicians and psychotherapists ▪ telemedicine providers ▪ DiGA directory website of company ▪ health insurances		
Cost Structure		**Revenue Structure**		
▪ sortware development ▪ certification following MDR ▪ registration with BfArM ▪ evidence studies ▪ operations cost ▪ maintenance cost ▪ marketing cost		▪ reimbursement after subscription and activation of DiGA ▪ billed use (privately insured and self-pay patients) ▪ revenues from contracts with insurances		

Fig. 2: Lean business canvas of somnio

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4. Acceptance of social networking sites by older people before and after COVID-19 confinement: a repeated cross-sectional study in Chile

Patricio Ramírez-Correa
Universidad Católica del Norte (Chile)
patricio.ramirez@ucn.cl

Elizabeth Grandón
Universidad del Bío-Bío (Chile)
egrandon@ubiobio.cl

Muriel Ramírez-Santana
Universidad Católica del Norte (Chile)
mramirezs@ucn.cl

Jorge Arenas-Gaitan
University of Seville (Spain)
jarenas@us.es

F. Javier Rondan-Cataluña
University of Seville (Spain)
rondan@us.es

Abstract

This study aims to examine the capacity of the Theory of Planned Behaviour (TPB) to explain the intention to use social networking sites by older people in two time periods, before and after their confinement by the SARS-CoV-2 virus, as well as the evolution of effects (paths) over time of TPB's determinants. Based on the samples of 384 and 383 Chilean adults collected before and after confinement, the evolution of the effects (paths) was analysed using the TPB model applying the PLS-SEM technique. In conclusion, as older people begin to use social networking sites to connect with their families and people of interest during confinement, their attitudes become more significant, their perceptions of control become less important, and social pressures remain permanent in time.

Keywords

Social networking sites, older people, Theory of Planned Behaviour, repeated cross-sectional study, Chile.

1. Introducción

El uso de tecnologías de información tiene un impacto positivo en el bienestar de las personas mayores. Dentro de los beneficios de salud se han descrito el mejoramiento del desempeño cognitivo y de la condición física para realizar actividades de la vida diaria, promoviendo el envejecimiento activo y la participación social (Liu et al., 2021; Marston & Musselwhite, 2021). No obstante, antes del confinamiento por el virus SARS-CoV-2, en Chile existía una gran brecha de uso de Internet por personas mayores. En el año 2014, un 66% no utilizaba Internet, cifra que se mantiene hasta el año 2017 (54% de acceso en hogares en que sólo viven personas mayores de 64 años). Esta brecha aumenta a medida que disminuye el nivel de ingresos (34,2% de acceso en el quintil 1 versus 70,8% de acceso en el quintil 5) (SUBTEL, 2017). En general y previo al virus SARS-CoV-2, se habían identificado barreras en el uso de tecnologías digitales en este grupo de personas, relacionadas con temas psicológicos y sociales, tales como la motivación, la actitud, la privacidad, la confianza y el aprendizaje sobre el uso de tecnología (Marston & Musselwhite, 2021). En particular, en Chile se ha descrito que cerca de un 40% de las personas mayores tiene motivaciones hedónicas para el uso de redes sociales, sin diferencias por sexo, antes del confinamiento (Ramírez-Correa et al., 2019).

La situación epidémica obligó a la población mayor a usar más las tecnologías de información, incluyendo las relacionadas a servicios de atención de salud, uso de aplicaciones para entrenamiento físico y mensajería (Peng Ng et al., 2022; Yu & Hagens, 2022). Según investigaciones internacionales, los beneficios obtenidos se relacionaban con mejoras en la salud mental, disminución de la soledad, fortalecimiento de la capacidad física, mejoras de ánimo y memoria (Ory et al., 2021; Wong et al., 2022). Un estudio de adherencia a programas digitales de salud para adultos mostró que los mayores de 65 años tenían mejor adherencia a la plataforma digital que adultos de menor edad (Pattichis et al., 2021). Así mismo, diversos trabajos han reportado las variables que influyeron en la utilización de servicios de telesalud al inicio de la pandemia. Los adultos mayores adoptaron la tecnología digital y tenían el conocimiento suficiente y la ayuda, pero se sentían aprensivos y tenían barreras financieras para adoptar la tecnología (Wong et al., 2022). Además de las barreras socioeconómicas, otras variables que influyeron en el uso de estas tecnologías en personas mayores fueron el acceso a Internet y uso previo de vídeo llamadas (Peng Ng et al., 2022), nivel de educación, alfabetización digital y actitudes hacia el propio envejecimiento (Bastani et al., 2021; Choukou et al., 2022; Yu & Hagens, 2022).

La mayoría de los estudios citados previamente se centraron en describir los beneficios y barreras en el uso de tecnología digital por parte de las personas mayores. En el caso de las redes sociales, y tal como lo mencionan Ramírez-Correa et al. (Ramírez-Correa et al., 2019), se requiere analizar la intención y uso por parte de este grupo etario a través de modelos teóricos de aceptación tecnológica basados en las creencias y actitudes de los sujetos. Mas aún, fundamentados en estos modelos teóricos, se demanda desarrollar estudios longitudinales para determinar la capacidad explicativa de estos modelos, con el fin de examinar las consecuencias que la pandemia puede haber causado en las percepciones de las personas mayores.

La teoría del comportamiento planeado (TPB, por sus siglas en inglés) (Ajzen, 1991), con raíces en la psicología social, presenta un modelo teórico ampliamente aceptado, el cual, basado en las creencias conductuales, normativas y de control de los sujetos de investigación, ayuda a explicar la intención y uso de tecnologías (p.e. Yu, Yi, Feng, & Liu, 2018; Nadlifatin, Ardiansyahmiraja, & Persada, 2020). En este contexto, el objetivo de este estudio es examinar la capacidad de la TPB para explicar la intención de usar redes sociales por personas mayores en dos periodos de tiempo, antes y después del confinamiento por el virus SARS-CoV-2, como también examinar la evolución de los efectos en el tiempo de sus determinantes.

2. Marco Teórico

2.1 Personas Mayores y Tecnologías Digitales durante la Pandemia por SARS-CoV-2

El mayor riesgo de gravedad y muerte de la infección por SARS-CoV-2 para personas mayores se tradujo, en los primeros dos años de pandemia, en un confinamiento mucho más estricto para ese grupo de la población. En esta reclusión el uso de tecnologías les permitió mitigar los efectos del aislamiento social. Por ejemplo, en Italia, durante el primer año de pandemia, alrededor del 50% de las personas mayores aumentó el contacto no físico intergeneracional, en que los medios digitales más usados fueron vídeo llamadas y mensajes instantáneos (Arpino et al., 2021). En Canadá se identificó que sólo el 15% de las personas mayores no usaba redes sociales o aplicaciones durante la pandemia. Estas personas eran hombres de edad más avanzada que vivían solos, de mala salud y escasas redes de apoyo social. La fiabilidad de la conexión de Internet y el acceso a teléfonos inteligentes también fueron predictores del no-uso de redes sociales (Savage et al., 2021).

En Chile, en un estudio de uso de tecnologías digitales en personas mayores, realizado en el año 2021 por una compañía de comunicaciones, muestra que un 40% aprendió a usar teléfonos inteligentes durante la pandemia y que sólo un 8% se sintió limitado en sus actividades por no saber usar Internet. Así mismo, el 91% de las personas mayores tenía su computador personal, utilizándolo habitualmente en un 90%. El 91% consideraba que Internet es útil en su vida cotidiana, un 89% busca películas o noticias y el 86% se conecta diariamente a redes sociales. Las redes sociales más utilizadas por ellos fueron WhatsApp (95%), Facebook (82%) y YouTube (60%); el 80% realizó trámites por Internet, y de ellos, sólo al 14% le gustaría volver a realizarlos presencialmente (Fundación VTR, 2021).

2.2 Teoría del Comportamiento Planeado

La TPB supone que el comportamiento de un individuo está influenciado por la intención de realizar el comportamiento en estudio. De acuerdo con Ajzen (1991), "las intenciones capturan los factores motivacionales que influyen en el comportamiento" (p. 181). Así, la intención es determinada por tres factores: la actitud hacia el comportamiento (ATT, por sus siglas en inglés), la norma subjetiva (SN, por sus siglas en inglés) y la percepción de control conductual (PBC, por sus siglas en inglés). Las actitudes hacia el comportamiento se refieren al grado en que una persona tiene una actitud favorable o desfavorable de la conducta en cuestión. La norma subjetiva corresponde a la presión social percibida para realizar o no realizar la conducta. Finalmente, la percepción de control conductual refleja las percepciones de que existen impedimentos personales y situacionales a la realización de la conducta. Ajzen (Ajzen, 1991) señaló que cuanto más favorable sea la actitud y la norma subjetiva con respecto a un comportamiento, y cuanto mayor sea el control conductual percibido, más fuerte debe ser la intención de un individuo para realizar el comportamiento bajo consideración. La teoría también plantea que las percepciones de control conductual determinan directamente el comportamiento cuando la persona percibe que tiene todo el control para ejecutar el comportamiento.

La TPB ha sido empleada para explicar la intención de comportamiento en una variedad de sujetos y dominios (p.e. Jung, Shin, Kim, Hermann, & Bice, 2017 ; Farrukh, Alzubi, Shahzad, Waheed, & Kanwal, 2018; Cruise & McLeary, 2018; Nasco, Grandón, & Mykytyn Jr., 2008). En el ámbito de las tecnologías, la teoría se ha utilizado para determinar la intención de utilizar sistemas de aprendizaje mixtos (Nadlifatin et al., 2020), sistemas comerciales (Yu et al., 2018), y tecnología en general (Baker, Al-Gahtani, & Hubona, 2007). En el domino del uso de las redes sociales, y utilizando una extensión de la TPB, Jafarkarimi, Saadatdoost, Sim, & Hee (2016) identificaron los factores que inciden en la toma de decisiones éticas en las redes sociales entre estudiantes universitarios en Malasia. . Además de la actitud, norma subjetiva y percepciones de control conductual, los autores hipotetizaron que las creencias normativas personales, la intensidad moral y la amenaza percibida de castigo legal influyen directamente en la intención de comportarse no éticamente en redes sociales. Sus resultados indican que, además de las creencias normativas personales y la intensidad moral, todos los constructos asociados a la TPB influyen directamente en la toma de decisiones éticas por parte de los estudiantes. En una línea similar, Luqman, Masood, & Ali (2018) estudiaron la intención de discontinuar el uso de redes sociales por parte de estudiantes chinos y encontraron que tanto la actitud como la norma subjetiva y la percepción de control percibido influyen en la intención de dejar de utilizar las redes sociales, y tanto la motivación autónoma como la controlada actúan como antecedentes de las variables exógenas de la TPB.

A pesar de la amplitud y variedad de estudios que han utilizado la TPB, existe una carencia de investigaciones que validen esta teoría en estudios longitudinales. Algunas excepciones son las de Plotnikoff, Lubans, Trinh, & Craig (2012), Leung (2019), Roux, Gourlan, & Cousson-Gélie (2021); Thaker & Ganchoudhuri (2021) y Liu et al. (2022) quienes examinaron diferentes comportamientos y poblaciones objetivo. La Tabla 1 muestra los coeficientes de camino (B, betas) encontrados en cada relación de la TPB en los distintos tiempos considerados y los coeficientes de determinación R^2 que explican el porcentaje de varianza en la intención de ejecutar el comportamiento en cuestión. Dentro de estos estudios, solo los de Leung (2019) y (Liu et al., 2022) desarrollaron un análisis multigrupo para determinar si existían diferencias significativas en la fuerza de los determinantes de la intención entre los sujetos en los tiempos base (T1) y los tiempos posteriores en donde se tomaron los datos (T2).

En general, y como se puede observar de la Tabla 1, la actitud, norma subjetiva y percepciones de control predicen la intención de ejecutar el comportamiento estudiado. Sin embargo, las percepciones de las personas respecto de estos mismos constructos pueden cambiar su intensidad entre un tiempo y otro. Del mismo modo, los porcentajes de varianza explicada varían entre tiempos.

Plotnikoff et al. (2012). Objetivo: Predecir la intención de realizar actividad física en una muestra aleatoria de adultos canadienses y examinar si el género modera las relaciones entre TPB y la intención de realizar actividad física.			
	T1 (1998) (1427 sujetos)	**T2 (2003)** (1427 sujetos)	**Diferencias MGA**
ATT → Intención	0,30***	0,22***	No analizado
SN → Intención	0,11***	n/d	No analizado
PBC → Intención	0,29***	0,11***	No analizado
R^2	R^2 = 0,29	R^2 = 0,21	
Leung (2019). Objetivo: Examinar cómo cambian las intenciones de las personas después de que visitan una página de Facebook asociada a destinos turísticos.			
	T1 (base) (297 sujetos)	**T2 (3 meses después)** (172 sujetos)	**Diferencias MGA**
ATT → Intención	n.s.	-0,15*	-0,214* (disminuye en T2)
SN → Intención	0,25**	0,54**	0,293* (aumenta en T2)
PBC → Intención	0,21**	0,22*	0,008 (similar en ambos T1 y T2)
R^2	R^2 = 0,24	R^2 = 0,42	
Roux et al. (2021). Objetivo: Realizar un estudio longitudinal basado en la teoría TPB para explicar la intención de realizar actividad física por parte de niños de educación básica en Francia y examinar si el género modera las relaciones entre TPB y la intención de realizar actividad física.			
	T1 (base)	**T2 (3 meses después)**	**Diferencias MGA**
ATT → Intención	0,14**	0,14**	No analizado
SN → Intención	0,21***	0,12**	No analizado
PBC → Intención	0,34***	0,38***	No analizado
R^2	R^2 = 0,31	R^2 = 0,38	
Thaker & Ganchoudhuri (2021). Objetivo: Identificar cambios en la intención de inocularse con la vacuna del Covid-19 en la población de Nueva Zelanda.			
	T1 (marzo 2021)	**T2 (mayo 2021)**	**Diferencias MGA**
ATT → Intención	-0,31***	-0,16***	No analizado
SN → Intención	-0,14***	0,02	No analizado
PBC → Intención	No analizado	No analizado	No analizado
R^2	R^2 = 0,74	R^2 = 0,55	
Liu et al. (2022) [1]. Objetivo: Desarrollar un modelo basado en TAM y TPB para predecir la intención de usar tecnologías de información en salud (tablets) en pacientes con enfermedades crónicas en China.			
	T1 (baseline)	**T2 (24 semanas después)**	**Diferencias MGA**
ATT → Intención	0,03 (n.s.)	0,27**	B (8 semanas) > B (línea base)* B (24 semanas) > B (línea base)*
SN → Intención	0,09 (n.s.)	0,08 (n.s.)	No significativo
PBC → Intención	0,38**	0,19 (n.s.)	B (8 semanas) > B (24 semanas)*
R^2	R^2 = 0,51	R^2 = 0,73	

Notas: n/d: no se midió; *p<0.05; **p<0,01; ***p<0,001;

[1] En este estudio longitudinal se recolectaron datos además a las 8 y 16 semanas.

Tabla 1: Estudios longitudinales basados en TPB

Dado lo anterior, proponemos la siguiente hipótesis:

> **H:** Existen diferencias significativas en la fuerza de los determinantes de la intención de usar redes sociales por las personas mayores antes y después del confinamiento por Covid-19.

Basado en TPB, la Figura 1 muestra el modelo de investigación.

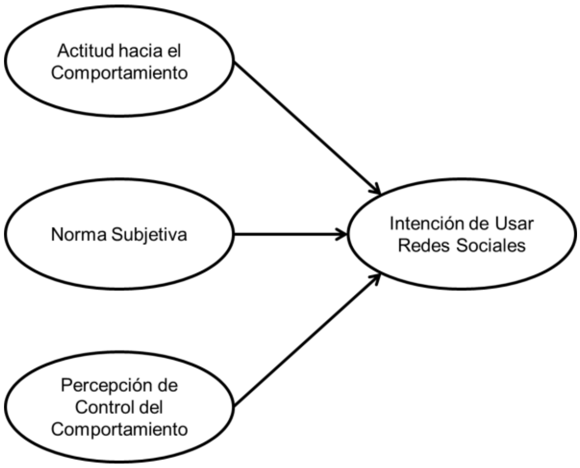

Figura 1: Modelo de investigación

3. Metodología

3.1 Recolección de Datos

A través de una encuesta cara a cara, que utiliza escalas de medida validadas en la literatura, se procedió a obtener datos de personas mayores[1] usuarias de Redes Sociales en base al modelo de investigación. Adicionalmente, se midieron edad, género, educación, actividad laboral, grupo socioeconómico y experiencia en el uso de Internet. Este procedimiento de recolección de datos se realizó en dos momentos del tiempo, el primero (T1) en octubre de 2019, y el segundo (T2) en septiembre de 2021. Utilizamos un diseño transversal repetido, que también se conoce como pseudo-longitudinal, este tipo de diseño de encuesta y uso de datos solicita la misma información a una muestra independiente en cada ciclo (Pan, 2022). Debido a la naturaleza de la propuesta, se hizo inviable el análisis de todos los elementos de la población, por tanto, se llevó a cabo un muestreo estratificado con similares bases de cálculo para cada momento del tiempo. Se consideraron las regiones de Coquimbo y Biobío toda vez que presentan una mayor proporción de población mayor de 60 años comparado en Chile. Como marco de muestreo se utilizó los resultados del censo de población más actualizado de que dispone el país para las regiones de Coquimbo y Biobío. Para determinar la proporción de usuarios de Internet por género y rango de edad se utilizó los resultados de la IX Encuesta Accesos y Usos de Internet de la Subsecretaria de Telecomunicaciones de Chile, cuya información constituye el estudio más actualizado existente en Chile. Se consideró usuario a quien reporta que ha usado Internet hace tres meses o menos. Luego de filtrar esta base de datos y calcular las proporciones se obtuvo el total de personas mayores. El compromiso entre el costo total de la encuesta y el número de variables a recolectar nos llevó a plantear un procedimiento estratificado por afijación simple para determinar el tamaño de la muestra, considerando para ello un error máximo permitido de 5%. Con ello, el cálculo del tamaño de la muestra global para 2019 se redujo a 384 y para 2021 a 383. Como segundo paso se distribuyó la muestra global en los estratos por afijación simple. En la Tabla 2 se presenta las distribuciones de las muestras estratificadas de acuerdo con la afijación descrita.

La recolección de datos se realizó por encuestadores en lugares de afluencia de personas mayores usuarios de redes sociales, como programas de adulto mayor de universidades, cajas de compensación, centros médicos, entre otros. Los encuestadores están asociados mayoritariamente a profesiones de

[1] Acorde a la Ley 19.828 de Chile una persona mayor es una persona de 60 años y más.

salud y fueron entrenados para el proceso de recolección. Las tomas de datos contaron con aprobación de Comité de Ética de la Universidad Católica del Norte (R14/2019 y R05/2021).

Edad	T1: Antes del Confinamiento			T2: Después del Confinamiento		
	Mujeres	Hombres	n (%)	Mujeres	Hombres	n (%)
60-69	128	104	232 (60,4)	121	107	228 (59,5)
70-79	72	53	125 (32,6)	66	50	116 (30,4)
80 o más	15	12	27 (7,0)	26	13	39 (10,2)
Total (%)	215 (56,0)	169 (44,0)	384 (100,0)	213 (55,6)	170 (44,4)	383 (100,0)

Tabla 2: Distribución de las muestras estratificadas

3.2 Análisis de Datos

Para el análisis de datos se utilizó la técnica de modelamiento de ecuaciones estructurales basado en la varianza (PLS-SEM, de las siglas en inglés) (Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, 2014). Esta técnica examinó tanto el modelo de medida como el modelo estructural. El análisis fue realizado para cada modelo (T1 y T2). De acuerdo con el procedimiento propuesto por Roemer (2016), para examinar la existencia de evoluciones significativas en los coeficientes de camino entre T1 y T2 se empleó el análisis multigrupo de mínimos cuadrados parciales (PLS-MGA de las siglas en inglés) (Henseler, 2012). En específico, el procedimiento propuesto por Roemer (2016) es una visión sistemática sobre cómo utilizar PLS-SEM en estudios longitudinales. Este procedimiento plantea que, si el principal objetivo de investigación es examinar la evolución de los efectos en un modelo a lo largo del tiempo y la base de datos no consiste en datos de panel, pero si los investigadores han medido los mismos indicadores en diferentes momentos del tiempo con diferentes muestras (datos transversales repetidos), se deberían seguir los siguientes pasos: establecer los modelos PLS-SEM separados según los diferentes momentos en el tiempo; realizar un análisis multigrupo para probar los cambios en los coeficientes de trayectoria a lo largo del tiempo; y realizar pruebas t de muestras independientes de las puntuaciones del constructos. Por otra parte, PLS-MGA es un enfoque basado en PLS-SEM para el análisis multigrupo propuesto por Henseler (2012). Este método es una prueba de significación no paramétrica para las diferencias de resultados específicos de grupos que se basa en los resultados de un muestreo autodocimante del modelo PLS-SEM. Para una determinada diferencia de coeficientes de trayectoria entre dos grupos, un resultado es significativo al nivel del 5% de probabilidad de error si el valor p de la prueba es inferior a 0,05 o superior a 0,95. Antes de realizar el PLS-MGA se comprobó la invariancia de medida utilizando el procedimiento MICOM (Henseler et al., 2016). MICOM, por las siglas en inglés de evaluación de la invariancia de la medición, es un método de tres pasos que permite analizar la invarianza de medición de los modelos antes de realizar análisis multigrupo en PLS-SEM. El primer paso propone asegurar en el cálculo de los modelos asociados a cada grupo que todos los parámetros del análisis PLS-SEM sean los mismos. El segundo y tercer paso se basan en permutaciones de los datos, la evaluación exitosa del segundo paso permite realizar un análisis de las diferencias de coeficientes de trayectoria entre dos grupos, y, por otra parte, la evaluación exitosa del tercer paso establece una invarianza completa entre los grupos evaluados. Para todos los análisis se usó el software SmartPLS (Ringle, Christian M., Wende, Sven, & Becker, 2015).

4. Resultados

4.1 Modelos Estructurales

Los resultados de PLS-SEM se muestran en Tabla 3, Tabla 4 y Figura 2, el detalle de este examen se incluye en el Anexo A. Basados en el procedimiento propuesto en Kock y Hadaya (2018), en T1 y T2 los tamaños de las muestras alcanzaron el número mínimo para proporcionar al análisis un poder estadístico del 80%. El análisis muestra coeficientes de camino positivos en la mayoría de las relaciones, excepto entre percepción del control del comportamiento e intención de usar redes sociales después del confinamiento. Esto es, después de pandemia, la percepción del control del comportamiento es insignificante para explicar la varianza de la intención de usar redes sociales por las personas mayores. Por otra parte, entre los antecedentes de la intención de usar redes sociales, la actitud es el principal determinante antes y después del confinamiento; le sigue, antes del confinamiento, la percepción del control del comportamiento, y después del confinamiento, la norma subjetiva.

Camino	T1: Antes del Confinamiento			T2: Después del Confinamiento		
	ß	Intervalo de confianza corregido por sesgo de ß		ß	Intervalo de confianza corregido por sesgo de ß	
		2,5%	97,5%		2,5%	97,5%
Actitud hacia el comportamiento -> Intención de usar redes sociales	0,236***	0,109	0,360	0,514***	0,419	0,601
Norma Subjetiva -> Intención de usar redes sociales	0,142**	0,042	0,246	0,259***	0,174	0,345
Percepción del control del comportamiento -> Intención de usar redes sociales	0,308***	0,185	0,425	0,071ns	-0,019	0,151

Nota: Intervalo de confianza corregido por sesgo basado en un procedimiento bootstrap de 10.000 muestras.

ns: no significativo, ** valor $p < 0,01$, *** valor $p < 0,001$.

Tabla 3: Resultados de PLS-SEM

La Tabla 4 muestra los coeficientes de determinación de la intención de usar redes sociales. En T1 los coeficientes tiene una magnitud de varianza explicada débil, pero en T2 estos aumentan a una magnitud moderada, pasando de una varianza explicada de la intención de las personas mayores de usar redes sociales del 27% antes de pandemia a una por sobre el 50% después de ella.

Coeficiente	T1: Antes del Confinamiento	T2: Después del Confinamiento
R^2	0,270*	0,505**
R^2 ajustado	0,270*	0,502**

Nota: Magnitud de la varianza explicada: **moderada, * débil.

Tabla 4: Coeficientes de determinación

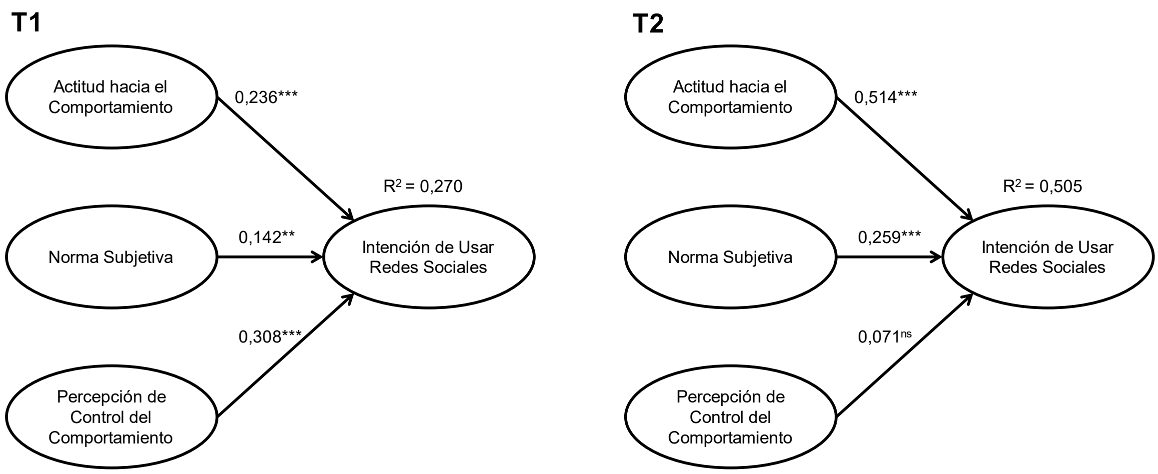

Figura 2: Resultados antes (T1) y después (T2) del confinamiento

4.2. Análisis Multigrupo

Antes de realizar el PLS-MGA de ejecuto el procedimiento MICOM para determinar la invarianza de medida. Este análisis indicó que existía invarianza de medida parcial, por tanto, era posible el análisis multigrupo. Como se puede apreciar en la Tabla 5, existen dos caminos que tienen evoluciones significativas en los coeficientes de camino entre T1 y T2. Por una parte, el efecto de la actitud se incrementa significativamente entre antes y después del confinamiento, y, por otra parte, el efecto de la percepción del control disminuye significativamente entre antes y después del confinamiento.

Camino	**T1 vs T2**	
	ß1- ß2	**Valor p**
Actitud hacia el comportamiento → Intención de usar redes sociales	-0,278**	0,001
Norma Subjetiva → Intención de usar redes sociales	-0,118^{ns}	0,080
Percepción del control del comportamiento → Intención de usar redes sociales	0,237**	0,002

Nota: ns: no significativo, ** valor p < 0,01

Tabla 5: Resultados de PLS-MGA

Los resultados anteriores soportan la hipótesis establecida en el estudio.

5. Discusión y Conclusión

Nuestra investigación representa el primer estudio transversal repetido de la TPB para la explicación del uso de redes sociales en una muestra de personas mayores en Chile, en un periodo de dos años. Consistente con esta teoría y con estudios previos (Gibson, Magnan, Kramer, & Bryan, 2021; Roux et al., 2021), en el tiempo T1 antes del confinamiento las actitudes, norma subjetiva y percepciones de control se relacionaron directamente con la intención de utilizar redes sociales por parte de personas mayores. Sin embargo, casi dos años después de experimentar el confinamiento, el modelo se validó parcialmente toda vez que las percepciones del control del comportamiento resultaron no ser predictoras de la intención de utilizar redes sociales. Este resultado va en línea con el estudio longitudinal de Yu et al. (2018) y de Liu et al. (2022), quienes utilizando la TPB concluyeron que las percepciones del control del comportamiento no inciden en la intención de utilizar dispositivos digitales móviles en pacientes con enfermedades crónicas en China en un tiempo T2.

Por otro lado, este estudio encontró que las percepciones de las personas mayores cambiaron producto del confinamiento al cual fueron sometidas, de modo que, la fuerza explicativa de la actitud en la intención de usar las redes sociales aumenta significativa y positivamente después del confinamiento, mientras que las percepciones de control disminuyen significativa y negativamente después de este evento. Esto puede deberse a que las personas mayores han adquirido experiencia en el uso de redes sociales durante el confinamiento, lo que ha causado se sientan más seguras y que cuentan con el conocimiento, las competencias y, en general, con los recursos para utilizarlas. Por su parte, la norma subjetiva no sufre variaciones significativas en los tiempos T1 y T2. Este hallazgo es consecuente con lo encontrado por Liu et al. (2022).

Los hallazgos sugieren que el aislamiento provocado por el confinamiento obligó a las personas mayores a comunicarse a través de redes sociales y a utilizar Internet para realizar trámites, compras y mantenerse informados, entre otras motivaciones. Con ello, las personas mayores aprendieron a usar esta tecnología, modificándose la fuerza de las variables que determinan la intención de uso de redes sociales. La reducción de la influencia del control percibido podría relacionarse con ese aprendizaje, considerando que era el determinante más importante del modelo observado antes del confinamiento. Creemos que, si bien el cambio de la influencia de la norma subjetiva no fue significativo, se aprecia un aumento de su influencia hacia la intención del uso de redes sociales, y probablemente esto es explicado por la importancia que tiene mantener la vida social y familiar de manera virtual.

En conclusión, a medida que las personas mayores comienzan a utilizar las redes sociales para conectarse con sus familiares y personas de interés durante el periodo de confinamiento, sus actitudes se tornan más significativas, sus percepciones de control se vuelven menos importantes mientras que las presiones sociales que pueden sentir se mantienen permanentes en el tiempo.

Una de las principales limitaciones de este estudio se relaciona con el escaso tamaño de la muestra, que, si bien el número total de encuestados es concordante con otros estudios en este mismo grupo etario, su alcance restringe la generalización de los hallazgos.

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ANEXO A: Detalles del análisis con PLS-SEM[2]

Ítem	T1				T2			
	ATT	BI	PBC	SN	ATT	BI	PBC	SN
ATT1	0,931				0,924			
ATT2	0,850				0,890			
PBC1			0,886				0,868	
PBC2			0,888				0,866	
IU1		0,961				0,961		

[2] BI: Intención de usar redes sociales; ATT: Actitud hacia el comportamiento; PBC: Percepción del control del comportamiento; SN: Norma social.

IU2		0,980				0,980		
IU3		0,969				0,953		
NS1				0,875				0,902
NS2				0,847				0,921
NS3				0,885				0,887

Tabla A1: Cargas externas de los ítems

Constructo	**T1**		**T2**	
	Fiabilidad compuesta	**Varianza extraída media (AVE)**	**Fiabilidad compuesta**	**Varianza extraída media (AVE)**
ATT	0,885	0,795	0,903	0,823
BI	0,979	0,941	0,976	0,931
PBC	0,880	0,786	0,858	0,751
SN	0,902	0,755	0,930	0,816

Tabla A2: Fiabilidad y validez de constructos

Criterio / Constructo	**T1**				**T2**			
	ATT	**BI**	**PBC**	**SN**	**ATT**	**BI**	**PBC**	**SN**
Fornell-Larcker								
ATT	0,907				0,891			
BI	0,668	0,965			0,400	0,97		
PBC	0,395	0,346	0,867		0,378	0,433	0,887	
SN	0,487	0,529	0,277	0,903	0,336	0,298	0,251	0,869
HTMT								
BI	0,763				0,455			
PBC	0,542	0,431			0,501	0,515		
SN	0,583	0,571	0,358		0,424	0,330	0,321	

Tabla A3: Validez discriminante

Constructo	**T1**	**T2**
ATT	1,257	1,451
PBC	1,190	1,198
SN	1,150	1,326

Tabla A4: Evaluación de colinealidad (VIF)

Relación	T1			T2		
		Intervalos de confianza			Intervalos de confianza	
	Beta	2,5%	97,5%	Beta	2,5%	97,5%
ATT -> BI	0,236	0,119	0,377	0,514	0,414	0,602
PBC -> BI	0,308	0,181	0,428	0,071	-0,008	0,162
SN -> BI	0,142	0,038	0,243	0,259	0,172	0,343

Tabla A5: Coeficientes de camino del modelo structural

Coeficiente	T1	T2
R cuadrado	0,270	0,505
R cuadrado ajustado	0,264	0,502

Tabla A6: Coeficientes de determinación

Relación	T1	T2
ATT -> BI	0,061	0,368
PBC -> BI	0,109	0,009
SN -> BI	0,024	0,102

Tabla A7: Tamaño del efecto f^2

Paso 2					
Constructo	**Correlación original**	**Correlación de medias de permutación**	**5,00%**	**P-valores de permutación**	
ATT	0,999	0,999	0,995	0,436	
BI	1,000	1,000	1,000	0,397	
PBC	1,000	0,997	0,989	0,964	
SN	1,000	0,999	0,997	0,608	
Paso 3a					
Constructo	**Media - diferencias originales (T1 - T2)**	**Media - diferencia de medias de permutación (T1 - T2)**	**2,50%**	**97,50%**	**P-valores de permutación**
ATT	-0,014	-0,006	-0,144	0,142	0,854
BI	0,216	-0,003	-0,146	0,144	0,001
PBC	0,381	-0,003	-0,142	0,129	0,000
SN	0,070	-0,002	-0,145	0,150	0,320
Paso 3b					

Constructo	Varianza - diferencia original (T1 - T2)	Varianza - diferencia de medias de permutación (T1 - T2)	2,50%	97,50%	P-valores de permutación
ATT	0,123	0,008	-0,284	0,300	0,455
BI	-0,049	0,002	-0,358	0,340	0,784
PBC	-0,120	0,003	-0,248	0,264	0,372
SN	0,012	0,003	-0,246	0,226	0,918

Tabla A8: Pasos 2 y 3 de MICOM

Relación	Coeficientes path-dif. (T1 - T2)	PLS-MGA		Test paramétrico		Test de Welch-Satterthwaite	
		Valor p original 1 cola (T1 vs T2)	Valor p nuevo 2 colas (T1 vs T2)	Valor t (T1 vs T2)	Valor p (T1 vs T2)	Valor t (T1 vs T2)	Valor p (T1 vs T2)
ATT -> BI	-0,278	0,999	0,001	3,430	0,001	3,432	0,001
PBC -> BI	0,237	0,001	0,002	3,149	0,002	3,150	0,002
SN -> BI	-0,118	0,960	0,080	1,760	0,079	1,761	0,079

Tabla A9: Análisis multigrupo

Indice	T1	T2
SRMR	0,057	0,055
d_ULS	0,181	0,164
d_G	0,177	0,186
Chi-cuadrado	441,831	481,95
NFI	0,830	0,835

Tabla A10: Ajuste del modelo de medida (modelo saturado)

5. An Accessible Web CAPTCHA Design for Visually Impaired Users

Mansour Alqarni,
Ontario Tech University
Mansour.alqarni@ontariotechu.net

Fangyi Yu,
Ontario Tech University
Fangyi.Yu@ontariotechu.net

Rupendra Raavi,
Ontario Tech University
Rupendra.Raavi@ontariotechu.ca

Mahadeo Sukhai,
ARIA Team
mahadeo.sukhai@cnib.ca

Abstract

In the realm of computing, CAPTCHAs are used to determine if a user engaging with a system is a person or a bot. The most common CAPTCHAs are visual in nature, requiring users to recognize images comprising distorted characters or objects. For people with visual impairments, audio CAPTCHAs are accessible alternatives to standard visual CAPTCHAs. Users are required to enter or say the words in an audio-clip when using Audio CAPTCHAs. However, this approach is time-consuming and vulnerable to machine learning algorithms, since automated speech recognition (ASR) systems could eventually understand the content of audio with the improvement of the technique. While adding background noise may deceive ASR systems temporarily, it may cause people to have difficulties deciphering the information, thus reducing usability. To address this, we designed a more secure and accessible web CAPTCHA based on the capabilities of people with visually impairments, obviating the need for sight via the use of audio and movement, while also using object detection techniques to enhance the accessibility of the CAPTCHA.

Keywords:
Accessibility, CAPTCHAs, Computer Vision, Human-computer Interaction, Impairment.

1. Introduction

CAPTCHAs (Completely Automated Public Turing Tests to Distinguish Computers from Humans) are often used online to distinguish between human users and non-human bots (Von Ahn et al., 2004). Most CAPTCHAs do this by requiring users to perform visual-processing tasks that are easy for humans but complex for bots (Kaur & Behal, 2014). These visual-processing tasks, on the other hand, are unavailable to the world's 285 million persons with visual impairments (PVIs), 39 million of whom are completely blind and 246 million of whom have impaired vision. Rather than that, PVIs depend on audio CAPTCHAs, which use auditory processing tasks to distinguish people from bots.

Audio CAPTCHAs are substantially less useful than their visual counterparts in their present condition (Sasse et al., 2001). While visual CAPTCHAs take an average of 9.8 seconds to solve and have a 93% success rate, audio CAPTCHAs take an average of 51 seconds to complete and have a 50% success rate (Bursztein et al., 2010). This performance and accuracy disparity exists because current audio CAPTCHAs are modeled after their visual equivalents rather than using audio-specific designs (Bigham et al., 2009). As such, present audio CAPTCHAs impose unreasonably high demands on the users who rely on them in terms of attention and memory capacity. This implies that visual CAPTCHAs are not a comparable challenge to audio CAPTCHAs; audio CAPTCHAs are more troublesome for PVIs than visual designs are for fully sighted individuals (Holman et al., 2007).

Interference in audio is one of the most significant challenges people have while attempting to solve audio CAPTCHAs. Many PVIs, for example, depend on screen readers to assist themselves with navigating user interfaces. When these users begin entering the letters they hear in a CAPTCHA task, their screen reader system reads each typed letter aloud while they listen for the next character in the task. As a result of the auditory conflict between the written and spoken letters, needless user aggravation and mistakes are created.

2. CAPTCHA Solutions for PVIs

2.1 Crowdsourcing and Friend-sourcing

A lot of PVIs rely on distant support services or seek direct assistance from friends and family (Wu & Lada, 2014). While both strategies involve collaboration, crowdsourcing and friend-sourcing can assist PVIs in overcoming the accessibility issues inherent in today's online CAPTCHA challenges. Prior work (Bigham et al., 2010) has examined the possibility of linking PVIs with remote support from sighted assistants, for instance, answer inquiries about the situation or seek verbal advice when utilizing inaccessible interfaces. These applications, however, are restricted to descriptive instruction, limiting their effectiveness in solving task-based CAPTCHAs.

There are other trade-offs to crowdsourcing or soliciting assistance from friends. Crowdsourcing may raise privacy and security concerns for remote control — where a stranger takes over the PVI's system to answer CAPTCHAs on their behalf — friend-sourcing is more in line with PVIs' established workflows: PVIs typically seek support from friends and family members to address physical world accessibility problems (Abdrabo et al., 2016). Nevertheless, friend-sourcing might also create privacy concerns, since users may not want their continuing behaviors exposed to their friends. Additionally, friend-sourcing might help PVIs save money by eliminating the need for professional crowd workers. However, friend-sourcing is slower and less dependable compared with crowdsourcing according to a study on people with Alzheimer disease (Bateman et al., 2017), and PVIs may prefer to avoid flooding their social networks with repetitive requests for assistance (Rzeszotarski & Morris, 2014).

Zhang et al. (Zhang et al., 2021) developed and implemented a novel framework, termed WebAlly, that enables PVIs to obtain immediate assistance from friends or trained crowd workers at the point of need. Their solution, which was implemented as a Google browser extension, consists of mainly two parts: (1) A one-way request from the requester and (2) a synchronous cooperation procedure between the helper and the requester. Their framework, however, was restricted to only one specific type of CAPTCHA challenge (the Google reCAPTCHA) and cannot generalize to other visual-based CAPTCHA challenges (such as dragging puzzles; differentiating and typing distorted letters). Additionally, their approach necessitates interaction between PVIs and their supporters, which may impair PVIs' perceived independence when doing everyday duties.

2.2 Audio CAPTCHAs

In comparison to crowdsourcing and friend-sourcing, audio CAPTCHAs are more pervasive and commonly adopted alternatives to PVIs. There are two categories of audio CAPTCHAs, according to prior research: rule-based and content-based. Rule-based tasks require users to interpret what they hear. For instance, “count the number of times you hear the digit eight”. This type of tasks can alleviate the strain on short-term memory, as they need simply the recall of a running total (Bock et al., 2017). Whereas for the content-based tasks, users need to translate the voice in an audio recording to text. For example, “type the letters in the audio recording in the textbox to pass the CAPTCHA”.

Sauer et al. investigated the impact of content-based designs that closely approximate the latest design standard for audio and visual CAPTCHAs. They played eight digits in distorted voices and asked people to input them sequentially in their experiment. As a result, they found that this strategy dramatically increased the cognitive burden from PVIs, which require them to remember the CAPTCHA sequence or utilize external tools to swiftly identify the objects they heard. The content-based designs are proved to be not usable based on the experiment result of a 46 percent CAPTCHA passing success rate and lengthy average time required to complete tasks (Sauer et al., 2008).

Fanelle et al. (Fanelle et al., 2020) developed CAPTCHAs with a reduced short-term cognitive burden, requiring users to recall only one or two entities at a time. They achieved this using rule-based design and the elimination of acoustic interference. They created four new CAPTCHAs: Math (e. g., answer the sum of two digits), Pauses (e. g., record each letter played in the recording), Character (e.g., count how many times the word “3” is spoken and type the result), and Categories (e.g., count the number of sounds made by trains). They recruited PVIs globally for a comprehensive user study to assess the usability of their CAPTCHA designs, as well as participants' perceptions and opinions. Additionally, they evaluated the CAPTCHAs' security using cutting-edge natural language processing technologies (Solanki et al., 2017). Consequently, Pauses is the least secure design (67 percent of problems were resolved by machines), followed by Match (22 percent were solved by machines). Furthermore, participants regarded the Character design as the most usable and satisfying, while the Categories design was the quickest and most accessible.

3. Methodology

In contrast to the previously discussed CAPTCHA types, we suggest a web CAPTCHA design that incorporates object detection techniques, requiring PVIs to simply obey the audio instruction to turn their heads in order to pass the CAPTCHAs.

Recently, neural networks have returned to the forefront of classification challenges thanks to AlexNet (Krizheysky et al., 2012). A deeper version of the VGG (Simonyan et al., 2014) and the GoogLeNet (Szegedy et al., 2015) suggested an "inception" design to tackle the problem of depth and breadth limitations in deep convolutional neural networks. As time passed by, the residual neural network (ResNet) (Zhang et al., 2016) offered a new residual neural network block design which allowed a weaker and small link to counteract network depth's disappearance of gradients. When DenseNet (Huang et al., 2017) was introduced, it enhanced the accuracy and increased the efficiency of the network, and the computational cost was significantly lowered.

R-CNN (Girshick et al., 2015), Fast R-CNN (Ren et al., 2015), Faster R-CNN (Liu et al., 2016) and other multi-step networks are widely used. Convolution is required for each R-CNN region proposal box, which is a considerable time investment. Fast R-CNN here does a single convolutional proceeding over the complete picture which increases the speed drastically, and the convolution features that are extracted will be directly given as an input to the RPN to obtain feature information from each proposal box, which further enhances the speed and accuracy. Despite this, the two-step network's rate is much lower than that required for real-time detection. YOLO (Shafiee et al., 2017) and SSD, two prominent one-step networks, are at the top of this list of one-step networks. Moreover, object detection algorithms such as YOLO use the intersection over union (IOU) to calculate accuracy which makes themselves more effective than other algorithms.

4. Our Proposal and Implementation

We propose to use the deep learning-based facial recognition model called tiny face detection, built on top of the several ingle-shot shot detector (SSD) units (Liu et al., 2016). Our deep learning model is written in JavaScript, which enables us to deploy it via the web. After developing the model, we distributed it through the web.

The main objective of our model is to detect if there is a human in front of the webcam. Once PVIs click the “identify” button, the webcam will open and determine if a person is present based on the facial recognition model. If a person is recognized, then the CAPTCHA is successfully passed; otherwise, it indicates that the CAPTCHA has failed and prompts the user to try again. Our CAPTCHA design is illustrated in Figure 4.

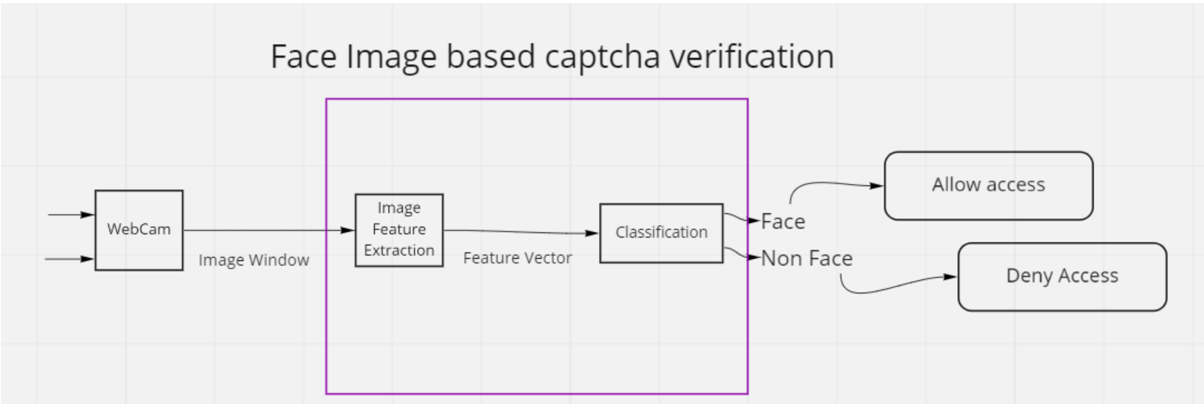

Figure 4: Our CAPTCHA Design (Webcam Model Face Recognition)

In our web CAPTCHA design, a user activates the camera first, and then our deep learning model extracts features from each frame of the webcam's recorded image. After that, the model evaluates whether to grant or prohibit access depending on the extracted features. Figure 5 shows several experiments we ran for testing our CAPTCHA.

5. Evaluation of the Deep Learning Model

In the process of evaluating a model, there are certain metrics on which the model should be evaluated against about what makes a certain method trustworthy. These metrics are more important when it comes to setting face recognition evaluation practice standards in terms of how models are evaluated.

To maintain the audit's credibility, the benchmarks must be consistent, both in terms of ethical expectations and standards, and the data itself. It may be difficult to compare one year's achievements with the previous year's if ethical standards and performance criteria are not consistent. Audit scheduling is the only part of the procedure that has yet to be standardized. In the absence of a regular audit period, there is no expectation that standards or expectations will be met consistently, and this is a significant problem. Benchmark features, such as data resolution, can be affected by equipment modifications, such as those made to digital cameras. In our research, photo sizes and resolutions ranged from 32x32 to 3072x2048 or even higher among benchmarks. When the amount of pixels is utilized as the direct input to methods such as deep learning, it becomes more difficult to establish which aspects of reported performance measurements are dependent on these other characteristics.

Figure 5: CAPTCHA Testing

In these regards, we are planning to use several standardized metrics to evaluate our model, including accuracy, precision, and recall. All these measurements take into account four critical values: true positive (TP), false positive (FP), true negative (TN) and false negative (FN).

A true positive is an outcome for which the model forecasts the positive class correctly. A true negative, similarly, is an outcome for which the model properly predicts the negative class. On the other hand, a false positive occurs when the model forecasts the positive class inaccurately, meaning that the sample is indeed negative, whereas a false negative is an outcome in which the model forecasts the negative class incorrectly, where the sample is in the positive class.

Accuracy is the ratio of the correctly labeled subjects to the whole pool of subjects. Precision means the percentage of the predicted results which are positive. On the other hand, recall refers to the percentage of total positive results correctly classified by our model. The formulas are shown as follows:

$$Accuracy = (TP + TN)/(TP + TN + FN + FP)$$

$$Precision = TP/(TP + FP)$$

$$Recall = TP/(TP + FN)$$

6. Limitations

Our web CAPTCHA has several drawbacks such as the inability to discriminate between a photograph and a regular person. Our CAPTCHA recognizes the human face in photographs and allows users to proceed (as shown in Figure 6). This might result in serious security vulnerabilities if attackers utilize photographs to circumvent our CAPTCHAs. To address this problem, we intend to embed audio instructions into the web CAPTCHA and require users to follow the instructions (e.g., head adjustments, head rotation right, left, up and down) to pass our CAPTCHA.

7. Conclusion

In this paper, we propose to develop a web CAPTCHA design using a deep learning face detection model in order to enhance the usability for PVIs. In the future, we plan to build a real-time detection model to recognize human by asking the users to move their head in different directions to alleviate any visual load for PVIs.

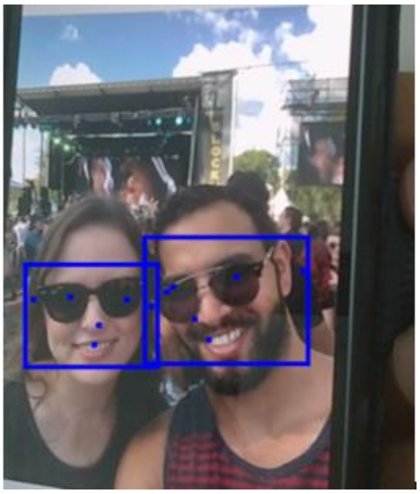

Figure 6: Our model detects the photo as a person and allows passing the CAPTCHA

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6. An Exploratory-Descriptive Review of Main Big Data Analytics Reference Architectures – an IT Service Management Approach

Manuel Mora
Autonomous University of Aguascalientes
jose.mora@edu.uaa.mx

Jorge Marx Gomez
University of Oldenburg
jorge.marx.gomez@uni-oldenburg.de

Paola Reyes-Delgado
Autonomous University of Aguascalientes
pyrd25@hotmail.com

Oswaldo Diaz
INEGI
oswaldo.diaz@inegi.org.mx

Abstract

Big Data Analytics (BDA) aims to create decision-making business value by applying multiple analytical procedures from the Statistics, Operations Research and Artificial Intelligence disciplines to huge internal and external business datasets. However, BDA requires high investments in IT resources – computing, storage, network, software, data, and environment -, and consequently the selection of the right-sized implementation is a hard business managerial decision. Parallelly, IT Service Management (ITSM) frameworks have provided best processes-practices to deliver value to end-users through the concept of IT services, and the provision of BDA as Service (BDAaaS) has now emerged. Consequently, from a dual BDA-ITSM perspective, delivering BDAaaS demands the design and implementation of a concrete BDAaaS architecture. Practitioner and academic literature on BDAaaS architectures is abundant but fragmented, disperse and uses a non-standard terminology. ITSM managers and academics involved on the problematic to deliver BDAaaS, thus, face the lack of mature practical guidelines and theoretical frameworks on BDAaaS architectures. In this research, consequently, with an exploratory-descriptive purpose, we contributed with an updated review of three main non-proprietary BDAaaS reference architectures to ITSM managers, and with a hybrid functional-deployment architectural view to the BDAaaS literature. However, given its exploratory status, further conceptual and empirical research is encouraged.

Keywords: Big Data Analytics as a Service (BDAaaS), IT Service Management (ITSM), BDAaaS architectures, Reference Architecture, NIST Big Data Reference Architecture V3.0.

1. Introduction

In the modern business environment, thousands of Big Data Analytics (BDA) projects are pursued by multiple business organizations given the expected organizational value to be generated (Oesterreich et al., 2022; Fortune, 2022). Big Data business relevance has been recognized from about one decade (Davenport et al., 2012; McAfee & Brynjolfsson, 2012). For instance, Davenport et al. (2012) realized the potential value of the 3V - volume, velocity and variety - Big Data attributes, and McAfee and Brynjolfsson (2012) qualified Big Data as a critical input to improving the modern business decision-making process due to the data richness provided by Big Data – i.e. high data variety, faster generation of data, and huge data volume –. At present days, 5V Big Data model has also included veracity attribute – i.e. quality and trust on data and data sources - and has done explicit the value attribute (Wamba et al., 2015).

Business value of Big Data only can be generated when Big Data is analyzed by human and/or machine decision makers (Klee et al., 2021). For this aim, multiple Artificial Intelligence – including Data Mining and Machine Learning approaches -, Statistics, and Database Management techniques (Phillips-Wren et al., 2015) are used through the umbrella of Analytics. Analytics was defined as the organizational ability to "collect, analyze, and act on data" (Davenport, 2006; p. 1) before its convergence with Big Data, but currently the joint Big Data Analytics approach is fundamental for modern business organization to support data-driven decision-making and creating business value (Klee et al., 2021). Big Data Analytics is the joint approach to creating data-based business value by applying analytics techniques to complex high-volume, high-velocity and high-variety data sets that require advanced technologies for their gathering and transmission, pre-processing and storage, veracity management, processing, analysis, and visualization. However, despite the highest potential business value of Big Data Analytics, its realization counter demands high investments in IT resources – computing, storage, network, software, applications, data, and IT environment – (Rao et al., 2019).

Parallelly, IT Service Management (ITSM) frameworks and standards have provided to business organizations with the best processes-practices to deliver value to end-users through the concept of IT services (Hunnebeck, 2011; TSO, 2018; ISO/IEC, 2019), and Big Data Analytics as Service (BDAaaS) (Delen & Demirkan, 2013; Wang et al., 2017) has emerged from the convergence of three components – Big Data Analytics, Big Data Analytics IT resources, and ITSM frameworks -. From the perspective of ITSM managers and academics, delivering BDAaaS implies a hard design effort given that despite the abundant literature on BDAaaS architectures (Sena et al., 2017; Ataei & Litchfield, 2020), it is highly fragmented, disperse and uses a non-standard and formal terminology (ISO/IEC/IEEE, 2011).

Consequently, to design-select the right-sized BDAaaS architecture implementation for a business organization is a hard business managerial-technical decision for ITSM managers. Similarly, the diversity, fragmentation, and lack of compliance to the standard and formal terminology of the system architecture ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE, 2011) delay the scholastic maturation of this research stream. In this research, thus, with an exploratory-descriptive purpose, we report an updated review of three main non-proprietary BDAaaS reference architectures to ITSM managers and contribute to the literature with an integrative hybrid functional-deployment architectural view. This paper continues as follows. In Section 2, we describe the research approach. In Section 3, the theoretical foundations of Big Data Analytics capabilities, and IT service architecture models are reported. In Section 4, the selected three main non-proprietary BDAaaS reference architectures are exploratory reviewed. In Section 5, a discussion of contributions is presented. Finally, in Section 6 the conclusions of this research are reported.

2. Research Method

This research applies a Conceptual Review and Analysis (CRA) research methodology adapted from Glass et al. (2004) and Mora et al. (2008), where an exploratory-descriptive was pursued. This CRA was performed through four general activities: CRA.1 Research Definition; CRA.2 Research Purpose and Method; CRA.3 Conceptual Data Collection; and CRA.4 Conceptual Analysis and Synthesis.

CRA.1 activity corresponds to Sections 1 and 3. Section 1 describes the context, knowledge gap, motivation, and methodological justification for conducting this research. Section 3 presents the technical theoretical foundations to support this research. CRA.2 and CRA.3 activities correspond to Section 2. In CRA.2, the exploratory-descriptive purpose was stated as "**to provide an updated review of top-three non-proprietary BDAaaS Reference Architectures useful to ITSM Managers relying in an integrative BDAaaS hybrid functional-deployment architectural view**". A Selective Literature Review (SeLR) method was used instead of a Systematic Literature Review (SLR) (Pare et al., 2015). SLR is usually conducted for mature domains to generate quantitative-based summaries of attributes-topics from the vast generated knowledge rather than to provide deep conceptual reviews on a small but representative group of studies (Boell & Cecez-Kecmanovic, 2015). Because BDAaaS Reference Architectures research stream is still under developing, we consider worthy a SeLR method. We applied three steps: SeLR.1 Definition of Sources and Search Statements; SeLR.2 Definition of Study Selection Criteria; and SeLR.3 Search Execution and Study Selection.

In SeLR.1 step, we defined GoogleScholar and ACM Digital Library as the two sources for searching studies. The generic search statement was defined as "TitleIncludes("big data" AND "reference architecture") AND Period(2010-2022)". In SeLR.2 step, we defined the study selection criteria as "C.1 OR C.2". C.1 was defined as ("study is published in a journal JCR or Scopus indexed journal" AND "study has been highly cited (at least 100 citations) AND "study does not address a specific domain"). C.2 was defined as ("study is reported by a trustable international association") AND "reference architecture is non-proprietary"). In SeLR.3 step GoogleScholar and ACM Digital Library located 45 and 2 studies respectively, and we applied the selection criteria (C.1 OR C.2), and two studies satisfied these conditions (Pääkkönen & Pakkala, 2015; NIST, 2019). Research team added manually a third study that was considered highly relevant given that the publisher of the manuscript is an international association that groups the main international providers of BDAaaS (Cloud Standards Consumer Council, 2017). Despite this SeLR collected only three documents, they provided a representative sample of high-quality and mature studies. First manuscript was reported in a premier journal, and it is the highest cited study on this topic (300+ times). Second manuscript is the unique and most referenced formal standard of the practice issued by the National Institute of Standards and Technology at the USA, and this study is the most extensive detailed study (65 pages in the volume six; the full standard includes nine volumes). Third study is endorsed by an international association from Cloud and Big Data Analytics professional enterprises. SeLR.2 and SeLR.3 steps, thus, implicitly used a non-random judgment (purposive) sampling approach to select units of study (Zikmund et al., 2012). Finally, CRA.4 activity correspond to sections 4 and 5.

3. Theoretical Basis

3.1 On Big Data Analytics Capabilities

In "Big Data Analytics" concur two data-based computational approaches (Phillips-Wren et al., 2015). The "Big Data" side refers to the stages of 1) Raw Data Sources Identification and Acquisition, 2) Raw Data Pre-Processing, and 3) Data Storing and Processing, and the "Analytics" side to the stages of 4) Data Modeling and Analysis, and 5) Data Access and Usage. This flow of stages is known as the "Big Data Analytics Pipeline".

To summarize, the "Big Data" side is responsible for making available processed Big Data sets with the potential of creating business value, and the "Analytics" side for providing business value through the application of analytics procedures to the processed Big Data sets. Regarding the Data Modeling and Analysis stage, there are three types of analytics procedures. Exploratory and Descriptive Analytics refers to procedures to report summary metrics and graphs of the Big Data sets that represent historical and current status of the business processes and systems related to the big data sets. Predictive Analytics refers to procedures to create data-driven models that permit estimating future status of the business processes and systems related to the Big Data sets. Prescriptive Analytics refers to procedures to create data-driven models that determine the optimal solutions or best viable alternative solutions. Table 1 reports the stages, purpose, main activities, key issues and main involved information and communication technologies (ICT) for a generic "Big Data Analytics Pipeline", adapted from the main literature (Jagadish et al., 2014; Phillips-Wren et al., 2015).

Stage	Purpose	Main Activities	Main Issues	Main Involved ICT
1. Raw Data Sources Identification and Acquisition	To identify the set of raw data sources for the big data analytics pipeline, agree legally on its accessibility, collect the agreed raw data, transmit them, and register them.	1.1 Identification of the available raw data sources. 1.2 Analysis of the available raw data sources. 1.3 Selection and legal agreement of raw data sources. 1.4 Raw data collection and transmission. 1.5 Raw data registering.	Variety of raw data formats (structured, text, image, audio, video, device signal). Velocity (generation rates of raw data). Volume (raw data size). Veracity (trust level of raw data). Value (business need for raw data). QoS metrics for LAN/WAN/Internet data transmission systems. Variety, velocity and volume of raw data.	Business ERP systems. Business devices. External IoT. Social networks. External open data repositories. External commercial data repositories. LAN/WAN/Internet data transmission systems. Cloud Platforms (OpenStack, Apache CloudStack, OpenNebula). Streaming/CEP engines (Kafka, Flink, Storm). IoT sensors (IoTDB). Data Lakes platforms (Hudi, Delta).
2. Raw Data Pre-Processing	To apply pre-processing procedures to raw data.	2.1 Raw data pre-processing (compression / decompression, cleaning, redundancy elimination, transformation).	Performance metrics for pre-processing platforms. Data security issues.	IT cluster management (Mesos, YARN). Big Data pre-processing tools (CKAN, Apache Griffin, Open Refine, DataCleaner).
3. Data Storage and Processing	To pull data of interest, apply them processing procedures, and load them in the persistent storage platforms.	3.1 Data Integration, aggregation, and representation. 3.2 Data replication. 3.3 Processed data ingestion/ETL.	Performance metrics for storage server cluster, cloud storage services, and processing server clusters. Performance metrics for processing platforms. Data security and privacy issues.	Storage servers clusters (Hadoop/HDFS). Storage processing engines (Apache Pig). Big Data warehouses (Hive, Impala, BigQuery, Presto). Big Data non-SQL databases (MongoDB, Cassandra, HBase).
4. Data Modeling and Analysis	To elaborate data-driven models and apply them analytics procedures for specific business goals.	4.1 Exploratory and descriptive analytics (OLAP, descriptive statistics, descriptive charts/graphs). 4.2 Predictive analytics (classification, regression, clustering, association). 4.3 Prescriptive analytics (optimization, simulation, heuristic methods, expert systems).	Performance metrics for processing servers clusters, and analytics platforms. Taxonomy of exploratory-descriptive, predictive and/or prescriptive analytics procedures.	Big Data Analytics servers clusters (Mahout, Apache Drill, Spark, MLlib, RHadoop, RHive, TensorFlow, Pytorch, Keras). Big Graphs engines (GraphX, GraphLab, neo4j, Giraph, ArangoDB).
5. Data Access and Usage	To use data-driven models in stand-alone and/or embedded into end-user or automatic control systems for specific business goals.	5.1 Visual interactive analytics. 5.2 Development of end-user big data analytics systems. 5.3 Development of automatic control big data analytics systems.	QoS metrics for LAN/WAN/Internet data transmission systems. Usability metrics. Performance metrics. Business goals metrics.	LAN/WAN/Internet data transmission systems. Laptops, desktops, mobile devices, IoT devices, workstations. Web programming languages. Visual interactive analytics packages (Kibana, Google Data Studio, MS Power BI, RStudio).

Table 1: A Generic Big Data Analytics Pipeline

3.2 On Systems Architectures and IT Service Management Frameworks

The concept of system architecture is fundamental for achieving a high-quality and cost-efficient IT service (ISO/IEC/IEEE, 2011). According to the ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE, 2011), the architecture of a system conveys the “fundamental concepts or properties of a system in its environment embodied in its elements, relationships, and in the principles of its design and evolution” (ISO/IEC/IEEE, 2011; p. 2). The architecture of a system, which is abstract, is manifested through the functional and non-functional properties of the system. Systems Engineering discipline (ISO/IEC/IEEE, 2011; ISO/IEC/IEEE, 2015) defines a system as a set of interacting elements integrated for achieving a purpose. Systems Engineering addresses systems that are “man-made and may be configured with one or more of the following: hardware, software, data, humans, processes (e.g., processes for providing service to users), procedures (e.g. operator instructions), facilities, materials and naturally occurring entities” (ISO/IEC/IEEE, 2015; p.1).

To guide systems architects in the design of a system architecture, have been proposed Architecture Frameworks (AF), Reference Architectures (RA), and Architecture Design Processes and Practices (ADPP) (ISO/IEC/IEEE, 2011; Angelov et al., 2012). An AF “establishes a common practice for creating, interpreting, analyzing and using architecture descriptions within a particular domain of application or stakeholder community” (ISO/IEC/IEEE, 2011; p. 9). A RA refers to “a generic architecture for a class of systems that is used as a foundation for the design of concrete architectures from this class” (Angelov et al., 2012; p. 417). ADPP define the activities and practices for analyzing the functional and non-functional architectural requirements, designing candidate architectures, and selecting the solution architecture. According to (ISO/IEC/IEEE, 2011), the architecture of a system can be designed and represented through an architecture description (AD) document. An AD document reports stakeholders and their concerns, architecture decisions and rationale, and architecture views and viewpoints. Stakeholders are any entity that will be affected by the system of interest. Concerns are the expected system properties of interest for the stakeholders. Architecture decisions and rationale are the architectural design selections done and their justifications. Architecture views are diagrams – called architecture models – governed by architecture viewpoints that depict a set of specific concerns.

The main ITSM frameworks and standards – ITIL v2011, ITIL v4, and ISO/IEC 20000:2019– do not provide Architecture Frameworks nor Reference Architectures for IT services (Hunnebeck, 2011; TSO, 2018; ISO/IEC, 2019). However, the main ITSM frameworks and standards have provided the best processes-practices to deliver business value to IT users through the concept of IT services. An IT service can be defined as a functionality enabled to IT users that delivers business value and that is provided by an IT service system composed of IT resources, IT processes-practices, and IT people (Hunnebeck, 2011; ISO/IEC, 2018; TSO, 2018). Value is realized when the expected IT service utility (fit for purpose) and IT service warranty (fit for use) are achieved. The utility of an IT service refers to what the service does that is valued by the customer. The warranty for an IT service refers to how well it is delivered – i.e. how well are reached the levels of availability, capacity, continuity, and security agreed -. Figure 1 - adapted from (Hunnebeck, 2011) – illustrates the concept of IT service and IT service system. The specific elements of the IT service system are: IT resources (APP: end-user applications; SW: software base; HW: hardware equipment; NW: network devices; DATA: datasets; and ENV: physical environment); IT processes-practices (applied by IT Teams and IT Suppliers to manage the IT resources to provide the IT services), and IT people (IT Teams; IT Suppliers).

Big Data Analytics as Service (BDAaaS) can be delivered through an on-Premise or a Cloud-based deployment model (Rao et al., 2019). Independently of the type of BDAaaS deployment, BDAaaS can be delivered in three different service models (Mell & Grance, 2011): BDASaaS (BDA software as a service), BDAPaaS (BDA platform as a service), or BDAIaaS (BDA infrastructure as a service).

BDAIaaS refers to the customer agreement for paying the utilization of physical and virtual IT resources. The cloud provider owns and hosts the physical IT resource layer, but the BDAIaaS customer remotely manages them. In this BDAIaaS provision model, the customer is free and responsible to install and manage the upper cloud layers. BDAPaaS provision model refers to the customer agreement for paying the utilization of the required cloud layers for developing BDA systems. These cloud layers are Big Data Cluster Management, Big Data Analytics Cluster Management, and Big Data Analytics Development Tools. The two lower cloud layers are considered black boxes, and the next upper layer is responsibility of the customer. Finally, BDASaaS refers to the customer agreement for paying the utilization of an end-user Big Data Analytics system. All lower cloud layers are black boxes for the customer. Figure 2 illustrates the three IT service models for BDAaaS using a hybrid functional-deployment architectural view from a cloud-based IT service provider viewpoint. Figure 2 maps also the generic Big Data Analytics pipeline reported in Table 1.

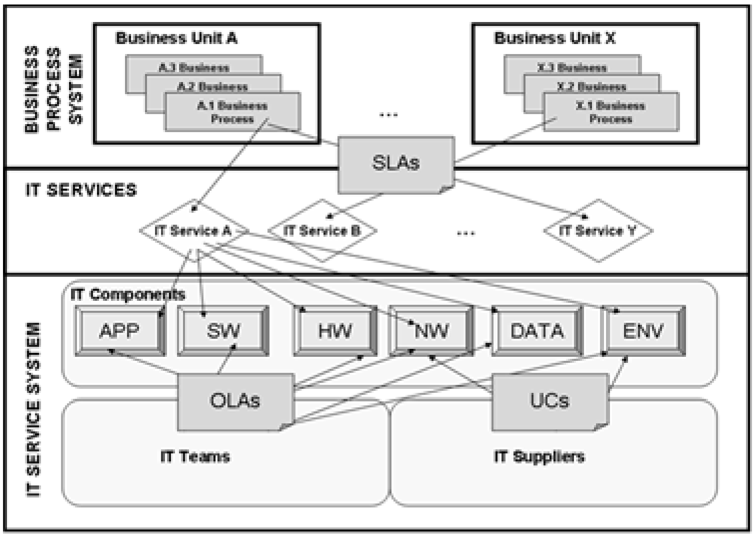

Figure 1: IT Service and IT Service System Concepts

(Source: adapted from Hunnebeck, 2011)

4. Exploratory-Descriptive Review of main BDAaaS Reference Architectures

3.1 BDAaaS Reference Architecture Conceptual Lenses

To conduct this exploratory-descriptive review, we have derived from the main literature a BDAaaS hybrid functional-deployment architectural view from a cloud-based IT service provider viewpoint – Fig. 2 – with six functional layers (Physical IT Resources, Virtual IT Resources, Big Data Storage Cluster Management, Big Data Analytics Cluster Management, Big Data Analytics Development Methods, and End-User Big Data Analytics Systems). The two bottom layers correspond to the BDAIaaS. The next three layers correspond to the BDAPaaS, and the last top layer corresponds to the BDASaaS.

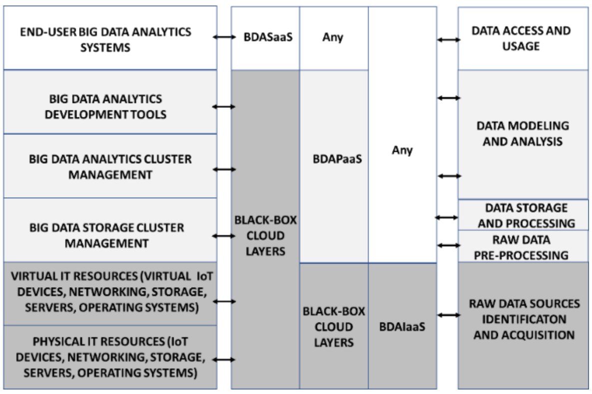

Figure 2: A BDAaaS Hybrid Functional-Deployment Architectural View from a Cloud-based IT Service Provider Viewpoint (Source: authors)

In this hybrid functional-deployment architectural view, we have included a generic 5-stage Big Data Analytics pipeline – Table 1-. The first stage of Raw Data Sources Identification and Acquisition is mapped to the two bottom layers of virtual and physical IT resources. Internal and external, structured and non-structured, and batch, interactive or stream data sources from business enterprise systems, business devices, external IoT networks, social networks, external open data repositories, and external commercial data repositories, need to be identified and acquired. LAN/WAN/Internet data transmission systems, cloud platforms, streaming/CEP engines (such as Kafka, Flink, or Storm), IoT sensors databases (such as IoTDB), and data lakes platforms (such as Hudi, Delta) are design components that must be also considered for the first stage. For this aim in the first stage, the two mapped bottom cloud layers refer to the virtual and physical IT resources that enable access to these data sources. These two cloud layers correspond to the BDAIaaS delivering model.

The second and third stages of Raw Data Pre-Processing, and Data Storage and Processing, were mapped to the third cloud layer of Big Data Cluster Management. This cloud layer refers to the IT Big Data tools for managing the SQL- and non-SQL based storage through a cluster of storage nodes, as well as for pre-processing (compression / decompression, cleaning, redundancy elimination, transformation) and processing (integration, aggregation, representation, replication, and processed data ingestion/ETL) tasks. In this third cloud layer, the design components are IT cluster management systems (such as Mesos, YARN), Big Data pre-processing tools (such as CKAN, Apache Griffin, Open Refine, DataCleaner), Storage Servers clusters (such as Hadoop/HDFS), Storage Processing engines (such as Apache Pig), Big Data warehouses (such as Hive, Impala, BigQuery, Presto), and Big Data non-SQL databases (such as MongoDB, Cassandra, HBase).

The fourth stage of Data Modeling and Analysis was mapped to the fourth and fifth cloud layers of Big Data Analytics Cluster Management, and Big Data Analytics Development Tools. These cloud layers enable the design and building of data-driven models and the application of analytics procedures for specific business goals. Analytics procedures can be Exploratory and Descriptive (e.g. OLAP, descriptive statistics, and descriptive charts/graphs), Predictive (e.g. classification, regression, clustering, and association), and Prescriptive (e.g. optimization, simulation, heuristic methods, and expert systems). In these fourth and fifth cloud layers, the design components are Analytics Servers clusters, Big Analytics engines (such as Mahout, Apache Drill, Spark, MLlib, RHadoop, RHive, TensorFlow, Pytorch, Keras), and Big Graphs engines (such as GraphX, GraphLab, neo4j, Giraph, ArangoDB). These third, fourth and fifth cloud layers correspond to the BDAPaaS delivering model.

The fifth stage of Data Access and Usage was mapped to the sixth cloud layer of End-User Big Data Analytics Systems. This top cloud layer enacts the remote access and utilization of the data-driven models in stand-alone applications and/or embedded into end-user or automatic control systems for specific business goals. This sixth cloud layer corresponds to the BDASaaS delivering model.

4.2 Review of BDAaaS Reference Architectures

For BDAaaS, several proprietary Reference Architectures from IT business consulting companies have been proposed. From the non-proprietary side, three main BDAaaS Reference Architectures are available. These are: Reference Architecture for Big Data Systems (RABDS) (Pääkkönen & Pakkala, 2015), Cloud Customer Architecture for Big Data and Analytics V2.0 (CCABDA) (Cloud Standards Consumer Council, 2017), and NIST Big Data Reference Architecture (NBDRA) V3.0 (NIST, 2019).

RABDS (Pääkkönen & Pakkala, 2015) was proposed from an inductive design from seven real cases. RABDS includes seven primary layers (Data Sources, Data Extraction, Data Loading and Pre-processing, Data Processing, Data Analysis, Data Loading and Transformation, and Interfacing and Visualization) and two support layers (Data Storage, Job Model and Specification). RABDS architectural views are reported as a Big Data Pipeline. From a BDAaaS perspective, no information is provided. Figure 3 – derived from (Pääkkönen & Pakkala, 2015) – illustrates a functional architectural view of RABDS.

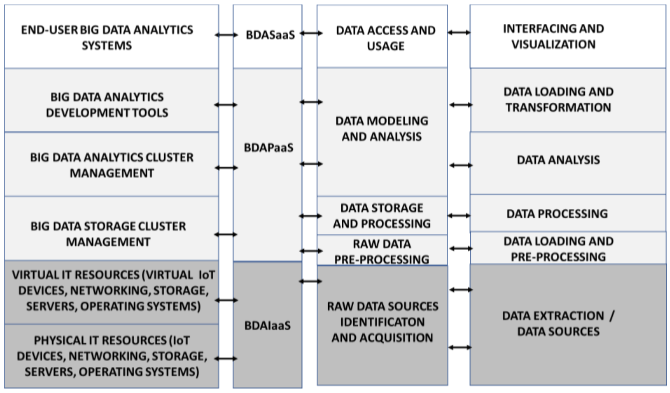

Figure 3: RABD mapped to the BDAaaS Hybrid Functional-Deployment Architectural View from a Cloud-based IT Service Provider Viewpoint (Source: authors)

CCABDA (Cloud Standards Consumer Council, 2017), provides a reference for deploying BDAaaS using three network zones: public network, provider cloud, and enterprise network. The core components of the public network are Public Data Sources and SaaS Applications. The core components of the provider cloud are Streaming Computing, Data Repositories, Cognitive Assisted Data Integration, Cognitive Analytics Discovery and Exploration, Cognitive Actionable Insights, API Management, Transformation and Connectivity, and Security. The core components of the private enterprise network are Enterprise Data, and Enterprise Applications. CCABDA (Cloud Standards Consumer Council, 2017), promotes explicitly BDASaaS and implicitly BDAPaaS. BDAIaaS is not promoted explicitly but it is referred as a capability infrastructure functionality required for BDAaaS. Capability infrastructure refers to "platform tools that enable connectivity, load balancing, routing, and the like, or hardware resources such as suitable storage, compute, and networking." (Cloud Standards Consumer Council, 2017; p. 20). Figure 4 – derived from (Cloud Standards Consumer Council, 2017) – illustrates a functional architectural view of CCABDA.

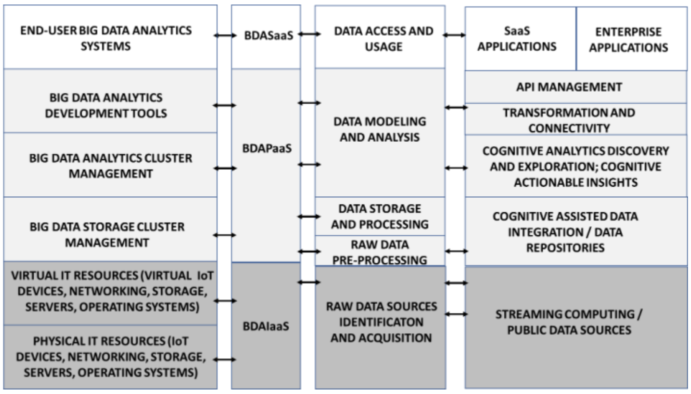

Figure 4: CCABDA mapped to the BDAaaS Hybrid Functional-Deployment Architectural View from a Cloud-based IT Service Provider Viewpoint (Source: authors)

NBDRA V3.0 (NIST, 2019) consists of a vendor-neutral, technology- and infrastructure-agnostic conceptual model and two architectural views (activity view and functional view). It was designed by NITS (National Institute of Standards and Technology, USA) after several rounds of sessions in the NIST Big Data Public Working Group (NBD-PWG) with participants from industry, academia, and government agencies. According to NIST (2019; p. 3) a reference architecture provides “an authoritative source of information about a specific subject area that guides and constrains the instantiations of multiple architectures and solutions.”. NBDRA supports the requirements of interoperability, portability, reusability, extensibility, data usage, analytics, and technology infrastructure. NBDRA is structured with five main functional components (System Orchestrator, Data Provider, Big Data Application Provider, Big Data Framework Provider (Infrastructures Frameworks, Processing Frameworks, Data Platforms Frameworks), and Data Consumer) and two fabrics (Management Fabric, and Security and Privacy Fabric) that that provide critical internal support services for the five functional components. Figure 5 – derived from (NIST, 2019) – illustrates a functional architectural view of NBDRA.

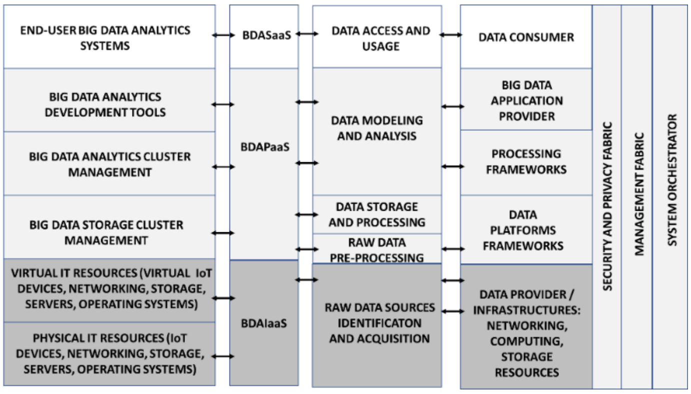

Figure 5: NBDRA mapped to the BDAaaS Hybrid Functional-Deployment Architectural View from a Cloud-based IT Service Provider Viewpoint (Source: authors)

Table 2 reports a summary of the main findings found in this research for the three Reference Architectures analyzed.

	BDAaaS Reference Architectures		
Issue	**Reference Architecture for Big Data Systems**	**Cloud Customer Architecture for Big Data and Analytics V2.0**	**NIST Big Data Reference Architecture V3.0**
Formal ISO/IEC/IEEE 42010 terminology?	**No.** A high-level implementation view is considered. Stakeholders’ concerns, architecture decisions and rationale, and additional views and viewpoints are not reported.	**Partial.** A high-level functional view is considered. Stakeholders’ concerns are reported. Architecture decisions and rationale, and additional views and viewpoints are not reported.	**Yes.** Stakeholders’ concerns, architecture decisions and rationale, and diverse views and viewpoints are reported (high-level conceptualization view, activities view, and functional components view).
Big Data Analytics pipeline stages?	**Yes.** Seven main stages and two support stages.	**No.** No explicit Big Data Analytics pipeline is reported. An implicit one can be derived from the high-level functional view.	**Yes.** Five main stages in the Big Data Application Provider component is reported.
BDAaaS delivering models?	**No.** BDAIaaS, BDAPaaS, and BDASaaS are not reported.	**Partial.** Only the BDASaaS is considered.	**Yes.** Cloud deployment issues are reported.

IT Service Management terminology?	**Yes**. Essential issues are considered.	**Yes.** Essential issues are considered.	**Yes**. Essential issues are considered.
BDA technologies for design components?	**Yes.** BDA technologies are considered for the stages.	**No.** BDA technologies are not considered for the stages.	**No.** BDA technologies are not considered for the stages.
Contribution to ITSM managers?	**Yes.** It provides a RA for BDA systems and analysis of seven real BDA platforms.	**Partial.** It provides a RA for BDA systems but a BDA pipeline is not reported.	**Yes.** It provides a full comprehensive RA for BDA systems.
Contribution to BDAaaS literature?	**Yes.** It provides a RA for BDA systems, and a classification of BDA technologies.	**Partial.** It provides a RA for BDA systems but limited to BDASaaS type.	**Yes.** It provides a RA for BDA systems well-documented using the ISO/IEC/IEEE 42010 standard.

Table 2: Summary of Findings

4.3 Contributions

We consider this exploratory-descriptive review provides contributions to ITSM practitioners and literature focused on designing BDAaaS architectures. Previously, two Systematic Literature Review (SLR) studies (Sena et al., 2017; Ataei & Licthfield, 2020), have provided important contributions to this research stream. These SLR studies located 19 and 23 final studies respectively – after several filters-. Both SLR studies identified an accounting of several expected architectural quality requirements – Consistency, Scalability, Real-Time Operation, High Performance, Security, Availability, Modularity, and Interoperability, all of them mapped to the ISO/IEC 25010 standard (ISO/IEC, 2011) -, and five common expected architectural layers (L1 Data Sources, L2, Data Integration, L3 Data Storage, L4 Data Analytics, and L5 Data Visualization). However, SLR uses a shallow quantitative-oriented analysis with summarization purpose (Boell & Cecez-Kecmanovic, 2015), and thus their insights are limited. In these two SLR studies, most of the reported studies were short papers, did not provide sufficient technical design details, did not use the terminology and concepts from the system architecture ISO/IEC/IEEE 42010 standard (ISO/IEC/IEEE, 2011), did not consider the ITSM approach neither the relevant BDAaaS concept, and some of them are proprietary models requiring additional high consulting costs to accessing them, with some particular exceptions (NIST, 2011; Pääkkönen & Pakkala, 2015).

This research provides an updated descriptive review of the three main BDAaaS Reference Architectures reported at present, which helps ITSM managers to acquire a better understanding on the architectural design implications for delivering BDAaaS. ITSM managers, thus, can use this review for elaborating a high-level design for a required BDAaaS, avoiding to adding extra unnecessary architectural layers or omitting required layers. ITSM managers have also a brief but informative list of the main IT technologies possible to deliver BDAaaS. This research also contributes to the BDAaaS literature providing a hybrid functional-deployment architectural view that includes an updated integrative generic Big Data Analytics Pipeline. This research makes sense also that ITSM core literature on IT service architecture design required maturation toward the utilization of formal systems architectures standards. Finally, we consider this research contributes scholastically providing implicitly a didactical resource that organizes the vast but fragmented, disperse and using informal terminology literature on BDAaaS.

5. Conclusions

This research reviewed three of the main Reference Architectures for BDAaaS and illustrated their correspondence with a hybrid functional-deployment architectural view from a cloud-based IT service provider viewpoint derived from the core literature. This correspondence also included an updated generic Big Data Analytics Pipeline, and a brief but succinct exemplification of BDA technologies that can be used as design components for the BDAaaS architecture. From a practitioner perspective, the three architecture descriptions provided useful practical insights (i.e. a high-level conceptualization, main functional components, BDA pipeline stages, and BDA technologies). From a theoretical perspective (i.e. architecture of systems), only the NIST Big Data Reference Architecture V3.0 (NIST, 2019) description is reported formally (i.e. it uses the expected terminology and conceptual structures from the systems architecture literature).

Hence, this research contributes with an updated review of three main non-proprietary BDAaaS Reference Architectures to ITSM managers, and adds to the BDAaaS literature, a hybrid functional-deployment architectural view that includes an updated integrative generic Big Data Analytics Pipeline. However, further conceptual and empirical research to reach a mature theoretical BDAaaS Reference Architecture, and their associated application guidelines for ITSM managers is required.

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7. Audio Description in Video Games Research in Progress

Stevie C. F. Sansalone
Ontario Tech University
stevie.sansalone@ontariotechu.ca

Claire M. Culver
Ontario Tech University
claire.culver@ontariotechu.ca

Mahadeo A. Sukhai
Canadian National Institute for the Blind
mahadeo.sukhai@cnib.ca

Abstract

As video games continue to grow in popularity, accessibility is a key concern which developers must consider to ensure the most people possible can enjoy the games they create (Cairns et al., 2019; Nova et al., 2021). With approximately 500,000 blind and partially sighted people in Canada alone, visual accessibility is a central concern of game accessibility. Visual accessibility has developed for decades with one of the most popular and effective methods of this being audio description (AD) (Fryer, 2016). Audio description comes in different styles depending on its use, with standard and extended AD being 2 of the most common types (Canadian National Institute for the Blind, 2019). Despite the success of this option in film and television, AD has not caught on in the game industry (SightlessKombat, 2020). This research looks to investigate AD as a method for visual accessibility in video games with a focus on determining the advantages and disadvantages of both standard and extended AD in this medium.

Keywords: Visual Accessibility Technologies, Accessible Game Development, Audio Description

1. Introduction

Video games are an increasingly popular pastime and serve both as a source of entertainment and a method for connecting with other people through shared interests (Cairns et al., 2019; Nova et al., 2021). The social aspect of games has only grown in recent years with multiplayer centered games such as Fortnite and Apex Legends captivating audiences around the globe (Cairns et al., 2019; PlayerCounter, 2022a; PlayerCounter, 2022b). With this increased interest, it is vital that games are accessible to all communities so that everyone has the option to participate in this hobby and the social connections associated with it (Kulik et al., 2021). To ensure that as many users as possible are able to participate in gaming, accessibility options are necessary. In the case of visual accessibility, audio description (AD) has long been used as an accessibility tool in film and television, but, despite its success in these formats, has not caught on as an option in video games (Fryer, 2016; SightlessKombat, 2020; Bodi et al., 2021). AD is the practice of narrating visually displayed information to ensure that the full meaning, or narrative information, of a scene is conveyed in an accessible manner (Fryer, 2016; Wang et al., 2021; Bodi et al., 2021). In this paper, narrative information will refer to the intended message of a given scene. AD serves to impart this narrative information and provide context for scenes as they occur (Canadian National Institute for the Blind, 2019; SightlessKombat, 2020).

As an interactive medium, games use a variety of methods with varying levels of required user input to convey narrative information. These methods can loosely be split into 3 main categories no input scenes, low input scenes, and high input scenes. No input scenes require no interaction from users and will play regardless of what the player does once triggered. These sequences are independent of player input and will often cause the game to no longer receive input or will be unaffected by user input while they are playing. Cutscenes are the most common example of this type as they are effectively mini movies which are meant to be observed by the player and, once triggered, will play through without user input. Low input scenes require some simple interactions from users and may require occasional input to continue playing once they are triggered. These sequences are dependent on player input, but require such input infrequently. Finally, high input scenes require frequent and complex interactions from the user to continue playing once they are triggered. These sequences are dependent on player input and include gameplay sequences in which the player is required to navigate obstacles, complete puzzles, or complete some other form of challenge to receive narrative information. Given that no input scenes are the most similar to movies and television shows, where audio description has already been successfully implemented, these scenes are a logical place to start for testing audio description as a tool for visual accessibility in video games (SightlessKombat, 2020). The first step for implementing audio description is to create the transcripts which will then be narrated during the scene (Bodi et al., 2021; SightlessKombat, 2020; Wang et al., 2021). Multiple styles exist for writing and implementing audio description transcripts with the 2 main methods being standard audio description and extended audio description (University of South Carolina, 2020). This research seeks to confirm whether AD is an effective tool for visual accessibility in video games, and, if so, what style of AD is most suitable.

2. Types of Audio Description

Audio Description, sometimes referred to as described audio, has been used for many years in the medium of film and television to provide audible descriptions of visual elements for the benefit of blind and partially sighted audiences (Bodi et al., 2021; Fryer, 2016). Ideally, descriptions are provided during pauses in dialogue, but this is not always possible; some scenes may either be too short or too dialogue heavy to fit an audio description that is long enough to adequately convey all important narrative information. The necessary solutions to these issues are to either provide descriptions while dialogue is playing, or to pause a scene in order to provide the necessary information without interrupting the dialogue (3PlayMedia, 2022; University of South Carolina, 2020). These 2 methods are known as standard and extended audio descriptions respectively (3PlayMedia, 2022; University of South Carolina, 2020).

2.1 Standard

For standard AD, scenes are played normally, with an additional audio track providing a description for any elements in the scene that are only portrayed visually (3PlayMedia, 2022). These audio tracks are inserted between lines of dialogue that occur naturally in the scene (3PlayMedia, 2022; University of South Carolina, 2020). There are limits to this when a scene is filled with a lot of dialogue with few spaces to insert an audio description. In these cases, the content covered in the AD must be limited to avoid delivering AD at the same time as dialogue. While some information may be lost, it is necessary to ensure that the AD does not detract from the experience and make users miss important information from dialogue (University of South Carolina, 2020). In these cases, an alternative is to use extended AD to ensure that dialogue is delivered and the AD is still comprehensive (University of South Carolina, 2020).

2.2 Extended

Extended AD functions similarly to standard AD, but implements pausing in the scene to provide more time for AD (University of South Carolina, 2020). In practice, this means that scenes will run as usual until they hit a point where AD is required, but more time is needed for the delivery. When this occurs, the scene will pause so AD can be provided and will automatically resume once the AD is finished (3PlayMedia, 2022). This ensures that users are provided the full range of information in a scene, but does so at the cost of lengthening scenes, and, by extension, increases the overall length of the viewed media. This pausing can disrupt narrative tension and so extended AD is generally only used when required (3PlayMedia, 2022). Cases where standard AD may not suffice include scenes that are heavy with dialogue and offer few pauses as well as scenes that are complex and require more time to describe than is offered in existing pauses. In situations such as these, extended AD is a better option for providing users with the full range of narrative information in a scene (3PlayMedia, 2022; University of South Carolina, 2020).

3. Audio Description in Video Games

3.1 Current Projects

While audio descriptions have been present for television and film for many decades, audio description has only recently begun to gain traction as a tool for visual accessibility in video games (Fryer, 2016; SightlessKombat, 2020). One notable effort to introduce AD to video games is the Transcribing Games Project, a community–driven effort to create AD transcripts for commercially available games (SightlessKombat, 2020). The initiative looks to raise awareness about visual accessibility in video games and create AD transcripts as a proof of concept for the benefit of AD in video games (SightlessKombat, 2020). Some of these transcripts have additionally been implemented on existing cutscenes which have then been posted on YouTube as a demo for what this would look like in game (SightlessKombat, 2020). While the AD transcripts created by members of the initiative are at this time only for internal use, some companies such as Sony have taken an interest in collaborating with the Transcribing Games Project to develop AD transcripts for some of their games (SightlessKombat, 2020). While this is still in early stages, the fact that there are large studios which are interested in pursuing this option is a good sign for its future inclusion as an option for visual accessibility.

3.2 Challenges of Adding AD to Video Games

Unlike film and television which rely solely on pre-recorded video sequences, most games have content that is dynamic and require user interaction. This makes it more difficult to implement AD as developers need to find suitable times during gameplay to play AD transcripts rather than just looking for pauses in dialogue. However, this problem is not present in cutscenes as these sequences do not rely on player input and function the same way as film and television. When applying AD to cutscenes, developers can rely on established techniques of finding pauses in dialogue or implementing pauses when necessary to deliver AD narration (3PlayMedia, 2022; University of South Carolina, 2020). The issue of pausing scenes becomes more complicated in the case of multiplayer games where truly pausing the game would result in pausing the game for all other players. For this reason multiplayer games typically do not give players the ability to pause gameplay which may create issues in the case of extended AD where pauses are necessary (Feuchtner et al., 2016). Additionally, implementing AD requires more file space as additional narration must be recorded and downloaded along with other game files to make this option possible. In games that are especially heavy on cutscenes, the additional space required for AD will become more noticeable which may present a potential barrier to accessing the game for some users.

4. Research Proposal

4.1 Problem Statement

While a variety of options exist for visual accessibility in video games ranging from colour filters to spatial audio, these options are only able to assist some users in receiving narrative information in scenes heavily reliant on visuals (Yuan et al., 2011). Despite the success of AD in films and television as a tool for providing narrative information, AD has not similarly been pursued as a tool for visual accessibility in video games (Bodi et al. 2021; Fryer, 2016; SightlessKombat, 2020). Without AD, narrative information contained in cutscenes is often not effectively communicated to blind and partially sighted users, resulting in the meaning of a scene being lost (Bodi et al., 2021; Fryer, 2016; Wang et al., 2021). This affects both the user's experience of the cutscene they are experiencing as well as future cutscenes given that later scenes will often build upon information presented earlier in the plot, thus creating an increasingly disjoint narrative as more pieces of information are lost in each scene due to lack of description and lack of context from previous scenes.

4.2 Solution

This research aims to fill this gap and strengthen the communication of narrative information in cutscenes by investigating the use of audio description in video games with the goal of developing guidelines for effectively writing audio description transcripts to be implemented in cutscenes. Both standard and extended audio description formats will be tested with a pair of demo scenes intended to both deliver narrative information and get participants emotionally invested in the stories they are experiencing. The primary focus of this research will be on judging the effectiveness of each style of audio description in clearly delivering narrative information and generating an emotional response. Scenes will focus on 2 salient emotional states, sadness and excitement, but the specific content contained in each will evolve over the course of the study as demo scenes are tested with participants to ensure they are effective at eliciting the desired emotional states.

4.3 Research Plan

Research for this project will be split into 2 stages representing the development of the scenes to be analyzed with audio description and the eventual audio description study using these scenes.

4.3.1. Phase 1 Developing and Refining Scenes

To begin, the 2 scenes being used in the study will be written and built using Unity, a video game engine that is commonly used to create novel simulations and experiences for research of this kind. The first scene will be a science-fiction themed action scene with a focus on eliciting excitement in participants, while the second will be a fantasy themed drama scene with a focus on eliciting sadness in participants. Each scene will be designed to use a mixture of visual information, such as silent character actions, and audio information, such as dialogue, to convey narrative information in the same way as cutscenes. Following this, a small study will be conducted to test how well these scenes convey information and elicit emotional responses in sighted audiences when no audio description is used. This study will perform similarly to the eventual audio description study with 10 sighted participants first being given a survey to collect information regarding demographics, experience with gaming, and preference for science fiction and fantasy as genres of fiction. This information will be used to give context to collected data and control for the effects of differing levels of gaming experience, narrative preferences, and individual backgrounds. After this, participants will be split into 2 groups of 5 with each group being shown the scenes in opposite order from each other (i.e. group A will start with scene 1 and move to scene 2 while group B will start with scene 2 and move to scene 1) to control for ordering effects in scene presentation. Once the first scene has concluded for each group, participants in both conditions will be interviewed individually. Interviews will begin with having participants describe the events of the scene to determine how well the scene communicated the intended narrative information and will then have participants answer a series of questions intended to gauge their emotional response to the scene. This interview process will then be repeated after the second scene is shown and results collected from participants in both groups will be analyzed to determine if scenes were effective in both clearly presenting narrative information and eliciting the desired emotional responses from participants. Depending on the results of this study, scenes may be adjusted before proceeding to the next phase of research.

4.3.2. Phase 2 Audio Description Study

The second phase of the study will begin with the creation of audio description transcripts for the refined scenes. Standard and extended transcripts will be written to narrate the visual information present in each of these scenes and these transcripts will then be implemented. With audio description in place, participants will then be gathered and split into groups for the audio description study. This study will function with 3 groups of 10 then each split into smaller subgroups of 5 in the same way as was done with the previous study. The first group of participants will include blind or partially sighted users who are reliant exclusively or nearly exclusively on audio for the presentation of information, the second group will include partially sighted users who rely on a mixture of audio and visual information, and the third group will include fully sighted users. These groups will then be divided in half so that scenes can be presented with counterbalancing for each group. Participants will then be given a survey for baseline data collection as was done in the scene analysis study before being shown the sequence of scenes assigned to their group.

On each of the tracks, participants will start by viewing a scene with no AD, then that scene will be viewed again with standard AD. Following this, participants will be shown the remaining scene in no AD format and then again with extended AD format. Similar to the previous study, participants will be interviewed individually after each of the viewings with questions focusing on how clear the scene was in providing narrative information, how emotionally engaged participants were, and, in the case of scenes with AD, participant preferences regarding the form of AD they experienced. Additionally, blind, and partially sighted participants from groups 2 and 3 will be asked whether they have any additional comments on what they would like to see implemented to improve their experience of playing video games. While this exploratory inquiry is not the direct focus of this study, it is imperative to listen to members of blind and partially sighted communities when determining how best to improve visual accessibility and answers given may inspire other lines of inquiry. Responses will then be compared across groups to see how audio description influenced the experience of each scene for participants in each of the conditions. Questions related to AD will focus on learning whether participants preferred it to no AD and what they felt the style of AD they were shown contributed. Once all scenes have been viewed and participants have been interviewed about the individual scenes, participants will then be asked questions comparing their experiences of standard and extended AD to determine the advantages and disadvantages of each format. The qualities which will be highlighted in the comparison will be clarity of the AD, emotional engagement, and seamlessness of implementation, or whether the AD was disruptive to the experience. Following these questions, participants will be asked for any further comments they have regarding audio description and how it contributed to their experience of each scene.

5. Conclusion

This research looks to fill the gap of audio description in video games by analyzing AD as it is practiced currently in film and television to determine how it may be applied to video games and whether it is an effective tool for visual accessibility in this medium. If this research determines that AD is well-suited for games, the results will then be used to develop guidelines for effectively applying AD in video game cutscenes. Using the results of the interviews, the benefits and drawbacks of each form of AD will be determined so that developers can make informed decisions about which style of AD to apply in their cutscenes. This will help developers to ensure they are not over-relying on visually presenting narrative information, and, if they are, that they understand the associated costs of scenes requiring pausing for extended AD to fully describe everything that is occurring. These guidelines will assist in applying AD to video games and getting developers to think critically about how they are choosing to display narrative information throughout the games they are creating. This research also seeks to amplify the voices of blind and partially sighted gamers by drawing attention to the importance of presenting narrative information in visually accessible ways and demonstrating to developers that, without steps such as AD, they will be unable to effectively communicate their narrative ideas to members of their player base.

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8. Blockchain-based vaccine passports: A multi-case analysis based on perceived risk facets

Sultana Sabina Chowdhury
Carleton University
sabinachowdhury@cmail.carleton.ca

Gerald Grant
Carleton University
GeraldGrant@Cunet.Carleton.Ca

Abstract:

The covid pandemic has heightened the need for uniformity across healthcare measures. As the healthcare standards in different countries can significantly vary, a homogeneous platform with standard regulations is required to examine and analyze relevant data. The lack of unanimous acceptance of the vaccines being used adds to the challenges of using such a platform. A blockchain-based vaccine passport can store, review, and verify vaccine data in a secure and scalable manner. If the proper architecture is put in place, it will save cost, time, and human intervention. But as much as there is an urgent demand for technology reinforcement, certain risks and concerns are associated with it. Following a secondary case study approach, this paper highlights the risks, benefits, and challenges of existing blockchain-based vaccine passports. The findings of the paper suggest Blockchain has the potential to transform the vaccine verification process as the shared distributed ledger can optimize data management. It will enhance the operational process, reduce cost and improve compliance. However, more attention needs to be given to the social, ethical, and regulatory risks of this neoteric initiative.

Keywords: blockchain, COVID, vaccine, passport, risks.

1. Introduction

The Covid-19 outbreak has put the world at a standstill. The imposed travel restrictions for safety affected multiple industries and resulted in an economic downturn in many countries. Many countries had to close their borders entirely or partially. Imposed travel restriction has affected international trade, global supply chain, and immigration. To restore pre-pandemic normalcy, countries need to resume domestic and international travel. Relaxing travel restrictions on people who have been vaccinated is the first stage of doing that (Beriain & Rueda, 2020). The technology that was developed to address these growing concerns is 'Vaccine Passport'. A vaccine passport refers to a printed or digital certificate with a QR code that can certify the vaccination status of an individual (Haque et al., 2021). The blockchain-based decentralized platform can instantly store and retrieve the vaccination details used to check the accuracy and authenticity of vaccination status. It can later be used for keeping records of other diseases as well. Therefore many countries and organizations have adopted vaccine passports that will allow people to work and travel around with attested proof of vaccination without compromising the safety of public health (Cao et al., 2020; Chaudhari et al., 2021; Chowdhury et al., 2020).

2. Rationale

Even within a short span of time, a wide range of research papers has intended to address the challenges associated with the global pandemic. The major areas of research have been focused on contact tracing

(Elmesalawy et al., 2020; Rajasekar, 2021; Shubina et al., 2020), vaccine distribution and management (Antal et al., 2021; Barakat & Al-Zagheer, 2021; Musamih et al., 2021), social distancing (Cao et al., 2020; Istomin et al., 2021), Covid diagnosis (Chowdhury et al., 2020; Maghdid et al., 2021; Udugama et al., 2020), immunity passport (Chaudhari et al., 2021; Eisenstadt et al., 2020; Hasan et al., 2020; Hernández-Ramos et al., 2021). In a vaccine passport, users are expected to have full control of their health data to share with appropriate parties, hence several papers that proposed a vaccine passport solution have used verifiable credential techniques and self-sovereign identity (SSID) to incorporate this feature (Eisenstadt et al., 2020; Hasan et al., 2020; Hernández-Ramos et al., 2021).

Blockchain is a growing field of study, and a diverse range of literature can be found on different aspects of blockchain. But in this multifaceted research field, feature analysis of existing blockchain services is untapped. Most articles featuring technological influence in vaccine passports are either too limited in scope or emphasize more concepts rather than implementation (Abd-Alrazaq et al., 2021). Many researchers have focused on the risk challenges and benefits of blockchain implementation from a general view (Atlam et al., 2018; Chang et al., 2020; Mackey et al., 2019; Osmani et al., 2021). But specific attention to adopted blockchain solutions such as vaccine passports is inadequate compared to the present context. This study will try to bridge the gap in sparse literature and highlight some of the key prospects and concerns of currently used vaccine passports worldwide. This research looks into the technical and ethical aspects of four blockchain-based systems that are currently operational in different countries. It also explores the use of perceived risk facets (Featherman & Pavlou, 2003) as an appropriate theoretical framework for analyzing the dynamic influences and outcomes associated with the implementation of blockchain-based vaccine passports.

3. Aims and research questions

The research will highlight the potential benefits, risks, and challenges of blockchain-based vaccine passports currently used worldwide. The research aims to address the following research question:

RQ1: What are the prospects and concerns of existing blockchain-based Covid vaccine passports?

4. Research Methods and Design

For this paper, the 'embedded multiple case' design approach suggested by Yin (1984) was followed. This approach involves multiple units of analysis. Multiple case design refers to the literal replication of logic, so the sample size consists of the number of cases needed to generate an effect (Yin, 1984). As demonstrated by Yin (2009) case study is a linear but iterative process. The linear process includes planning, designing, preparing, collecting, analyzing, and sharing (Yin, 2009). The reason for choosing multiple case studies for this research is to understand the factors that lead to more successful system implementation in one case compared to the others. As this study is focused on a comparative analysis of four systems to figure out which one is more fitted for the purpose, the multi-unit analysis highlights the parameters to analyze. For data collection and design, the research also takes help from the case study research method suggested by Cassell and Simon (2004). The exploratory research looks into secondary use case data for multi-case analysis. The four cases that were analyzed for this study are as follows:

1. IBM's Digital Health Passport "Common Pass"
2. The Linux Foundation Public Health's COVID-19 Credentials Initiative

3. The Vaccination Credential Initiative (Microsoft and Oracle) the International Air Transport Association's Travel Pass
4. EU Digital COVID Certificate.

The rationale for choosing these four technologies is they were identified as leading technologies in this field by expert examination of the vaccine passport of Ada Lovelace Institute, globally recognized for information system research (Ada Lovelace Institute, 2021). Moreover, these 4 technologies are the most successful and widely adopted technologies in the field that are currently in use. As they have been already implemented and achieved success to a high extent compared to other conceptual frameworks it is highly rational to review these technologies to propose future improvements.

4.1 Framework

This study followed the structure of the Type-II case study framework as shown in figure 1 (Reddy & Agrawal, 2012). The framework parameters are customized based on the research objective and positivistic research philosophy for this study:

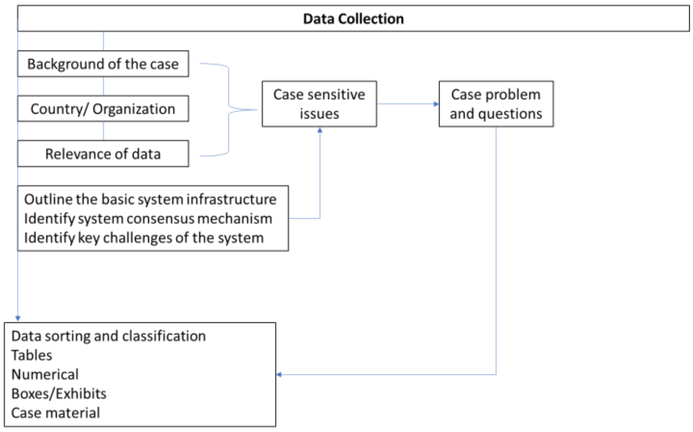


Figure 1: Case study design framework

4.2 Data collection

The secondary data was collected from multiple sources based on the availability of public data as shown in figure 2.

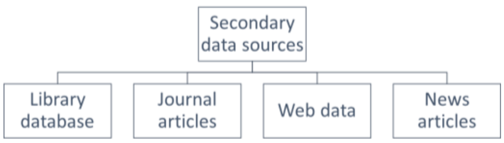


Figure 2: Secondary data sources

For the chosen solutions technical and marketing contents are available on the company website and Information Technology database accessible through the MacOdrum library (MacOdrum, 1942) of Carleton University and social, and ethical legal aspects are analyzed by collecting data from journal articles and news articles. The research did not include grey literature and maintained peer review articles as a selection criterion. The research concentrated on including high-quality peer-reviewed research articles, book chapters, conference proceedings, or preprints posing relevance to the research topic, other types of publications like conference abstracts, editorials, and commentaries were excluded from the study for the limited coverage of the subject area. Based on the secondary sources the research is mainly focused on comparing the generic features of existing vaccine passports. In-depth technical analysis is out of scope due to the unavailability of data.

5. Comparative analysis of four vaccine passports

5.1 IBM's Digital Health Passport "Common Pass"

Background: IBM's digital health pass (IDHP) powered by blockchain technology can be used to verify health status without involving any third party. The IBM digital health pass named Excelsior Pass was launched on 25 March 2021 in New York (Androulaki et al., 2021). It consists of three main components the portal, wallet, and scanner. Vaccinated/tested users can visit the portal where they can get their Excelsior pass based on their vaccination/test status. Then the users can download the wallet application on their smartphones to store the credentials of the pass. The scanner is also an application business/authorized organizations can download and use to scan the QR codes of Excelsior pass to verify the vaccination status of an individual (Patel, 2021). One of the key features of this pass is the flexibility it offers to the managing organizations to select the criteria for assessing health status (Moskvitch, 2021).

Country/Organization: IBM, USA

System architecture: IDHP uses Hyperledger Fabric infrastructure that incorporates the following stages:

- *Issuer registration and onboarding:*

the first stage involves registering issuers in the Trusted Registry system. Administrative authorities register issuers who can issue different types of health certificates. First administrative authorities receive a request from issuers for system registration. Then after proper due diligence, the authorities proceed to the enrolment stage. In the enrolment process issuers receive X.509 certificates detailing issuing authorization. Then issuer generates a signing key pair providing the verification key to the trusted registry which later maps the issuer to its verification key (Androulaki et al., 2021).

- *Health certificate schema:*

It includes the set of fields that compose a digital health certificate. The schema fields can be modified by respective issuers. The schema definition is available to all verifiers(Androulaki et al., 2021).

- *Verification:*

Digital health certificates are issued in the form of QR codes. The verifier can scan the QR code with delegated app and verify the vaccination status.

Figure 2 shows a process diagram of the IBM digital health data verification process. Users need to reach out to an issuer of their choice and perform a Covid test or receive the vaccination. Then they receive a health certificate in form of a QR code. The QR code is generated with the signing key of the respective issuer. The QR code will be readily available in users' IDHP app. Users can print it out in the physical form as well (Androulaki et al., 2021).

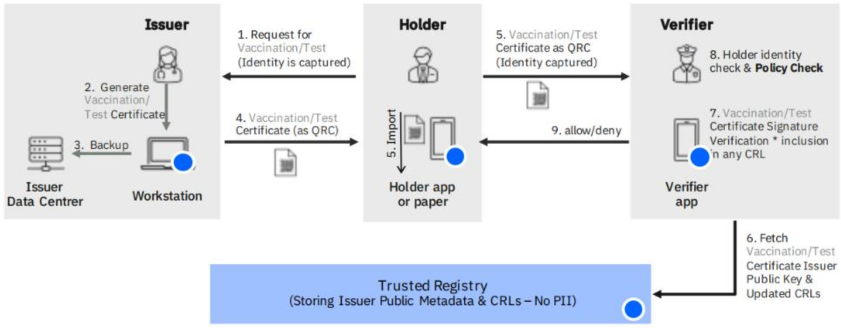


Figure 3: IBM digital health credential process diagram (Androulaki et al., 2021)

For verification, the subject/user gives access to their physical/digital QR code to a verifier who can scan the code and verify using the IDHP verifier app. The trusted registry gives the verifier access to the metadata related to the health certificate and also respective issuer details.

Consensus mechanism: The system uses traditional public-key encryption along with a digital signature. Authorized issuers generate digital key pairs that allow them to issue vaccine certificates. Verifiers send queries to the public registry to verify if a certificate was generated using authorized key pairs of issuers (Moskvitch, 2021).

Challenges: Vaccine supply chain is vulnerable to external threats like lack of automation, unsecure servers at the vendor's end, cyberattacks, etc (Quito, 2021).

5.2 The Linux Foundation Public Health's COVID-19 Credentials Initiative

Background: Covid Credential Initiative (CCI) was formed in April 2020. It's an open global community aimed at enabling interoperable use of privacy-preserving credentials for verifying health status. After nine months of developing Verifiable Credentials (VCs), CCI collaborated with Linux Foundation Public Health (LFPH). The combined effort facilitate the implementation of health credentials (Wilford et al., 2021). CCI brought together more than 300 technologists, healthcare professionals, and academics from more than 100 organizations to explore the potential of verifiable credentials. To advance this initiative in June 2021 LFPH launched the Global covid Certificate Network (GCCN) that will focus on data interoperability, security, and privacy concerns of vaccine passports.

Country/Organization: Linux Foundation Public Health (LFPH)

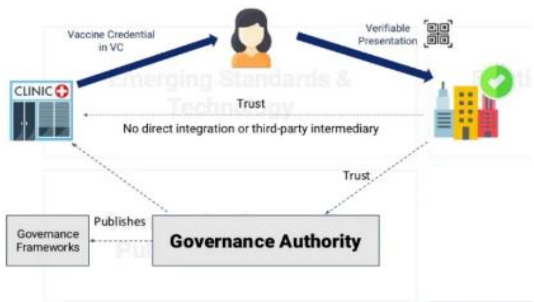


Figure 4: CCI operational process (Wilford et al., 2021)

System architecture: This system adopts a data minimization approach where a trusted issuer ensures the authenticity of the holder's vaccine credentials. Like IDHP there is no direct contact between issuer and verifier. Based on the vaccine credential the system generates a QR code that the verifier can scan and verify by querying the database (Wilford et al., 2021).

Consensus mechanism: The open-source trust management infrastructure will work on preparing a trust list to make a compilation of jurisdictions, regulations, and policies of different countries/organizations through a discovery mechanism (Whiting, 2022). If the certificate is issued from a valid source, then the verifier will be able to decrypt the certificate using a public key. This is a step forward toward the standardization process.

Challenges: It's still in the prototype stage and yet to be implemented on large scale.

5.3 The International Air Transport Association's Travel Pass

Background: After successfully completing the pilot phase with Singapore Airlines in March 2021, several airlines are planning to use International Air Transport Association's (IATA) Travel Pass. As of 26th April 2021 around 50 airlines signed up to trial this system. It comprises an app that allows users to create a secure digital version of an individual's passport in the app. On 15th April 2021, the app was launched on the Apple app store. Users can check travel regulations, upload their vaccine certificate and allow verifiers access to those certificates in the app. IATA travel pass can also inform users about the travel restrictions based on their travel date and flight details. It can also notify users whether they fulfill the requirement to fly (*IATA - Travel Pass Initiative*, 2021).

Country/Organization: International Air Transport Association (IATA)

System architecture: The architecture comprises four components. Figure 5 shows how the 4 modules work together as an integrated service (Otley, 2020).

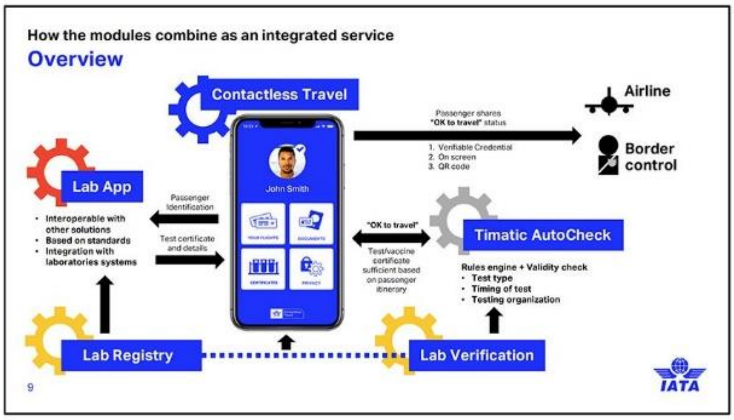
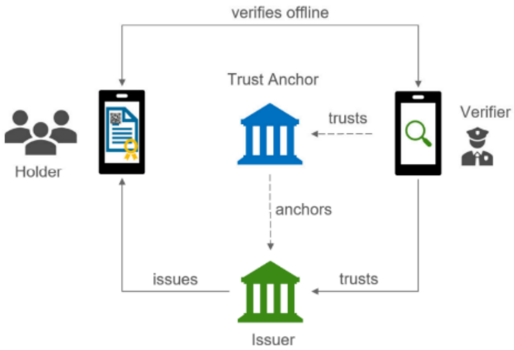


Figure 4: IATA travel pass modules (Otley, 2020)

- Global registry for health requirements that provides information about travel requirements, vaccine status, etc.
- Global registry for Covid testing/vaccination centers that has information of authorized labs and testing centers close to departure location.
- Lab app: this app allows authorized test centers to share test results and certificates with users in a secure environment.
- Travel app: this works as a digital passport module that allows users to store, share and upload their vaccine certificates



Consensus mechanism: The certificate uses Sovrin decentralized architecture of blockchain. However, it also has a centralized database for laboratories. Evernym has the ultimate control of issuing vaccine certificates as all laboratories delegate their private keys of encryption to Evernym (Lin, 2022).

Challenges: Lack of standardization regarding vaccine certificates (Sun et al., 2021).

5.4 EU Digital Covid Certificate

Background: The certificate was launched on July 1, 2021. The certificate has addressed the socio-ethical issues associated with vaccine passports and complies with General Data Protection Regulation (GDPR) to ensure data privacy (*EU Digital COVID Certificate*, 2022).

Country/organization: European Union

System architecture: Figure 6 shows the operational process of the EU digital certificae (*EU Digital COVID Certificate*, 2022). There are 3 main actors in the system (Fig 6).

Holder: a person having a digital or physical Covid certificate certifying vaccination status, test result, and relevant details.

Issuer: a government-authorized organization for issuing Covid certificates.

Verifier: different organizations that require a Covid certificate for their operation (i.e., custom offices, hotels, cinema halls, etc.).

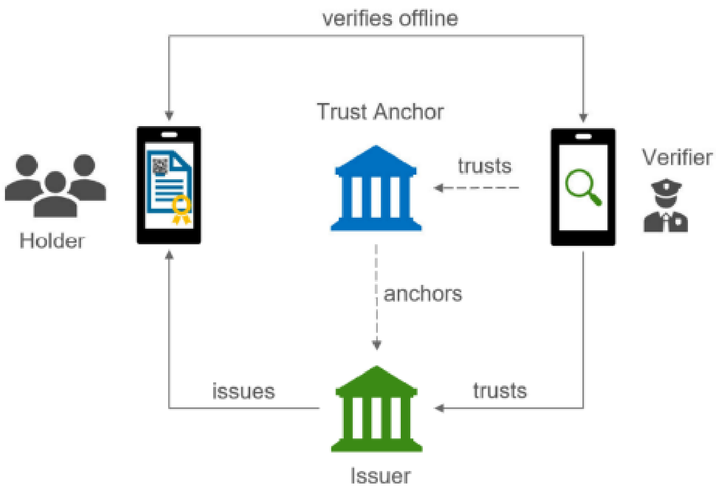


Figure 5: EU digital certificate system process (EU Digital COVID Certificate, 2022)

Consensus mechanism: This certificate uses cryptographic public keys to give access to sensitive data. each certificate carries a unique string that works as an identifier for the issuing authority (Mithani et al., 2021).

Challenges: The framework operates utilizing a public key infrastructure that creates regulatory concerns with GDPR requirements. Data saved in blockchain infrastructure is immutable so people might face restrictions to travel based on their earlier records that cannot be changed in the system (Montanari Vergallo et al., 2021). The summary of the cross-case analysis is shown in Table 1.

Vaccine passports	**IBM's Digital Health Passport "Common Pass"**	**The Linux Foundation Public Health's COVID-19 Credentials Initiative**	**International Air Transport Association's Travel Pass**	**EU Digital COVID Certificate.**
Background	Launched on 25 March 2021 in New York	Formed in April 2020	Launched on 15 April 2021	Launched on July 1, 2021
Country/ Organization	IBM, USA	Linux Foundation Public Health (LFPH)	International Air Transport Association (IATA)	European Union
System architecture	Hyperledger Fabric infrastructure	Data minimization approach where a trusted issuer ensures the authenticity of the holder's vaccine credentials	Sovrin decentralized architecture of blockchain	Decentralized blockchain architecture
Consensus mechanism	Public-key encryption along with a digital signature	Public-key encryption along with issuer validity	Private keys of encryption	Cryptographic public keys
Challenges	Lack of automation at user end, unsecure servers at the vendor's end, cyberattacks, etc.	Large scale implementation	Lack of standardization regarding vaccine certificates	Compliance with GDPR requirements

Table 1: Summary of cross-case analysis of chosen 4 technologies

6. Discussion

From the multi-case analysis following features were observed in all four systems that contributed to their success as vaccine passports:

- All four systems relied on decentralized blockchain architecture for data storing and sharing. Less dependency on centralized databases makes these systems highly scalable and less prone to cyberattacks
- All four systems designed their architecture based on 3 main actors: issuer, holder, and verifier, and created specialized portals for each of them
- Both physical and digital certificates were supported by system architecture in all four systems
- QR-code-based vaccine certificates were issued in all four portals that helped to ensure data anonymity and integrity
- Users have the ultimate control in all four systems to give access to their confidential health data
- The system required no direct interaction between the issuer and verifier. The identity of the issuer was embedded in the issued certificates which the verifier can use to authenticate the certificate

Based on the use cases of the four vaccine passports this study aims to analyze the attributes of vaccine passports based on perceived risk facets suggested by Featherman and Pavlou (Featherman & Pavlou, 2003). Perceived risk exerts a strong inhibiting influence on perceived usefulness and perceived ease of use. Perceptions of specific risk facets inhibit system evaluation and adoption trends among users which is important for the implementation of a vaccine passport. In table 2 the blockchain-based vaccine passports are analyzed based on perceived risk facets.

The key concern of all 4 systems is having full compliance with regulatory requirements. As the systems are constantly updated with hybrid blockchain architecture most of these concerns are expected to be minimized or resolved

Perceived Risk facets	**Concerns related to Blockchain-based vaccine passports**
Performance Risk	For concurrent requests, there are certain delay in the issuance of vaccine passports which needs to be resolved for making the system scalable (Wilford et al., 2021)
Financial Risk	Blockchain requires complex technical infrastructure hence, the implementation and maintenance require high investments (Nabil et al., 2021)
Time Risk	The use of a mobile app requires a user-friendly interface otherwise depending on the technical literacy it might be difficult for general users to be comfortable using the system (Hall & Studdert, 2021)
Psychological Risk	Hesitancy to get vaccinated, sharing health data across public platforms, reluctance towards new technology (Renieris, 2021)
Social Risk	Lack of access to authorized vaccines based on social inequality, lack of standardization in vaccine certificate requirements (Tsukayama, 2020)
Privacy Risk	Giving access to sensitive data across multiple platforms, the immutability feature of blockchain prohibits updating information but rather creates a new record for every update (Haque et al., 2021)
Overall Risk	Standardization of policies and regulations and ensuring uniformity in the entire process (Mishra, 2022; Renieris, 2021)

Table 2: Assessment of blockchain-based vaccine passports based on perceived risk facets

7. Conclusion

The peer-to-peer network of blockchain technology can ensure autonomous data transactions while maintaining transparency. The infrastructural support and legal obligations required for blockchain implementation and maintenance are significantly high. But considering the distinct advantages namely data authentication, interoperability, user control, and privacy blockchain technology gains a competitive advantage over other technologies currently being considered in the field (McGhin et al., 2019). Compared to the discussions in existing literature there have been very few implementations in the practical field to support the assumptions made by researchers (Mithani et al., 2021). An extensive review of the challenges and prospects of blockchain-based vaccine passports is imperative for the future development of vaccine validation and monitoring for safe travel resumption.

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9. Digital Social Innovation in Latin America: A Qualitative Comparative Analysis
Research in Progress

Sergio Cerda Castro
Universidad de Santiago
sergio.cerdac@usach.cl

Paola A. Gonzalez
Dalhousie University
paola.gonzalez@dal.ca

Abstract
Governments are under increasing pressure to meet the Social Development Goals (SDG) by 2030. Digital social innovation has been perceived as an important strategy to address several of the social and environmental needs of developing countries, especially Latin America. Digital social innovation results from the digitalization of resources, capabilities, processes, products, services, and business models with the goal of addressing a social or environmental need. Little is known about the factors that promote the success of these business initiatives in Latin America. In this paper, we analyzed 100 companies that developed and commercialized these initiatives and identified 4 general factors that might influence the success of these initiatives. Applying fsQCA and as preliminary results, we found that the prominence of the company, the type of technology used in the service or product offered, and funds raised are key factors to promote digital social innovation initiatives that are financially sustainable and socially scalable.

Keywords: Digital Social Innovation, ICT, fsQCA.

1. Introduction

Digital social innovation (DSI) has been regarded as a key platform to enable the required systematic changes needed in achieving sustainable development goals (SDGs) by, for example, providing affordable access to information or services to marginalised communities (Escobedo et al., 2021). DSI tends to be embedded in a collaborative ecosystem where innovators, users, and communities cooperate, co-create and co-innovate through digital technologies (Bria et al., 2015). Due to its social mission, most DSI initiatives are led by government agencies, charities, trust, cooperatives and non-government organizations (NGOs). However, given the scope, scale and current regulations to meet SDGs, these initiatives are more likely to include cross-sector partnerships and various stakeholders (Qureshi et al., 2021).

Digital innovation is growing in Latin America despite the frequent political turmoil. Notwithstanding the impact of the pandemic and the emergence of governments prone to economic intervention, venture capital has afloat into Latin America, especially the venture capital investment in technology (Hermans et al., 2020). In 2022, there were nearly 50 unicorns in tech ventures, referred as a new companies valued over $1 billon. Brazil has the largest number of unicorns, with Mexico and Argentina following close behind (Cancino et al., 2022). Despite this growth, DSI has not reached the same success and few start-ups when reached the unicorn status maintain their social mission of the business initiative.

With the intention to explore the reasons of why DSI has not reached the expected and desired reach in comparison to the general digital innovation entrepreneurship in Latin America, this study aims to identify key characteristics among companies that have successfully embarked in successful DSI initiatives – referred to initiatives that are financially sustainable and socially scalable. In addition, we explore basic configurations of these initiatives that can promote future sustainable DSI initiatives.

Based on prior studies that investigated common characteristics among tech-centric unicorns and on a list of a 100 of digital social initiatives that are transforming the region, we identify four characteristics that could play a critical role in the success of these DSI business initiatives in the region. We then follow a research approach that uses information from secondary sources, applying fuzzy set quantitative comparative analysis (fsQCA) to identify specific configurations of identified characteristics of successful initiatives in Latin America that have DSI as their hallmark. The configurational approach of fsQCA allows to identify combinations of characteristics that together result in a successful scalability and social impact in the region. We created our sample of business initiatives (or cases) based on a list developed by the center for social innovation at ESADE (Buckland et al., 2018) of 100 digital social innovation initiatives that are transforming Latin America. We ultimately identify a set of configurations that influence the degree of social reach and sustainable economic and financial impact of these initiatives. Our research seeks to contribute to the literature on leveraging digital social innovation in Latin America to create an international impact that transcends borders, understanding the role of technology in the development of digital social innovations, and thus, giving emerging companies the opportunity to strategically use their limited resources in order to increase their impact on the region.

2. Literature review

2.1 Digital Social Innovation

Digital innovations have disrupted and transformed economies in the last two decades by developing digital platforms and exploiting internet-based infrastructures (Jha et al., 2016). These innovations have led economies to promote models of sharing economies, collaborative consumption, and crowdsourcing. Compared to commercial use of information communication technologies (ICTs), the digital transformation and impact in the social space has rather been slow, especially in using digital technologies to address societal challenges (Shalini et al., 2021). This innovation is defined as Digital Social Innovation (DSI).

DSI refers to the use of digital technologies in the development and implementation of innovative products, services, processes, and business models that seek to improve the well-being of socially disadvantaged groups or address social problems related to marginality, inequality, and exclusion (Qureshi, Pan, & Zheng et al., 2017; Shalini et al., 2021). That is, DSI is usually perceived as less about technological innovation and more about social innovation, a process of finding innovative, effective, and sustainable solutions to urgent societal challenges, such as those listed in the Sustainable Development Goals (SDGs).

DSI are enabled by technologies that range from a simple WhatsApp-enabled groups (Parthiban et al., 2021) to a more complex supply chain advanced blockchain-enabled technology (Hota et al., 2021). These technologies enable the transformation of the most expensive and often lacking public services such as healthcare, education, energy, agriculture and environmental monitoring and protection (Pee et al., 2021). Prior studies identify several cases of DSI, despite of not using the DSI term itself. For example, studies in social enterprise have examined the leverage of technologies to address societal challenges. Some studies have studied how a financial intermediary leveraged a digital platform to provide small loans to marginalised farmers (Ravishankar 2021) or how a social intermediary uses block chain technology to offer affordable prices to rural farmers (Hota et al., 2021). Other successful examples of DSI intiatives in Latin America are Nubank, an independent digital bank that offers affordable financial services such loans and checking accounts to socially disadvantaged people. This company has raised more than $3B USD and has impacted more than 36 million people in Latin America (Reich 2022).

Despite a few existing and promising DSI initiatives; most DSI initiatives still operate on a small scale due to low level of investments, both public and private. A successful scalability of DSI initiatives occurs when a pilot project reaches a satisfactory level of performance and can be implemented on a larger scale to provide greater social value creation (Webb et al., 2010). A DSI initiative is considered successful when it reaches a systemic change in the market chosen by reaching a considerate large population.

2.2 Characteristics of Tech-centric Entrepreneurship

A recent study done at the University of Chile (Cancino et al., 2022) explored the common characteristics among the tech-centric unicorns in Latin America between January 2021 – February 2022. The study identified four common characteristics of these initiatives: (i) disruptive and innovative; (ii) focused on the use of technology and digital tools; (iii) sought to operate on a global scale not just locally, and (iv) venture capital played a key role in their development. In addition, these initiatives have been founded by entrepreneurs with prior and successful experience in the creation of new businesses and with postgraduate studies from Ivy league business schools. Due to this experience, these entrepreneurs tend to have larger networks that allow them to establish new collaboration and to seek external knowledge, infrastructure, and research.

This study also suggests that most unicorns tend to be successful in more developed economies with higher level of education, and thus human capital. The authors also highlight the need to promote the use of new technologies in diverse industries through the implementation of subsidies or other benefits that could increase the adoption of these new business models. That is, governments should support an ecosystem that promote private investment to these initiatives, programs such as tax reductions or changes in the regulatory framework of countries seem to have been successful programs to promote innovation.

3. Methodology

We performed fsQCA to establish configurations of the identified characteristics that promote digital social innovation initiatives that are financially sustainable and socially scalable. fsQCA is often perceived as a suitable method for determining causal relationships in a complex context such as digital innovation in which non-linear behavior can be present (Munoz et al., 2019). One of the big differences with other methodologies is that instead of looking for conditions common to all instances of the result, fsQCA focuses more on the possibility that the same result can be described through different combinations of conditions (Ragin et al., 2008). fsQCA identifies configurations of conditions rather than symmetric dependency relationships (i.e., those identified using variance-based models such as regressions). fsQCA facilitates the consideration of asymmetric relationships—while the presence of a predictor might lead to the achievement of an outcome, its absence does not necessarily imply that the outcome will not occur. Its presence could potentially lead to an outcome when combined with other specific predictors (or characteristics) (Fiss et al., 2011). The analysis consists of three steps. First, a truth table depicting all potential configurations is defined. Each case is assigned to a table row along with the degree to which the particular case corresponds to its assigned row. Second, the table is reduced using frequency and consistency thresholds. Frequency refers to the number of cases assigned to a single row. Therefore, the frequency threshold specifies the minimum number of cases required to support a row in the truth table empirically. Consistency indicates the degree to which the cases empirically support the given truth table row. Based on the selected thresholds, the truth table is reduced to solution formulas presenting configurations of conditions that lead to the required outcome (Ragin et al., 1987;

Soto Setzke et al., 2020). To evaluate the quality of the resulting solution set, fsQCA provides measures of consistency and coverage.

3.1 Cases selection and data collection

We used the list of 100 DSI initiatives identified by ESADE (Buckland et al., 2018). These initiatives were identified using the following criteria:

- A group of experts from different fields classified the type of innovation in the four categories suggested by NESTA, the British foundation organization for innovation. These categories were: open knowledge (e.g., platform the crowdfunding), open networks (e.g., bandwidth infrastructure in remote areas), open data, and open technology (e.g., real-time information).
- The initiative contributes to the achievement of one or more SDGs.

Please refer to the references (Buckland et al., 2018) to access the complete and detailed list of the companies selected.

We collected additional information of the companies from secondary sources such as Crunchbase (platform that groups business information on private and public companies), LinkedIn (social network oriented to business use, business and employment), Google News (news aggregator and search engine), Web pages of the companies (information provided by the different organizations in an official manner).

The information collected for each of the initiatives can be summarized by name, country of origin, ODS challenge, year of foundation, investment raised, number of people impacted, business model, IPO status, industry, founder's name, founder's country, founder's previous experience, type of the technology that enables the solution, active digital technologies.

Based on prior literature and as a preliminary stage of our research, we examined four characteristics that play the role of causal conditions in the fsQCA model. There are:

Previous experience of the founder: Founder's experience in relation to innovation and entrepreneurship in startups.

Funds raised: Capital raised in investment rounds by the startup. All investment rounds are considered, from pre-seed to series C.

Technological complexity of the service or product offered: Considers the number of technologies required to enable the solution and the type of technologies (software or hardware). The greater the number of technologies and the different types of technologies that enable the solution, the greater the technological complexity.

Prominence or recognition of the firm: Takes many signals into account, including the number of connections a profile has, the level of community engagement, funding events, news articles and acquisitions.

As an outcome measure of the fsQCAmodel, we selected the reach of social impact and viability of the business model. The DSI initiatives (or cases) were classified in: Startup phase (e.g., initiatives in their initial stage that already demonstrate a viable model and have reached less than 5,000 people); Consolidated phase (e.g., a sustainable economic model that have reached more than 5,000 people); and the international phase (e.g., for initiatives that operate in more than one country in Latin America, or even other regions, and that in many cases have already impacted more than a million people)

The software used in the 113odelling is fsQCA 3.0 (Compass, n.d), available on the website of the creator of the method. The algorithm used for the truth table solution is Quine-McCluskey. Note that due to character limitations, each column has been abbreviated, being CBRank (firm position in Crunchbase ranking), TFA (total founding amount raised), Eexp (founder's previous entrepreneur experience), Complex (technology complexity), impact (people impacted). The column "number" is the total amount of cases that show the configuration.

4. Preliminary Results

Table 1 presents the results of the Truth Table (table that lists in its rows all the theoretically possible configurations of the causal conditions).

CBRank	TFA	Eexp	Complex	Number	Impact	Raw consist.	PRI consist.	SYM consist
1	1	1	1	1	1	0.961722	0.636364	1
1	1	1	0	1	1	0.907173	0.696552	0.782946
1	0	0	0	1	1	0.87472	0.762712	0.762712
1	1	0	1	1	1	0.869942	0.383562	1
0	0	1	0	6	0	0.777164	0.553505	0.769231
0	0	0	0	3	0	0.771084	0.537994	0.662922
0	0	0	1	1	0	0.731343	0	0
1	0	0	1	1	0	0.698979	0.276073	0.276073

Table 1: Truth Table

Preliminary results in Table 2 confirm that the set relation between configurations of conditions and the outcome is highly consistent: individual results are above .8 and overall consistency is almost .80. The total coverage of the solution is near to .50, which indicates that causal paths explain most of the outcome.

<table>
<tr><th>Solution/Condition</th><th>CB Rank</th><th>Technology complexity</th><th>Founded amount raised</th><th>Previous entrepreneur experience</th><th>Raw coverage</th><th>Consistency</th><th>Solution coverage</th><th>Solution consistency</th></tr>
<tr><td>CBRank*~Complex</td><td>●</td><td>○</td><td></td><td></td><td>0.392676</td><td>0.87453</td><td rowspan="2">0.484507</td><td rowspan="2">0.794824</td></tr>
<tr><td>CBRank*TFA</td><td>●</td><td></td><td>●</td><td></td><td>0.390423</td><td>0.806752</td></tr>
</table>

Table 2: Model solutions

Table 2 presents the results of the fsQCA. We follow the notation suggested by Ragin and Fiss (2008). The fsQCA reveals two significant configurations for DSI initiatives in Latin America. Focusing on the core conditions (big circles), the first condition indicates that leveraging the prominence of the firm and offering a solution with low technology complexity are essential characteristics of successful DSI initiatives in the region that are starting (e.g., start-ups and unicorns). In particular, the Crunchbase ranking used as proxy for the prominence of the firm represents the importance for scaling and thus the subsequent social impact (greater number of people in more countries) and positioning of the DSI initiative in the ecosystem. The prominence also refers to events and news, types of investment, equipment, and number of workers. In addition, the technology must be highly scalable and easy to adopt, therefore of low complexity. Such cases are more related to platform-type technologies, which allow the target audience or client to be massive, such as a smartphone or laptop.

The second configuration suggests that prominence still plays a significant role for firms in a more stable stage in addition to the funds raised. Although previous studies have not shown a direct relationship between the investment raised and the success of the initiative, in this case it can be inferred that raising a greater amount of investment raised translates into investor confidence and validation of the business model. In turn, high investments allow startups to be able to scale their digital models in order to penetrate and impact a greater number of clients.

For this study, the previous experience of the entrepreneur does not seem to be a determining factor for the scaling and impact of the initiatives, although it is possible that this experience could be used for the successful development of the initiatives, as well as for the generation of trust to capital raising.

5. Conclusion

The objective of this research was to identify key characteristics among companies that have successfully embarked in DSI initiatives that are financially sustainable and socially scalable. Since most research has focused on exploring the factors and theoretical frameworks to understand and promote digital innovation, we wanted to examine a more specific domain in this literature, the digital innovations developed to meet and address societal challenges in Latin America. DSI is sought to be a promising solution to meet the persistent economic and social inequalities as well as the environmental issues in Latin America. Therefore, we analyzed case studies of approximately 100 DSI initiatives in Latin America to identify the common characteristics and configurations that have make them successful in their vision of meeting a social need. Based on prior literature and a recent study of tech-centric entrepreneurship in Latin America, we identified and examined four common characteristics. Applying configurational analysis using fsQCA, we found out that the technology used for the solution or product to offer (e.g., accessed through an app via smartphone versus a block-chain enabled technology) is a key resource in enhancing the scalability of the initiative as well as the efforts in keeping a prominence of the firms in the ecosystem. In addition, raised funds are also a key resource for the DSI initiative to scale internationally. We continue our exploration of factors that can promote these initiatives and sustainable business model that can support the development and growth of these innovative ideas.

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10. Disappearing Messages: Privacy or Piracy?

Áine MacDermott
Liverpool John Moores University
a.m.macdermott@ljmu.ac.uk

Howard Heath
Merseyside Police, Digital Forensics Unit
howard.heath@merseyside.police.uk

Alex Akinbi
Liverpool John Moores University
o.a.akinbi@ljmu.ac.uk

Abstract

Disappearing messages is an optional feature available in popular applications for more privacy. The Telegram instant messenger application is a rival and alternative to the popular messaging application WhatsApp, with both applications citing end-to-end encryption for both messages and calls as a key offering. While Telegram doesn't officially have a 'disappearing message' feature like WhatsApp it still is possible to send disappearing messages using the secret chat functionality. In this paper, we analyse and evaluate 'disappearing messages' across Telegram and Snapchat to see whether they can be forensically preserved and/or recovered across Apple and Android operating systems. As these messages could be vital to investigations, with potential evidence and intelligence stored on them, not to mention the limited timeframe in which they are 'viewable' to the user, it is a great opportunity for digital forensic analysts to understand how they are stored, managed, and 'deleted' compared to traditional messages on the same platforms/applications.

Keywords: digital forensics, messages, privacy, security, telegram.

1. Introduction

Instant Messengers (IMs) are one of the most common ways of communicating in the modern world. With 2 billion active users, WhatsApp is the number one IM application, followed by the Chinese messaging app WeChat with 1.2 billion users and the Messenger app by Meta with close to 1 billion users (Statistica, 2022). While their underlying features are very similar, users are attracted to different applications for improved security and privacy. Applications that offer 'secure messaging' utilise end-to-end encryption which means that other parties (e.g., your Internet service providers (ISP), the app maker, the government) can't see your data and your messages. Telegram (Das, 2022) is cited as being one of the best messaging applications for secure encrypted messaging offering client-server encryption for standard chats. In addition, messages cannot be forwarded on the Telegram app to anyone by the recipient from secret chats.

Recently, Instagram and Facebook Messenger have introduced 'secure messaging' options on their platforms, such as 'Disappearing Photo/Video' on Instagram (Instagram, 2022) and 'disappearing messages' listed as 'Secret Mode' on Messenger (Facebook, 2022). Meta was not the first to offer such measures to improve users' privacy matters, as Snapchat had these features included by default since its launch in 2011 (Wikipedia, 2022), and WhatsApp's main rival Telegram was later released in 2013 (Telegram, 2022). However, despite these apparent privacy safeguards, just how private are these 'secret/disappearing messages' on these platforms, and are they truly secure? At present, the only known ways of being able to preserve these 'disappearing' messages as evidence are as follows:

- Screenshotting the messages using the device (which is not forensically sound/contains time constraints)

- Photographing the device in which the messages are displayed (which imposes time constraints and yields no metadata)
- Replying to a message (which is not forensically sound and imposes time constraints)
- Extracting a backup from the Cloud (which is subject to legal issues surrounding cloud forensics, and does not guarantee that the message will not expire upon extraction)

Currently, of all the above, photographing the device while it displays these messages is the most effective means of providing evidence. However, we argue that even this method is subject to several further issues such as:

- The state of the device (damage, powered off)
- Security measures (passwords, hidden/secure areas)
- Network access (in network isolation, the device may not be able to retrieve messages from servers i.e., Snapchat)
- Outdated applications (some apps require verification by synchronizing to a server after being disconnected i.e., WhatsApp).

Disappearing messages present an increase in risk to all cases involving modern technology and set a hard timeframe for the investigators to adhere to, with many cases to balance and high-risk cases taking priority. With other risks involved in the mobile forensic process, such as password/PIN protection, encryption, and data sizes, any hindrance to the investigation, such as the mobile device requiring a PIN/password (with the suspect being non-compliant), alongside other issues (e.g., compatibility problems and/or extraction length) result in no time remaining for analysis and potentially unrecoverable messages.

Our study aims to find the most forensically sound and effective manner for capturing the data, and being able to present it as credible evidence. We explore Telegram and Snapchat, as Telegram is a popular alternative to WhatsApp, and Snapchat has disappearing messages by default. These two applications will also be used to compare the separate ways in which messages can ‘disappear’, answering the following research questions: *Can these messages be forensically recovered and/or secured? Are these messages truly secret?* Our results and analysis will provide reliable and repeatable means to recover these messages for digital forensics investigators; specifically, whether they can be recovered and preserved, and whether they pose a challenge to criminal investigations for digital forensic investigators in the field.

2. Related Works

While there are related works exploring the forensic analysis of Snapchat and Telegram the works are dated and not within our scope of the investigation - analysing the features of the disappearing message. Alyaha and Kausar (2017) focus on the analysis of Snapchat and its artefacts via an Android smartphone. Their methodology is simplistic, by following the process of population > acquisition > examine > report. While they do state how many data artefacts they have created on the device, they do not provide any details for these artefacts beyond a categorisation such as “photo”, “video”, and “message”. They locate the cache directory, main databases, and Snapchat folder which provides limited artefacts back; namely the messages and received images. From their findings, they recovered little in deleted artefacts, retrieving only one deleted story photo. However, they did recover the chat database which contained some messages (26 of the 36 sent – 11 of which were duplicates). The duplicate files were due to files having existed in multiple directories. They concluded that deleted snaps were not recoverable. As we are focusing on the disappearing side of these messages, it would have been useful to have provided a better insight as to why these messages were not presented, and whether any changes in the methodology would have changed this outcome.

Anglano et al. (2017) focuses on the forensic analysis of the Telegram messenger application on an Android smartphone. Their contributions are twofold; the creation of a methodology for the forensic analysis of Android-based IM Applications, and a thorough analysis of the Telegram messenger's artefacts (their structure, formatting, message data, etc). Their methodology revolves around a series of experiments, where user actions are performed and how this changes the extractable artefacts and investigations results are analysed. The experiments are varied and cover all aspects of the application's features, but the main contribution of the work is the analysis of secret chats (Anglano et al., 2017). From their findings, Telegram stores 'secret chat' messages in a separate table on the database, under "enc_chats". From here, they were able to discern distinct characteristics regarding these chats, such as: 'Chat ID (uid)', 'TDS Encrypted Chat (data)', 'Username of the owner (user)' and 'Name of the secret chat (name)'. From here, they were then able to dissect the TDS Encrypted down into a structure containing the following: 'ID of the chat (id)', 'TID of the secret chat partner (admin_ID)', 'Creation date/time of the secret chat (date)' and 'TID of users who join the chat (participant_ID)'.

Azhar & Barton (2016) conducted a forensic analysis of Wickr and Telegram in an attempt to recover artefacts removed by the ephemeral (disappearing) functions. Results from their experiment showed that disappearing messages set using the self-destruct timer were not successfully recovered from the digital forensic remnant for both apps. However, they were able to recover expired image files associated with the Telegram application from the cache directory on the Android device's physical image. Son et al. (2020) conducted a forensic analysis of instant messengers that also have disappearing messaging features including Signal, Wickr and Threema. The focus of their study was on the successful decryption and relevant forensic artefacts that could be recovered from the encrypted SQLCipher databases used by these instant messaging applications. Similarly, studies by Kim et al. (2020) and Kim et al. (2021), also focused on forensic analysis of ephemeral instant messengers, Telegram X, BBM-Enterprise and Wickr respectively, although the focus of both investigations were limited to the decryption of encrypted databases and not the recovery of disappearing messages. To the best of our knowledge, there has been no recent study that has focused on the successful recovery of disappearing messages for Telegram and Snapchat messaging apps on both iOS and Android devices. Therefore, by focusing on the recovery of disappearing messages, we can make the most of the potential investigative impact of our work.

3. Methodology and Experiments

Given that the goal of any forensic analysis is to allow the analyst to obtain the digital evidence generated by the applications under consideration, the methodology we adopted allowed completeness, repeatability, and generality (Anglano et al., 2017, Akinbi & Ojie, 2021). As the 'disappearing messages' trend is particularly new there are (at the time of writing) no viable reports to review and compare against our own set of results. We will use a Samsung S6 (Android 7 OS) and an Apple device (iOS 12.1). The results of the devices will be compared to provide an insight into how both operating systems handle the data differently. We created an investigative scenario followed by subsequent phases, "Installation of application" and "Design of experiments" respectively for each application. We installed and ran Telegram v 8.5.1 and Snapchat v 11.64.0.36.

In the "Design of experiments" phase, we define a set of experiments that involve using the applications, creating photos and videos using the camera, sending and downloading messages.

To ensure we knew what data should be present on the device we created a table of sample data, as well as interactions made with the device during the population period. This is useful as we can audit and log what data was seeded, to ensure that the data extracted could be cross-examined and checked for accuracy. Table 1 shows the types of media messages supported by the apps. Four images and four videos have been created, two of each on both devices. Audio and files have been excluded from the media used on the premise that we believe they will act in the same way as images and videos. Locations and contacts have been excluded from the media available, due to limitations in GDPR regarding personal information. The extraction of data from the mobile applications was completed using the tools: UFED' 4PC, and MSAB's XRY.

Application	**Texts/Chats**	**Images**	**Video**	**Audio/Voice**	**Files**	**Location**	**Contacts**
Telegram	✓	✓	✓	✓	✓	✓	✓
Snapchat	✓	✓	✓	✓	x	✓	✓

Table 1: Types of media supported by Telegram and Snapchat

We split the experiments into two test groups: *Snapchat Messages* and *Telegram Secret Chat*. 'Snapchat Messages' will be a comparison and test to see whether Snapchat messages can be recovered via forensic means by performing a standard mobile extraction on the device with both 'unsaved' and 'saved' messages on Snapchat. It will also determine what data can be brought back from the application from extractions, and how Snapchat deals with disappearing messages. 'Telegram Secret Chat' will be a comparison and test to see whether Telegram's 'Secret mode' messages can be recovered via forensic means by performing a standard mobile extraction on the device. It will also determine what data can be brought back from the application from extractions, and how Telegram deals with disappearing messages.

3.1 Snapchat Messages

Using the Snapchat application, we compared "disappearing by default" and "decisive disappearing" where Snapchat automatically deletes messages unless they are specifically saved by the user via tapping on them. The iPhone extraction was not able to extract any Snapchat data other than the application files, as seen below under the "toyopagroup.picaboo" (Figure 1) application name.

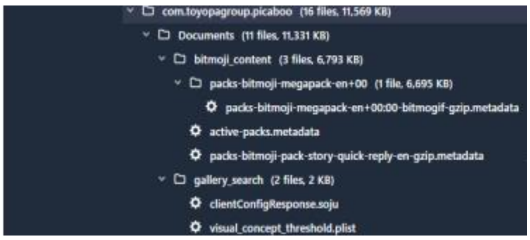

Figure 1: iPhone File System Snapchat

The Samsung phone managed to recover most of the chat data regardless of whether the messages were saved or unsaved (minus 1 timed photo, and 2 videos) as shown in Figure 2.

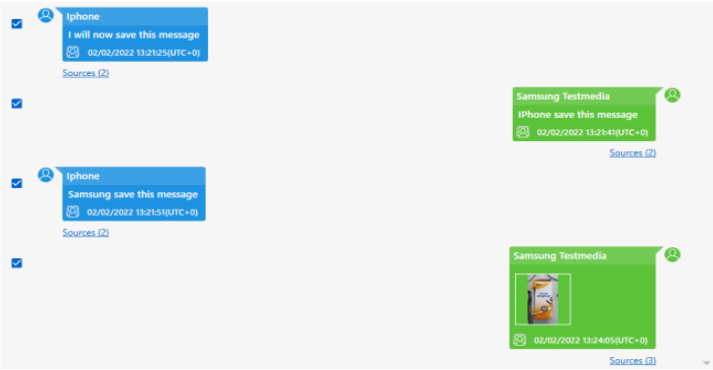

Figure 2: Samsung Snapchat Chats

By creating an Autopsy case and placing the extracted .com files out of the UFED extraction, a database known as "arroyo.db" (found in */com.snapchat.android/databases)* contained the data for the conversation shown above. Further work would have to be conducted to translate the BLOB data into messages using a hex viewer and decoder, images, or videos to see whether the missing data could still be recovered.

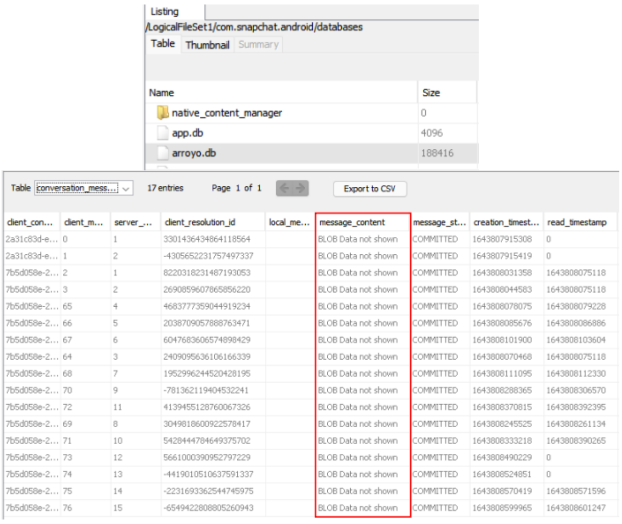

Figure 3: Autopsy "Arroyo.db"

3.2 Telegram Chats

We created two Telegram chats: a "regular chat" and a "secret messages" chat which enables

disappearing messages. Neither of these Telegram chats were extracted in either pre or post-expiry extraction on the iPhone. The only data retrieved was the application data as shown in Figure 4.

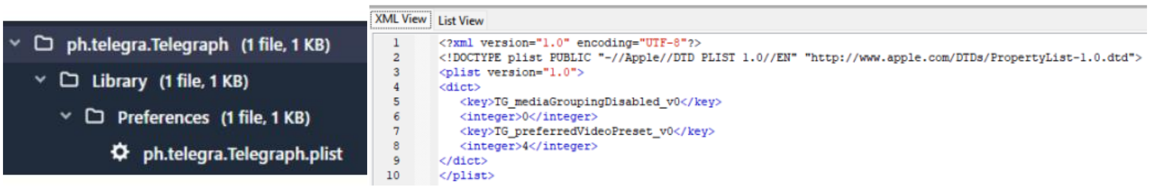

Figure 4: iPhone Telegram File System and plist details

When opened, the "preferences.plist" contained no data regarding disappearing messages. In both Samsung extractions, the regular chat was extracted without issue, showing both messages – Figures 5 and 6. Limited data were extracted from the secret chats in both extractions but the metadata was incorrect, showing "15/05/2015".

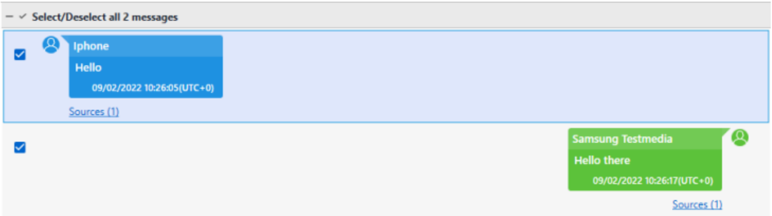

Figure 5: Telegram Samsung regular chats

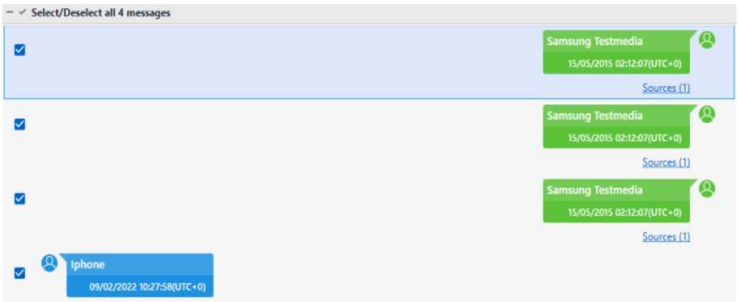

Figure 6: Telegram Samsung Secret Chats

The wrong metadata was surprising, so we investigated further to see where the data had been extracted from (as shown in Figure 7). As identified, we opened "Cache4.db" located within the Telegram "files" folder.

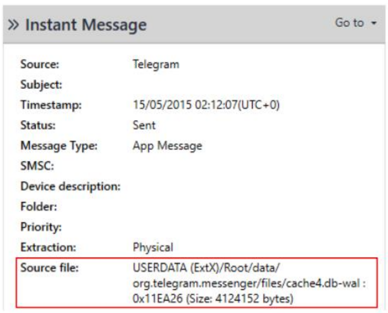

Figure 7: Storage Location Telegram Chats Samsung

As shown in Figure 8, the data has not been parsed correctly and there are fragments of data contained within the "data" column of the table "messages_v2". By converting the time into "Seconds from UTC

1970" the correct metadata times are now shown – see Figures 9 and 10. Using the in-built hex editor, the hex data shows some of the message contents that were sent.

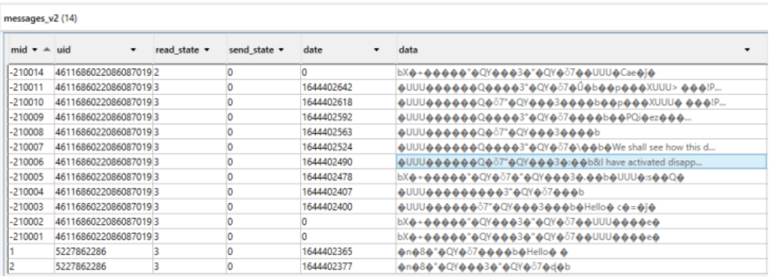

Figure 8: "Cache4.db" messages_v2 table

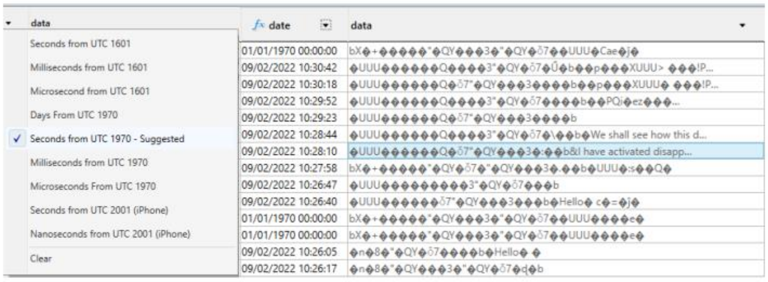

Figure 9: Date conversion

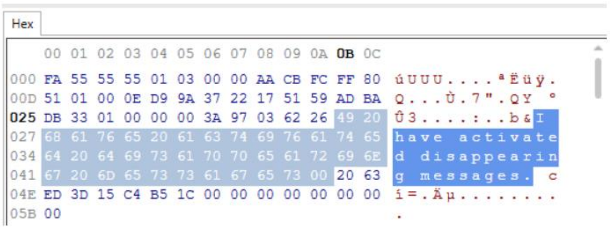

Figure 10: Cache4.db hex editor

Another piece of evidence found was the file path of the images that had been sent through the "secret chat" (Figure 11) within the hex.

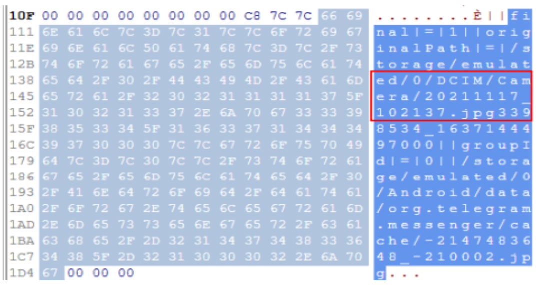

Figure 11: File paths from hex

Using this, and the Cellebrite search tool, “221117_102137.jpg” returned a result on both the pre and post-extractions, showing the original image as shown in Figure 12. It is clear that Cellebrite has not accurately parsed the data and further follow-up testing should be conducted to see whether this is a recurring issue. However, manual data can be extracted using the above techniques to retrieve incorrectly parsed artefacts. Not all artefacts may be available, as deleted messages and video messages were not recovered.

Figure 12: File path photo

4. Analysis and Significance of Findings

Within this section, we analyse and present the significance of our findings. We highlight the main findings from our Snapchat experiments, and Telegram experiments, and then compare Snapchat and Telegram.

Snapchat: A series of messages were sent/received between the two devices. When examining the iPhone, no data could be forensically recovered from the device, besides the installation of the application on the device. These results highlight sanitization of data within Snapchat, which in turn, poses an issue for forensic investigations. However, the same data when examined on the Samsung was almost completely retrievable (aside from 3 artefacts); showing that Snapchat for Android has a poor data sanitization procedure, alongside Telegram. Whether this is due to Samsung’s physical extraction or down to the specific hardware/software of the device in a forensic investigation is unclear, however, an Android device is likely to provide more data due to this. Overall, forensically analysing Snapchat for iOS should be conducted manually first (if possible) before attempting to conduct a logical extraction. For Android, a physical extraction (if possible) is the best available method for the extraction of Snapchat artefacts.

Telegram: Telegram was used on both devices to send/receive a series of messages and media. On the iPhone data was completely irretrievable, both pre and post-expiry; showing that Telegram for iOS has a commendable sanitization procedure. However, on Samsung, the examination of the device, while not as straightforward as the Snapchat examination did contain some artefacts from the experimental data. This required a manual review of the Telegram application files and even browsing hex-data contained within the BLOB entries. Telegram's data sanitization for Android is inconsistent but is better than Snapchat. Overall, a manual review of Telegram for iOS may be required before conducting any extractions. This would ensure that data residing on the device is captured before attempting to retrieve (and potentially lose) more data via an extraction. Regarding Android, a physical extraction is the best available extraction and the examiner should ensure that they verify and review the associated database files and data.

Snapchat vs Telegram: both Telegram and Snapchat share similar results. These are presented in more detail within Tables 3-6 below. The iOS retains no artefacts on either application (besides the basic installation files), whereas Samsung has a greater potential for the recovery of artefacts across both extractions. From a forensic perspective, Snapchat provides the examiner with an 'easier' extraction, without the need for manually reviewing database files, as well as the near complete recovery of artefacts, making Snapchat an easier application to analyse. Each of the tables below contains the results of each group testing, supplying an easy-to-read graphic of what data persists pre and post "disappearing".

Key	Meaning
Y	Data was fully retained and parsed
N	Data was missing/not extracted
/	Data was partially available/parsed

Table 2: Key explanation

Snapchat Extraction, Device: iPhone 6s

Tool Used: UFED 4PC

Extraction(s): Logical & Advanced Logical

Date/Time added	Sent/Received?	Data description	Cellebrite Recoverable?
02/02/2022 13:21	Received	"Hello"	N
02/02/2022 13:21	Received	"This is a test of the disappearing messages"	N
02/02/2022 13:21	Sent	"I will save this message" – iPhone saved	N
02/02/2022 13:21	Sent	"Hello"	N
02/02/2022 13:21	Sent	"I will now save this message"	N
02/02/2022 13:21	Received	"iPhone save this message" – iPhone saved	N
02/02/2022 13:21	Sent	"Samsung save this message" – Samsung saved	N
02/02/2022 13:23	Received	Photo of BIC pen – Saved by iPhone	N
02/02/2022 13:23	Received	Timed (10s) photo of screwdriver	N
02/02/2022 13:25	Sent	Photo of evidence tape – Replayed & saved by Samsung	N
02/02/2022 13:26	Sent	Timed (10s) photo of duct tape	N
02/02/2022 13:28	Sent	Photo of screwdriver	N
02/02/2022 13:28	Received	Photo of screwdriver	N
02/02/2022 13:29	Received	"This message will not be saved"	N
02/02/2022 13:90	Sent	"Neither will this"	N

Table 3: Snapchat extraction of iPhone 6s

Snapchat Extraction, Device: Samsung S6

Tool Used: UFED 4PC

Extractions(s): Physical (decrypted bootloader) – Full file system

Date/Time added	Sent/Received?	Data description	Cellebrite Recoverable?
02/02/2022 13:21	Received	"Hello"	Y
02/02/2022 13:21	Received	"This is a test of the disappearing messages"	Y
02/02/2022 13:21	Sent	"I will save this message" – iPhone saved	Y
02/02/2022 13:21	Sent	"Hello"	Y
02/02/2022 13:21	Sent	"I will now save this message"	Y
02/02/2022 13:21	Received	"iPhone save this message" – iPhone saved	Y
02/02/2022 13:21	Sent	"Samsung save this message" – Samsung saved	Y
02/02/2022 13:23	Received	Photo of BIC pen – Saved by iPhone	Y
02/02/2022 13:23	Received	Timed (10s) photo of screwdriver	/ (Blank message)
02/02/2022 13:25	Sent	Photo of evidence tape – Replayed & saved by Samsung	/ (Video file missing)
02/02/2022 13:26	Sent	Timed (10s) photo of duct tape	/ (Video file missing)
02/02/2022 13:28	Sent	Photo of screwdriver	Y
02/02/2022 13:28	Received	Photo of screwdriver	Y
02/02/2022 13:29	Received	"This message will not be saved"	Y
02/02/2022 13:90	Sent	"Neither will this"	Y

Table 4: Snapchat extraction Samsung S6

Telegram Secret Chat Messages, Device: iPhone 6S

Tools used: UFED 4PC

Extraction(s): Logical & Advanced Logical

Date/Time added	Sent/Received	Data Description	Cellebrite Pre-Disappearing?	Cellebrite Post-Disappearing?
09/02/2022 10:26	Sent - (non-disappearing)	"Hello"	Y	Y
09/02/2022 10:26	Received - (non-disappearing)	"Hello there"	Y	Y
09/02/2022 10:28	Sent	"I have activated disappearing messages"	/ (Required manual hex viewing)	/ (Required manual hex viewing)
09/02/2022 10:28	Received	"We shall see how this does"	/ (Required manual hex viewing)	/ (Required manual hex viewing)
09/02/2022 10:29	Sent	"Have a photo" PHOTO 2 attached	/ (Required manual hex viewing)	/ (Required manual hex viewing)

09/02/2022 10:29	Received	PHOTO 1 sent	/ (Required manual hex viewing)	/ (Required manual hex viewing)
09/02/2022 10:30	Sent	VIDEO 2 attached	N	N
09/02/2022 10:30	Received	VIDEO 1 sent	/ (Blank message)	/ (Blank message)
09/02/2022 10:30	Sent	"Can you delete messages?"	N	N
09/02/2022 10:31	Received	"I will also delete this message"	N	N

Table 5: Telegram extraction iPhone 6S

Telegram Extraction, Device: Samsung S6

Tools used: UFED 4PC

Extraction(s): Extraction: Physical (decrypted bootloader) – Full File System

Date/Time added	Sent/Received	Data Description	Cellebrite Pre-Disappearing?	Cellebrite Post-Disappearing?
09/02/2022 10:26	Sent - (non-disappearing)	"Hello"	N	N
09/02/2022 10:26	Received - (non-disappearing)	"Hello there"	N	N
09/02/2022 10:28	Sent	"I have activated disappearing messages"	N	N
09/02/2022 10:28	Received	"We shall see how this does"	N	N
09/02/2022 10:29	Sent	"Have a photo" PHOTO 2 attached	N	N
09/02/2022 10:29	Received	PHOTO 1 sent	N	N
09/02/2022 10:30	Sent	VIDEO 2 attached	N	N
09/02/2022 10:30	Received	VIDEO 1 sent	N	N
09/02/2022 10:30	Sent	"Can you delete messages?"	N	N
09/02/2022 10:31	Received	"I will also delete this message"	N	N

Table 6: Telegram extraction Samsung S6

5. Conclusion

Disappearing messages have a severe impact on digital forensics due to the time-sensitivity involved, as well as investigative inexperience with this new and evolving technology. With criminals requiring new ways to hide their crimes, and leaving no trail of evidence, they may indeed turn to disappearing messages to achieve this. Although a users right to privacy is not openly investigated within these experiments, the findings will help investigators determine the most appropriate way in which data could be retrieved, reviewed and preserved. For example, informing and training both technical and non-technical staff about disappearing messages and ensuring both sides are aware of the risks and impact which they may have on the investigation is the first step to ensuring that disappearing messages are dealt with correctly. In cases where disappearing messages are present on the device, a manual review should be performed at the earliest priority, ensuring a photograph of the screen (showing the expiring messages) is taken, which will allow for both evidence of the messages existing, as well as potentially verifying any post-expiry messages within the data verification stage of the examination. In cases where messages have not yet expired or have just expired, there is still potential for evidence to be recovered using extractions where deleted data can be recovered (such as file system and physical extractions).

However, both applications are somewhat competent for the thorough sanitation of data, which impacts potential forensic investigations being able to retrieve and accurately verify data's integrity, for admission to court as evidence. Of our investigated apps, Snapchat is the most destructive for potential evidence, whereas iOS devices would have to be subject to a manual review, and Android physicals could retrieve all the necessary artefacts required for admissible evidence. With Telegram incomplete data was the best extraction possible within our report, providing minimal artefact evidence.

Cloud extractions were not supported by Cellebrite Cloud Analyzer for either Snapchat or Telegram at the time of writing. This testing group and its limited data have shown that Cloud extractions are not a valid replacement for traditional mobile forensics as they currently stand and pose an unnecessary risk in the potential loss of data and evidence by breaking the traditional forensic practice of network isolation. Following this, the legal issues and complications in the retrieval of credentials provides further evidence that this methodology is best reserved as a "last resort" in gaining evidential data.

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11. Enterprise Risk Management and Information Systems: a Systematic Literature Review

Andre D Fernandes
Universidade de Lisboa
andre.fernandes@inov.pt

Daniel Ramalho
Universidade de Lisboa
daniel.ramalho@tecnico.ulisboa.pt

Miguel Mira Da Silva
Universidade de Lisboa
mms@ tecnico.ulisboa.pt

Abstract

Enterprise Risk Management (ERM) aims to help organizations better monitor, analyze, and control their risks and policymakers to focus on procedures to improve organization and risk governance. Over the years, several artifacts have been proposed in this area to address different goals in ERM. The main objective of this article is to provide an overview of the literature related to the areas of ERM and Information Systems in order to understand how traditional risk governance adapts to the new digital reality of organizations. To better structure the results obtained, the articles were divided into three distinct categories: articles that offer guidelines for ERM management, articles that propose ways to measure the maturity of organizations in ERM, and articles that propose methods to increase an organization's maturity in ERM.

Keywords: Enterprise Risk Management, ERM, Systematic Literature Review, Framework.

1. Introduction

Risk is a concept used in several domains and does not have a single definition (Janney and Dess 2006). Enterprise Risk Management (ERM) is a derivative of traditional risk management that aims to model, monitor, evaluate, and respond to organizations' risks (Gordon, Loeb, and Tseng 2009). ERM "allows/helps/enables/supports organizations in achieving their performance and profit targets and prevent resource loss" (COSO 2017).

As an essential part of ERM, enterprise risk analysis has been extensively developed by academics and practitioners (Oliva 2016), resulting in the development of different artifacts that aim to integrate the risk assessment into organizational cultures and, thereafter, the inclusion of risk management in the list of enterprises' organizational processes (COSO 2017; Purdy 2010; RIMS 2006). The COSO and ISO 31000 frameworks are examples of structured approaches for organizations to manage ERM efficiently (COSO 2017; ISO 31000).

Given the broadness of the ERM field and the variety of possible solutions in different scientific articles, we conducted a literature review to analyze the proposed solutions for ERM management. To the best of our knowledge, no existing article presents the state-of-the-art frameworks, models, and methods currently under development and implemented to help organizations manage ER, either by the industry or the scientific community. We want to point out that the work of (Anton and Nucu 2020) makes a unique summary of the topics covered in the ERM literature, but does not answer the questions we proposed. This article provides a structural overview of ERM management by categorizing existing research works based on a Systematic Literature Review (Kitchenham et al., 2009).

Nowadays, many organizations depend on information systems to be or become competitive in their field of competence. The technological element of organizations makes them vulnerable to natural and human-made threats, whose outcomes are highly unpredictable (Jovanović, Renn, and Schröter 2012). However, the authors are unaware of any research that considers linking the theoretical domains of IT Governance and ERM. Thus, in this SLR, all the selected articles considered the area of information systems in their domain or are abstract enough to encompass this area.

The paper is structured as follows: Section 2 describes the research methodology, the plan and the execution of the SLR. In Section 3, the Research Questions and the research results are reported. Section 4 concludes this article.

2. Systematic Literature Review

A Systematic Literature Review (SLR) is a methodology that provides a systematic and rigorous process for reviewing and analyzing the literature, identifying, analyzing, and interpreting all available materials in a particular domain (Kitchenham et al. 2009). An SLR consists of three stages:

- Planning – the research questions, SLR goals, and exclusion and inclusion criteria are defined, and a review process is written.
- Conducting – the articles are collected, organized and filtered using the process defined in the previous step.
- Reporting – the extracted information from the selected studies is summarized and the research questions are answered

2.1 Planning phase

In this phase, the execution process of the SLR was designed. To this end, the research questions were established, the databases to be used were chosen, the search string to find relevant articles was defined and the inclusion and exclusion criteria to filter the articles were defined.

2.1.1 Research Questions

This research explores the contents of existing studies published in the ERM domain, specifically to understand what kinds of options, in terms of models and frameworks, are available for organizations to implement, assess and improve their ERM processes. For this purpose, we defined the following Research Questions (RQ):

RQ1 - What frameworks are being used in the ERM domain?

RQ2 - What assessment models are being used to assess ERM maturity?

RQ3 - What methods are being used to increase maturity in ERM?

RQ3.1 - Which steps of risk management receive more attention?

RQ4 - What are the foundations used for the work?

RQ4.1 - Are they based on existing standards?

RQ4.2 – What conceptual models are being used or proposed?

The paper aims to attain a comprehensive view of the solutions proposed in the literature in recent years. Therefore, three macro questions were formulated, representing the three main vectors of analysis that were considered in this research: managing, assessing and improving ERM. The fourth vector of analysis, concerning the foundations of the works, has been added to understand the underlying basis of what was proposed.

2.1.2 Search Process
Five different databases were used in our search process to obtain a comprehensive set of publications for this research:

- EBSCO Host (http://eds.b.ebscohost.com/)
- SCOPUS (http://www.scopus.com)
- ACM Digital Library (http://portal.acm.org)
- Web of Science (http://www.isiknowledge.com)
- IEEE Xplore (http://ieeexplore.ieee.org)

The results were obtained by using a standard search string encompassing both the Title and Abstract (**Error! Reference source not found.**). The articles were collected from the different databases in March 2022.

Table 3 Generic Search String

Search String
Title (Risk AND (manage* OR erm) AND (model* OR framework OR method*)) AND Abstract ((process OR maturity OR capability) AND (digital OR info* OR software) AND (assess* OR eval* OR manage*))

2.1.3 Inclusion and Exclusion Criteria
To extract relevant publications for the research, a set of Inclusion Criteria (IC) and Exclusion Criteria (EC) were defined, as recommended by (Kitchenham et al. 2009).

- EC1: Articles published in 2010 or earlier
- EC2: Articles not written in the English language
- EC3: Publications not from scientific journals or conferences
- EC4: Surveys or educational articles
- EC5: National policies
- EC6: Articles focused only on a specific business field (e.g., civil construction, health, environment)
- EC7: Articles lacking peer review
- EC8: Duplicated articles (prioritizing the more complete and recent versions)
- IC1: Indexed conference or journal
- IC2: Articles focused on best practices, frameworks, models, taxonomies, and processes in the ERM domain

2.2 Search Process
The publications were identified by searching through databases of academic publications using the predefined search string (Table 1). After the articles were collected from the different databases, they were all centralized using the Rayyan tool (https://rayyan.qcri.org/).

The first step in this process was the removal of duplicate articles. Then, the screening phase was initiated, where the titles and abstracts of the remaining articles were read and the articles were classified, according to the predefined inclusion and exclusion criteria, into three categories: "Include", "Maybe" and "Exclude". The articles classified as “Include” automatically proceeded to the next process phase. The articles classified as “Exclude” were labeled with the criteria they violated to justify their exclusion. The articles classified as “Maybe” were analyzed in more detail and discussed among the authors until a consensus was reached on whether it should be included or excluded. The Scimago ranking (https://www.scimagojr.com/) and the Core (http://portal.core.edu.au) were consulted for the journals' and conferences' rankings. Articles published in conferences or journals that were not listed in any of these rankings were eliminated from the research.

In the next phase, the articles' introductions and conclusions were read and the articles were again classified and filtered as in the screening phase. The remaining articles were then fully read, classified, and filtered as in the previous phases. In the end, thirty articles were accepted and later analyzed and classified into different categories, as shown in the following sections. The process is summarized in **Error! Reference source not found.**.

2.2.1 Classification Scheme

Categories were defined to classify the articles during the screening phase in order to make their analysis clearer and more efficient. The classification process started in the screening phase and ended after the complete analysis of the articles. This process was iterative and discussed among the authors. In the end, all articles were classified according to the type of artifact created and whether validation was performed in their research. The types of solutions are explained in Section 3.

3. Discussion

A series of parameters were selected to analyze and categorize the articles based on the classification scheme process in order to answer the Research Questions. All articles were classified according to the type of their contribution and whether or not it was validated. **Error! Reference source not found.** shows the categories created to classify the articles. Articles were considered validated if they used any method (case studies, interviews, etc.) to validate their solution with real organizations or real-world scenarios. However, some articles in this category were classified as "Exemplified" as they used fictitious organizations or data to validate their research. Those classified as non-validated did not meet any of these criteria. The solution column summarize the artifacts presented in each of the articles. One nuance is present in **Error! Reference source not found.** in the form of the Framework* label. These articles consist of high-level, general guidelines, like common frameworks, but instead of guiding ERM directly, they guide the adoption or implementation of other pre-existing frameworks or standards.

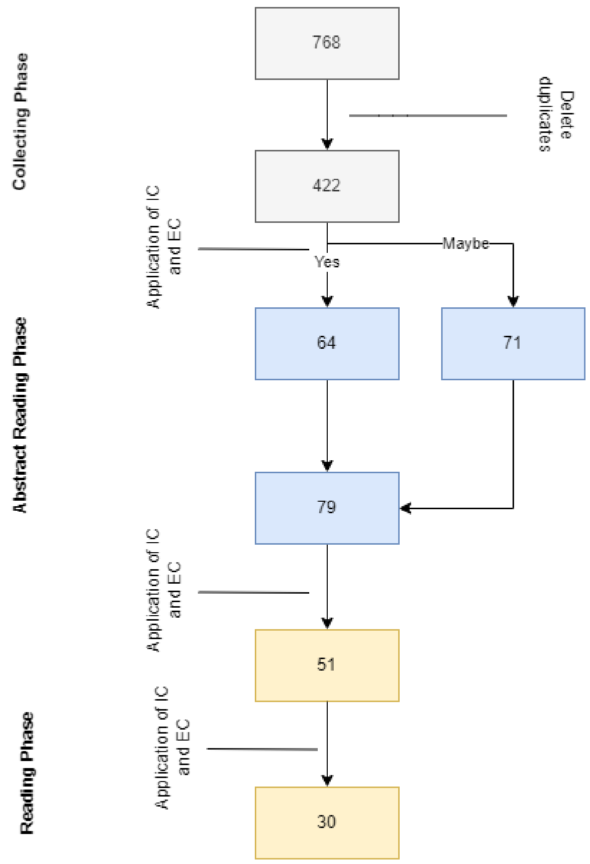

Figure 6 Article selection and filtering process.

Table 4 Classification Scheme definitions

Type	Definition
Assessment Model	The paper provides a model or significantly modifies an existing model for assessing the capability of processes or the maturity of organizations concerning the ERM domain.
Framework	The article provides a structured list of processes, guidelines or best practices designed for organizations in the ERM domain.
Method	The paper proposes solutions that fully or partially improve processes within the ERM domain.
Opinion Paper	The paper does not propose something new (assessment model, framework, or method) but rather analyzes and draws conclusions about certain concepts or solutions
Conceptual Model	The paper presents a model to represent concepts and/or relationships in the ERM domain.
Implementation	The article focuses on the implementation of frameworks in organizations

Table 5 Final set of papers

Reference	Type	Solution	Validation
(Webb et al. 2014)	Assessment Model	Application model for Information Security Risk Management	Yes
(Javaid and Iqbal 2017)	Framework*	Risk-based Maturity Model for Enterprise Risk Management application at operational level and integration of various risk management frameworks	Yes
(Deshpande and Desai 2021)	Framework	Risk-based Maturity Model for Enterprise Risk Management	No
(Khosravi-Farmad and Ghaemi-Bafghi 2020)	Framework	Bayesian Decision Network (BDN) based integrated framework for Security Risk Management of computer networks	Yes
(Ntouskas and Polemi 2012)	Framework	Multicriteria methodology for Risk Management, based on collaboration and the Analytical Hierarchy Process (AHP) method	No
(Zaydi and Nassereddine 2018)	Framework	“4D-ISS” proactive process for Risk Management inheriting best practices of Information System Security Risk Management	No
(Chen 2011)	Method	Insertion of the Risk Management Process into Bohem’s Spiral Model to strengthen safety controls and management quality	No
(Garcia-Porras, Huamani-Pastor, and Armas-Aguirre 2018)	Framework	Framework for Information Security Risk Management integrating OCTAVE-S and ISO/IEC27005 practices	Yes
(Spremic 2012)	Method	Method for vision of Corporate IT Risk Management and Risk Assessment	Yes
(Suyasa and Legowo 2019)	Implementation	Practical implementation of ERM practices via ISO 31000	Yes
(Lee 2021)	Framework	Cybersecurity: Risk management framework and investment cost analysis	Exemplified
(Flores and Morocho 2020)	Framework	Four-layer Cyber Risk Management framework, considering ecosystem and infrastructure	Yes

(Ganin et al. 2020)	Assessment Model	Multicriteria Decision Framework for Cybersecurity Risk Assessment and Management	Exemplified
(Saluja and Idris 2015)	Framework	Statistics Based Information Security Risk Management Methodology: SQRC (Statistical Quantitative Risk Calculator)	No
(Saleh and Alfantookh 2011)	Framework	Comprehensive framework for enterprise Information Security Risk Management	No
(Thalmann et al. 2014)	Framework	Holistic framework incorporating IT Security Management and Knowledge Management to guide development of Risk Management	Yes
(Huang et al. 2011)	Method	Quantitative evaluation model that aids auditors in assessing IT General Control	Yes
(Ali, Warren, and Mathiassen 2017)	Framework	Focused on Software-as-a-Service (SaaS) Cloud innovation. Synthesizes risks and resolutions into a comprehensive model	No
(Elmaallam and Kriouile 2012)	Assessment Model	Maturity model for Information Security Risk Management process. Refers to ISO 31000 for maturity assessment.	Yes
(Meng 2013)	Implementation	Studies the application of the AHP method and PDCA (Plan - Do - Check - Act) method for the purpose of Information Security Risk Evaluation	Yes
(Maneerattanasak and Wongpinunwatana 2017)	Framework	Proposes Framework for appropriation of IT Risk Management implementation in principle and practice	No
(Mayer et al. 2019)	Conceptual Model	Integrated EAM-ISSRM (Enterprise Architecture Management - Information System Security Risk Management) conceptual model supported by enterprise architecture management design.	Yes
(Torabi, Giahi, and Sahebjamnia 2016)	Framework	Improved Risk Assessment framework equipped with analytical techniques to support Business Continuity Management Systems	Yes
(Kohnke, Sigler, and Shoemaker 2016)	Opinion Paper	Opinion on the NIST Framework	No
(Khrisna and Harlili 2015)	Framework	Integration of COBIT 5 and RMFCC (Risk Management Framework for Cloud Computing Integration) into two main phases of a new Framework. Provides mitigating action as well as management strategies	Yes

(Anikin 2015)	Method	Risk Assessment method using fuzzy logic and AHP for quantitative evaluation.	Exemplified
(Anthony et al. 2016)	Assessment Model	Risk assessment model using knowledge codification and multi software agents	No
(Gandotra, Singhal, and Bedi 2012)	Framework	Proactive threat-oriented security model embedded into spiral process.	Yes
(Kitsios, Chatzidimitriou, and Kamariotou 2022)	Framework	Developing a Risk Analysis Strategy Framework for Impact Assessment in Information Security Management Systems: A Case Study in IT Consulting Industry	Yes
(Kure, Islam, and Mouratidis 2022)	Framework	An integrated cyber security risk management framework and risk predication for the critical infrastructure protection	Yes

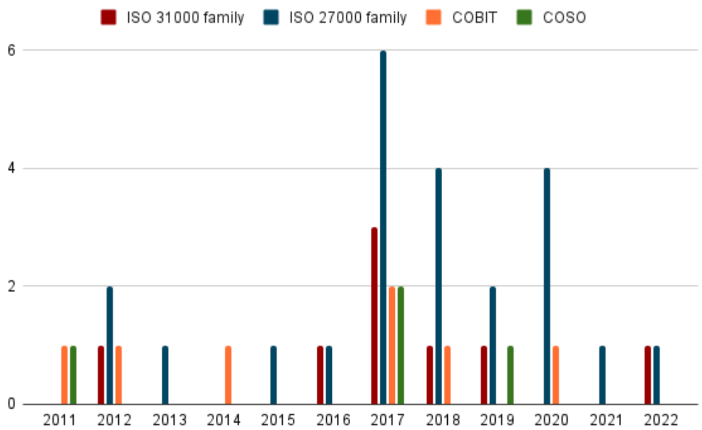

Figure 7 Algorithms referenced in the literature over the years.

The research questions RQ1, RQ2 and RQ3 are answered in Table 5, where the articles are classified according to the previously defined scheme. Although the number of articles was insufficient to identify trends, we extracted all algorithms used in the research and performed a time-based analysis, as shown in **Error! Reference source not found.**. It is possible to verify that OCTAVE (Operationally Critical Threat, Asset, and Vulnerability Evaluation) and Multi-Criteria Decision Making (MCDM) algorithms (Fuzzy and AHP) have been constantly referenced in the literature over the years. In the case of Bayesian methods, we speculate that the growing interest in the area of artificial intelligence was responsible for the peak in 2020. To answer question RQ3.1, the articles classified as "Methods" were analyzed to identify the phases in which the method operates. The articles that present methods are summarized in Table 6.

Table 6 Summary of articles classified as Method.

Paper	Summary
Chen (2011)	Inserts Bohem's spiral model into the Risk Management process to introduce constant, iterative actions that encourages systematic improvement. This method can be considered holistic as it covers the entire process of Risk Management.
Huang et al. (2011)	The proposal serves to improve the Evaluation of Governance Controls. The list of objectives that they construct covers a wide variety of issues in an organization, including explicit processes for Risk Identification, Risk Assessment, Risk Response, and general monitoring and management.
Anikin (2015)	The solution aims to improve the Vulnerability Risk Assessment process, based on the Common Vulnerability Scoring System proposed by NIST and Carnegie Mellon University. Those results are then combined with Threat Impact and Possibility metrics to obtain a Risk Assessment.
Spremić (2012)	Frames the solution in terms of Corporate IT Risk Management and elaborates a plan based on the literature to improve the Risk Identification and Risk Assessment processes.

To answer RQ4 and subsequently RQ4.1 and RQ4.2, the standards and taxonomies used by the collected articles were identified, as shown in **Error! Reference source not found.**. Many articles involve literature reviews on the area and solid related work sections. We make the following comment, not only on the articles collected but also on those that were fully read but removed in the last phase:

- ISO standards were one of the most often-used references. The ISO 27XXX standard family was used consistently throughout the timeframe, with ISO 27001 being the most constant. The PDCA Model from this standard was particularly emphasized. The ISO 31XXX standard family was referenced, but we expected that this would undoubtedly be the most used given its interconnection with the scope of this research. ISO 22301 was also mentioned, but not frequent enough to discern any patterns.
- We also expected more frequent reference to frameworks such as COBIT and ITIL, given that this research required that articles consider the IT Governance domain.

In the case of RQ4.2, we only identified one article (Mayer et al., 2019) that modeled ERM concepts using a modeling language (ArchiMate). We consider this kind of article essential to establish foundations, as throughout this research, we noticed some lack of consistency concerning concepts and definitions, for example, the inaccurate usage of certain concepts. This type of article may also help resolve inconsistencies found in ERM and Project Risk Management as they share similar concepts.

fter collecting and classifying all articles, we realized the final number of publications was too low. We concluded that this area is still relatively young and lacks specialization in particular areas, more specifically in ERM governance. We expected a more significant link to industry-recognized standards (e.g., ISO 31000, COBIT). We want to highlight the lack of research into the link between IT Governance and ERM. In our opinion, this is a possible area to be explored in the future, given the complexity and dependency that organizations have on information systems. During the research, we noticed a significant focus on Project Risk Management, given that a large percentage of the articles eliminated in the different phases were from this domain.

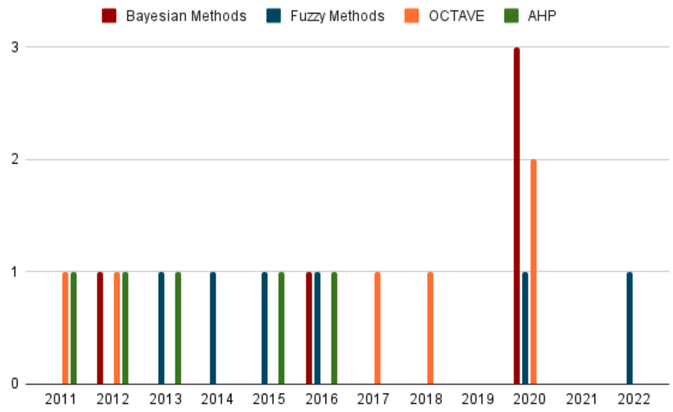

Figure 8 Standards referenced in the literature over the years.

4. Conclusion

In this paper, an SLR was performed to analyze the existing literature on ERM frameworks, assessment models and methods. This research answered four research questions about the existing research literature. A total of 30 publications were analyzed and classified, helping to clarify what is being researched in terms of best practices, models to assess ERM and methods to improve organizations in this area, and also determining what the most influential and significantly used artifacts are in this field.

In addition to the articles' classification as methods, frameworks, opinion papers, or assessment models, the integration with standards was also presented. This research attempted to identify conceptual models that clearly define the area of ERM, but only one relevant article was found, which might indicate a lack of attention towards this aspect in the literature. On the other hand, 15 of the 30 articles were classified as frameworks, indicating that this type of solution has received the most attention.

Our research leads us to conclude that the lack of ERM research and a potential enhancement by including IT Governance highlight an opportunity for future research. We also observed a strong focus on the risk assessment processes in the literature compared to other risk areas.

Even though this research follows the proper procedures suggested by the literature, there are nevertheless some major limitations. The number of articles is not exceptionally high and therefore, snowballing techniques could not be applied to increase the final number of articles. Although the low number of articles found can be justified by the fact that the areas of ERM and IT Governance are only recently being formally connected, this inevitably leads to limited statistical analysis. As future work, we recommend integrating grey literature in this review. We also recommend improving the search string and having more flexible filters to include more publications that were not analyzed in this research. Finally, we suggest a comparative analysis between the frameworks and assessment models classified in this research, as well as between the standards and frameworks recognized by the industry.

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12. Eyetracking para el estudio de la carga cognitiva y su relación con el desempeño académico enfocado al área de matemáticas

Uso de herramientas de EyeTracking para evaluar la calidad de interfaces al resolver un ejercicio digital

Angel Villegas Ortíz
Universidad Autónoma de Aguascalientes
Al235190@edu.uaa.mx

Eduardo Rodríguez López
Universidad Autónoma de Aguascalientes
emlopez@correo.uaa.mx

Francisco Álvarez Rodríguez
Universidad Autónoma de Aguascalientes
fjalvar@correo.uaa.mx

Abstract

This research compared the effect on cognitive load of exposing participants to items commonly used in academic assessments in order to establish what type of layout and items optimize information acquisition by allowing the participant to use working memory only for the given exercise without being altered by irrelevant information. To analyze the gaze patterns, an aid system was used and analyzed with gaze tracking tools to objectively find the best layout for presenting academic information.

This study aimed to generate a precedent in the development and objective analysis of interface designs for academic purposes, thus improving student learning and teacher knowledge sharing.

Keywords: EyeTracking, Usabilidad, Carga Cognitiva, Atención Visual, Desempeño Académico, Matemáticas.

1. Introducción

Durante la modalidad de clases a distancia todos los actores del ámbito académico tuvieron que adaptarse al uso intensivo de las nuevas tecnologías para adaptar sus temarios a las herramientas disponibles. Dentro de las áreas en las que se ha podido observar un decaimiento en la calidad del aprendizaje por parte de los alumnos es el de las matemáticas (Ponce et al., 2014). La falta de herramientas para remplazar un aspecto básico de las clases presenciales, como lo es el pizarrón para expresar conceptos matemáticos, ha expuesto las carencias de los sistemas internos de las instituciones educativas, así como de los softwares de gran distribución.

Para analizar objetivamente el uso y capacidad que poseen cuatro interfaces pensadas para realizar evaluaciones matemáticas, cada una con diferente disposición de sus elementos se plantea usar las métricas cuantitativas de las tecnologías de seguimiento de mirada y sustituir metodologías de pruebas de usabilidad convencionales.

En esta investigación se busca establecer un antecedente para futuros trabajos y, mediante el desarrollo de pruebas y versiones, mejorar la calidad de los sistemas de aplicación de evaluaciones, a la par que intenta encontrar una relación entre la usabilidad del sistema con la carga cognitiva presentada por el usuario.

2. Planteamiento y Justificación

Debido a los nuevos métodos de enseñanza y aprendizaje que tuvieron que ser improvisados por motivos de la pandemia de COVID-19 fue evidente la dificultad que experimentaron los docentes para aplicar sus métodos de enseñanza, por consiguiente, se tuvo una pobre retención de contenidos y bajo desempeño académico por parte de los estudiantes (V. Martínez, 2017).

De acuerdo con (Ponce et al., 2014) existen varios factores que conllevan a un alto índice de reprobación en las áreas de matemáticas básicas en la gran mayoría de las facultades de México, sin embargo, dentro de los principales se encuentran que, los alumnos perciben que sus calificaciones no aprobatorias se deben a carencias del docente al utilizar niveles altos de carga cognitiva, el poco uso de herramientas didácticas, emplear un lenguaje matemático que los alumnos lo perciben complejo y que no se les imparten los temas apropiados en la etapa de bachiller. Además de lo recién mencionado, existen otros factores que entorpecen o ensucian la cantidad y calidad de información. Según (Parodi & Julio, 2016) se puede concluir que la disposición de la información es casi igual de importante que la información en sí. Las maneras en que puede verse afectada la memoria de trabajo pueden ser desde un logotipo en la parte superior de la interfaz, el tipo y tamaño de la letra, imágenes de apoyo, títulos y subtítulos, entre otros.

Si bien hay una amplia documentación acerca de las disposiciones en páginas web y atención visual, hay pocas fuentes que relacionan lo anterior con la docencia y el desempeño académico en el corto plazo (Ponce et al., 2014). Según (Martínez, 2017) la principal desventaja que hasta esa fecha se percibía era la poca diversidad de cursos virtuales enfocados al área de matemáticas. También se menciona que parte fundamental del desinterés de los estudiantes es la pobre comunicación y elementos de diseño de software para intercambiar ideas de una abstracción matemática necesaria para un nivel de licenciatura.

Por otro lado, de acuerdo con (Sancho-Vinuesa & Pérez-Navarro, 2009) clarifica que en una ecuación matemática de los temarios vistos habitualmente a nivel licenciatura, contienen en su mayoría caracteres que no están presentes en el teclado y muchos otros que no es posible representarlos mediante ningún símbolo computacional. Como se mencionó anteriormente, en este trabajo se busca determinar el grado de mejora de un sistema para ofrecer respuestas en un ambiente de evaluación didáctica comparando la disposición y cantidad de elementos de cuatro diseños propuestos. Es decir, se propuso clarificar si la adición de elementos como botones, listas desplegables, barras de botones o tablas de símbolos, mejoran ampliamente la percepción del software del usuario y, por ende, la calidad de sus respuestas.

Para poder analizar objetivamente los efectos de los elementos didácticos indispensables para realizar a cabo una prueba mediante las herramientas *Tobii Pro Lab* y *Tobii Pro Nano* se diseñaron dos primeras disposiciones en la que una mostrara exclusivamente conceptos teóricos mientras que en la otra mostrara ejemplos referentes al tema del ejercicio, ambas a la par del ejercicio. Los diseños de ambas disposiciones permiten analizar a detalle el comportamiento de la mirada y la capacidad de los elementos para brindar información de valor. Para mejorar el alcance del análisis de estos elementos se desarrolló un tercer diseño que contuviera tanto conceptos teóricos como ejemplos a la par del ejercicio. De esta manera es posible cotejar de que elementos se está extrayendo más y mejor información.

Para entender el grado de afectación de la presencia de elementos distractores en las disposiciones se planteó una cuarta disposición adicional a las ya mencionadas pensada para elevar los niveles de carga cognitiva y estudiar los efectos de la abrumadora cantidad de elementos en los patrones de mirada del estudiante.

Mediante las métricas que ofrecen los softwares de ET (siglas en inglés de “Eye Tracking”) es posible obtener las veces que se posó la mirada en cada elemento de la interfaz para generar un conteo de visitas que indique cuáles elementos fueron los más importantes y los que menos influyen en la recopilación de información por parte del estudiante. Una vez analizada esta data y con los resultados de pruebas de usabilidad y observaciones del investigador se plantea generar un diseño de disposición de elementos que optimice la recogida de información para resolver un ejercicio. También se busca estudiar la viabilidad de implementar herramientas para establecer un canal de comunicación para intercambiar nociones matemáticas.

Dicho lo anterior se recopilaron los conceptos que permiten conocer los aspectos más importantes al analizar la atención visual de un estudiante frente a estímulos digitales y poder manipularla implementando o suprimiendo elementos hasta mejorar la calidad de las respuestas entregadas.

3. Compendio de Conceptos Claves

Antes de plantear métodos de desarrollo y aplicación de las disposiciones planteadas es preciso abordar conceptos importantes para tener la certeza que el ejercicio seleccionado exponga a los participantes a un esfuerzo tal que permita observar peculiaridades a la hora de cambiar los elementos alrededor de dicho ejercicio. Según (Duchowski, T, 2017) para poder entender la relación de los elementos en pantalla con la carga cognitiva se hace énfasis en la capacidad de procesamiento del cerebro humano en niveles de memoria de trabajo para evaluar el nivel de esfuerzo necesario que aplica una persona expuesta a información visual y a su vez lo cotejan con experiencias pasadas que fundamenta el conocimiento anteriormente adquirido. Así pues, los conceptos que permitieron seleccionar el ejercicio, así como realizar hipótesis sobre los posibles resultados fueron los siguientes:

Atención Visual: Según (Gonzales & Velázquez, 2012) se entiende como el proceso cognitivo que facilita la detección de estímulos en una escena visual compleja. La atención visual se ve afectada por la presencia de los elementos simultáneos. La excesiva presencia de elementos tiende a reducir el nivel de atención al detalle (Parodi & Julio, 2016).

Memoria operativa (Memoria de trabajo): Tiene la característica de ser muy limitada tanto en la cantidad de información que es capaz de procesar simultáneamente como en la volatilidad de los contenidos. Según (Ustárroz & Grandi, 2016) en este proceso cognitivo la información visual (acompañada de demás estímulos sensoriales) es recabada y concentrada para posteriormente ser cotejada por la memoria a largo plazo.

Memoria a largo plazo: La memoria a largo plazo se centra en la utilización de experiencias previas para dar forma a la información que es percibida por los sentidos humanos y posteriormente preparada para su interpretación en la memoria a corto plazo (Ustárroz & Grandi, 2016).

Carga cognitiva: La teoría de la carga cognitiva sugiere que el conocimiento se almacena en la memoria a largo plazo en forma de esquemas. Un esquema es una estructura general de conocimiento utilizada para la comprensión. La dificultad con la que la información se presenta es clave para aumentar el tiempo y la complejidad con la que la memoria busca los esquemas específicos para dar entendimiento a un tema (Andrade-Lotero, 2012). Factores como la cantidad y ubicación de elementos de información afectan directamente la capacidad de la memoria de trabajo de encontrar semejanzas entre la información presentada con los conocimientos o experiencias previamente adquiridas.

Sobrecarga cognitiva: (Tarouco, 2006) defiende que nuestro cerebro tiene una capacidad limitada para procesar información, y a la vez, que no se ha establecido límite sobre cuánta información podemos procesar simultáneamente. Es decir, el cerebro humano puede procesar una gran cantidad de información, pero hay que tener en cuenta su propia estructura para facilitar su procesamiento, sino la sobrecarga aparece y la entrada de información se imposibilita. Esta capacidad está íntimamente relacionada con la memoria de trabajo.
De acuerdo con (Moreno-Armella, 2013) "*Los símbolos matemáticos co-evolucionan con sus referentes matemáticos y la objetividad semiótica inducida hace viable que se les comparta en una comunidad de*

práctica". Lo que hace referencia a que los límites del aprendizaje o enseñanza de la matemática están estrechamente ligados a las herramientas de las que se dispone para instaurar un canal de comunicación que sirva para transmitir nociones matemáticas.

4. Metodología

Una vez abordado lo anterior se bosquejó un método experimental que mediante iteraciones y análisis de sus fases mantuviera un alto nivel de objetividad para generar pruebas aptas para su estudio y análisis de patrones de mirada. La capacidad iterativa con la que se dotó al diseño experimental permitió someter a las cuatro disposiciones a varios escrutinios y aplicarles constantes mejoras para determinar sus capacidades para brindar información y, mediante la selección de los mejores elementos generar nuevas disposiciones de estudio incrementando sus capacidades de usabilidad y como herramientas académicas.

Para poder generar las pruebas se desarrolló un sistema que mostrara las disposiciones al participante y guardar las respuestas que brinden estos. Lo anterior, aunado a las herramientas de *Tobii Pro*, permitieron generar n número de pruebas para cotejar los comportamientos al analizar la interfaz y forzar un nivel específico de carga cognitiva independientemente de la escolaridad o carrera del participante.

4.1 Diseño y Protocolo Experimental

Respondiendo a las necesidades de encontrar los diseños más óptimos para la aplicación de evaluaciones se planteó un método experimental que consistió en fases de Diseño de disposiciones, desarrollo de sistema, pruebas del sistema y aplicación de pruebas experimentales. En la Figura 1 se muestra el diagrama del método experimental que fue planteado para cubrir los requerimientos antes mencionados.

Para generar pruebas óptimas y analizar el uso de los elementos de cada disposición y su efecto directo en el participante se revisaron los trabajos de (Díaz Herráez & Varona, 2017; López Orozco et al., 2019) en las cuáles se toma un tamaño de muestra alrededor de 50 participantes para evaluar las primeras reacciones de los individuos al estímulo presentado. Sin embargo, para fines de esta investigación se hace énfasis en el desempeño general del individuo al ser expuesto a una mayor cantidad de estímulos y durante tiempo mucho más prolongados. Este enfoque, aunado a la manipulación de la carga cognitiva dificulta el análisis de cada uno de los eventos de la mirada que están presentes en una actividad con varios elementos.

Según (Florián et al., 2010) con una cantidad de 5 usuarios es posible determinar el agrado de usuario al usar una plataforma, si bien este enfoque únicamente brinda comentarios subjetivos por parte del *tester* se dotará de las herramientas de seguimiento de mirada para determinar el uso objetivo de la aplicación, proponiendo un primer tipo de análisis de usabilidad objetiva.

Mencionado lo anterior se generó un perfil para crear la muestra de la prueba dónde se escogió a estudiantes de pregrado en los que en sus planes de estudio se impartiera al menos un curso de matemáticas básicas o álgebra superior. No se hizo distinción por etnicidad, religión, orientación sexual, preferencias políticas, etc. Las pruebas experimentales fueron diseñadas para durar no más de 20 minutos incluyendo la etapa de calibración y sólo después de leer y firmar la carta de consentimiento informado (Véase Apéndice D). Para analizar el uso de las interfaces por pruebas de usabilidad se generaron un total de diez pruebas separadas entre las disposiciones 1, 2 y 3 y únicamente la disposición 4 para las cuales participaron tres mujeres y siete hombres. Una vez teniendo la muestra se siguió el protocolo experimental representado en la Figura 2.

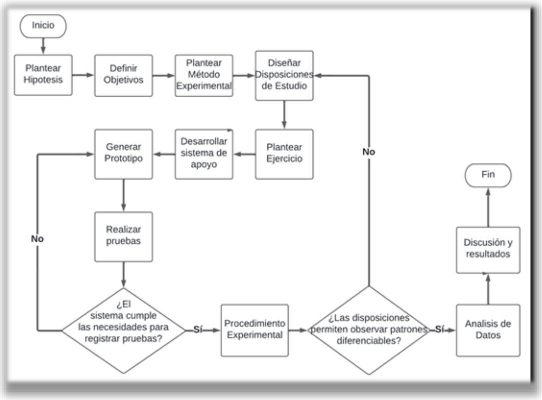


Figura 1: Diagrama de método experimental
(Fuente: Elaboración propia, 2022)

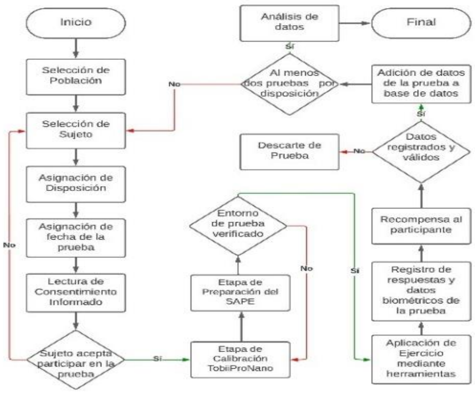


Figura 2: Protocolo Experimental para pruebas
(Elaboración Propia, 2022)

4.2 Diseño de Disposiciones

Para observar los diferentes comportamientos de los participantes al realizar el ejercicio se diseñaron las disposiciones de forma tal que las secciones fueran altamente diferenciadas. Cada elemento de los diseños debía contar con un propósito prestablecido para que posteriormente el análisis de las métricas brindadas por las herramientas de ET permitiera determinar el grado de uso y capacidad para presentar información de valor o, por el caso contrario, que tanto afectan a la carga cognitiva los elementos distractores.

Para tener datos diferenciados de los patrones de mirada se diseñaron disposiciones con y sin elementos distractores. Los contenidos teóricos también fueron separados para determinar el formato más óptimo para contener y obtener información.

4.2.1 Propuesta de Disposición de Elementos

Como anteriormente se mencionó, los diseños de las distribuciones fueron planteados para obtener información sobre los patrones, cantidad de fijaciones y porcentajes de tiempo que los participantes mostraban en la prueba. Teniendo en cuenta que el ejercicio seleccionado será implementado con base a su capacidad para establecer una carga cognitiva nivelada para todos los participantes. Las cuatro disposiciones planteadas pueden verse en la Figura 3.

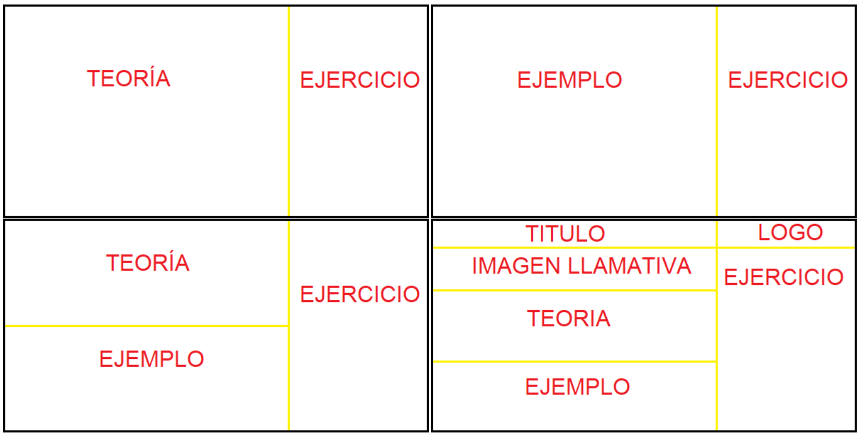


Figura 3: Conjunto de disposiciones de estudio planteadas
(Fuente: Elaboración propia, 2022)

4.2.2 Selección de Ejercicio

Para poder determinar los efectos producidos por las diferentes disposiciones en los usuarios se seleccionó un ejercicio extraído de un examen extraordinario basado en el contenido de la materia de Matemáticas Básicas brindado por el departamento de Matemáticas y Física de la Universidad Autónoma de Aguascalientes. El ejercicio debía cumplir con las características de poder ser representado de manera gráfica para poder tener lecturas que permitieran descubrir patrones de mirada al recorrer la pantalla en busca de información. Tomando en cuenta el nivel de carga cognitiva que se piensa aplicar se seleccionó un ejercicio referente a la teoría y operaciones de conjuntos. Esta rama de ejercicios y conocimientos es ampliamente impartida en la mayoría de programas de estudios de licenciatura, por lo que, los resultados pueden ser ampliamente analizados y aplicados a muchos centros académicos. El ejercicio seleccionado se representa en la Figura 4.

4.2.3 Diseño de Elementos del sistema

La principal característica por la que se seleccionó el ejercicio relacionado con conjuntos y el diagrama de Venn-Euler fue su capacidad para representar en un espacio limitado gran cantidad de información útil para resolverlo. Gracias a esto, es posible estimar la carga cognitiva del participante al ir añadiendo elementos de apoyo o de distracción. Como se observa en la Figura 5 el ejercicio propuesto es capaz de representar cuatro conjuntos y sus elementos, una operación de conjuntos (área verde) y las instrucciones del problema,

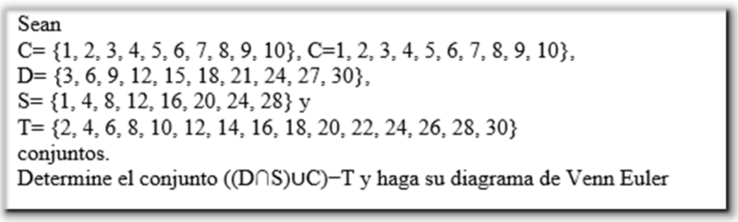

Sean
C= {1, 2, 3, 4, 5, 6, 7, 8, 9, 10}, C=1, 2, 3, 4, 5, 6, 7, 8, 9, 10},
D= {3, 6, 9, 12, 15, 18, 21, 24, 27, 30},
S= {1, 4, 8, 12, 16, 20, 24, 28} y
T= {2, 4, 6, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, 30}
conjuntos.
Determine el conjunto ((D∩S)∪C)−T y haga su diagrama de Venn Euler

Figura 4: Ejercicio Extraído de Examen Extraordinario
(Fuente: Elaboración Propia, 2022)

Para comparar los grados de utilización y eficacia de los elementos de teoría y ejemplos para brindar información útil para resolver el ejercicio se desarrollaron imágenes cuyo contenido consta de los conocimientos básicos del tema mencionado, dichos conceptos y ejemplos fueron obtenidos de un compendio de teoría de la materia de matemáticas básicas impartidas en la UNAM (Montiel et al., 2005). Estos elementos son representados en la Figura 6.

Para la cuarta disposición dónde es necesario forzar una alta carga cognitiva se dispusieron elementos adicionales para añadir información sin valor para dar solución al ejercicio. Elementos como un título, logotipo de la institución y una imagen llamativa aunada a un texto de antecedes históricos referentes a la teoría de conjuntos fueron los seleccionados para intentar crear distractores visuales que empañaran la claridad de la información en pantalla.

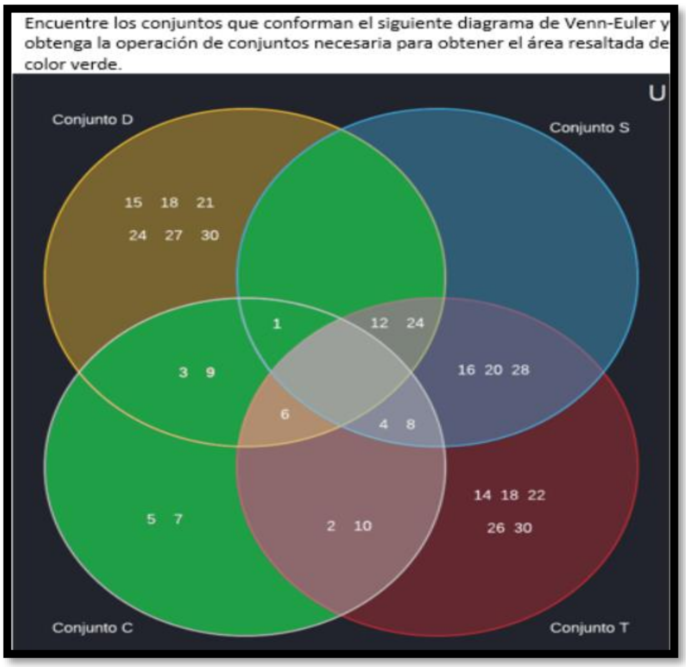
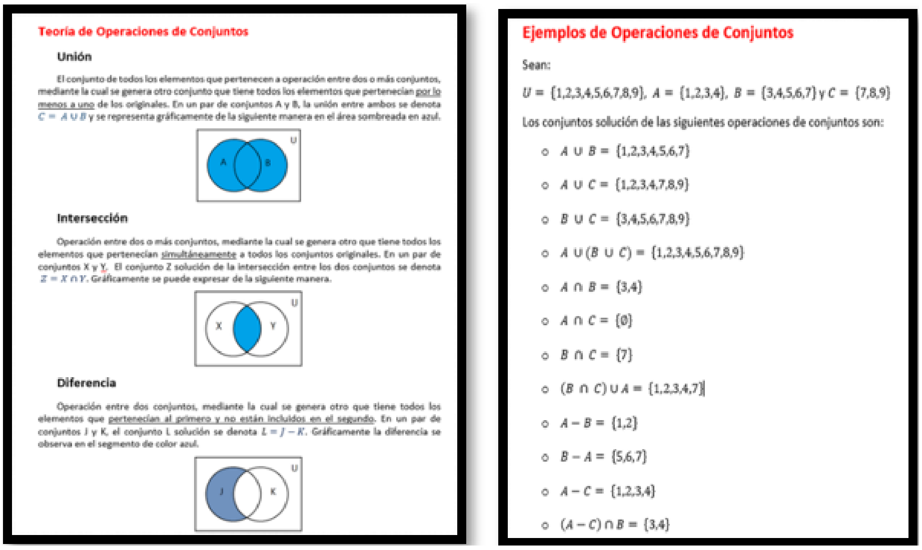


Figura 5: Ejercicio Propuesto para estudio.
(Fuente: Elaboración Propia, 2022)

4.3 Metodologías propuestas para desarrollo y pruebas del software.

Como se mencionó en la sección 2 de Compendio de Conceptos Clave, existe una correlación entre la calidad del canal de comunicación para intercambiar nociones matemáticas con el nivel de entendimiento entre dos individuos (Moreno-Armella, 2013). Planteado lo anterior se buscó una solución que partiera desde el diseño del software enfocado en la docencia.



Teoría de Operaciones de Conjuntos

Unión

El conjunto de todos los elementos que pertenecen a operación entre dos o más conjuntos, mediante la cual se genera otro conjunto que tiene todos los elementos que pertenecían por lo menos a uno de los originales. En un par de conjuntos A y B, la unión entre ambos se denota $C = A \cup B$ y se representa gráficamente de la siguiente manera en el área sombreada en azul.

Intersección

Operación entre dos o más conjuntos, mediante la cual se genera otro que tiene todos los elementos que pertenecían simultáneamente a todos los conjuntos originales. En un par de conjuntos X y Y. El conjunto Z solución de la intersección entre los dos conjuntos se denota $Z = X \cap Y$. Gráficamente se puede expresar de la siguiente manera.

Diferencia

Operación entre dos conjuntos, mediante la cual se genera otro que tiene todos los elementos que pertenecían al primero y no están incluidos en el segundo. En un par de conjuntos J y K, el conjunto L solución se denota $L = J - K$. Gráficamente la diferencia se observa en el segmento de color azul.

Ejemplos de Operaciones de Conjuntos

Sean:

$U = \{1,2,3,4,5,6,7,8,9\}$, $A = \{1,2,3,4\}$, $B = \{3,4,5,6,7\}$ y $C = \{7,8,9\}$

Los conjuntos solución de las siguientes operaciones de conjuntos son:

- $A \cup B = \{1,2,3,4,5,6,7\}$
- $A \cup C = \{1,2,3,4,7,8,9\}$
- $B \cup C = \{3,4,5,6,7,8,9\}$
- $A \cup (B \cup C) = \{1,2,3,4,5,6,7,8,9\}$
- $A \cap B = \{3,4\}$
- $A \cap C = \{\emptyset\}$
- $B \cap C = \{7\}$
- $(B \cap C) \cup A = \{1,2,3,4,7\}$
- $A - B = \{1,2\}$
- $B - A = \{5,6,7\}$
- $A - C = \{1,2,3,4\}$
- $(A - C) \cap B = \{3,4\}$

Figura 6: Elementos teóricos diseñados para las pruebas.
(Fuente: Elaboración propia, 2022)

Para generar un software mediante el esquema de UML primero se diseñaron los diagramas pertinentes a los requerimientos. Una vez que se han modelado se comenzó la primera iteración del desarrollo con el fin de recabar información proveniente de las pruebas unitarias, de **integración y especialmente las de usabilidad (Gómez et al., 2013; Paucar Ati, 2017; Prieto** Álvarez et al., 2015) para proponer un esquema de desarrollo para sistemas futuros. Este modelo de versiones permite al único desarrollador tener la certeza de que los procesos se cumplen a la par que el sistema se va dotando de los elementos pertinentes para llevar a cabo pruebas y analizar las métricas brindadas por las herramientas de ET.

Dotando al sistema de un modelo en espiral e incremental se optó por tomar dos iteraciones de desarrollo altamente diferenciadas entre sí. La primera contempló los aspectos vitales del sistema mientras que la segunda permitió el análisis intensivo del uso del sistema y la implementación de mejoras y modificaciones que fueran adaptando al sistema cada vez más para evaluaciones académicas mientras que la segunda iteración se analizaron las principales debilidades de usabilidad del sistema con el fin de perfeccionar el diseño de las disposiciones. A su vez, fue la etapa dónde se implementó una herramienta vital para el establecimiento de un canal de comunicación para transmitir nociones matemáticas: la barra de botones. Dicho elemento fue respaldado por los comentarios de pruebas de usabilidad una iteración anterior.

Continuando con la aplicación de la metodología en espiral, paulatinamente se fue construyendo un sistema que permitiera realizar pruebas válidas aunadas a las herramientas de ET mediante la aplicación de tres principales fases para cada iteración de desarrollo del sistema. Las pruebas de usabilidad e integración fueron realizadas por el investigador con el fin de presentar versiones avanzadas para las pruebas de usabilidad. Según (Florián et al., 2010) recabar información de usabilidad usando conceptos binarios no clarifica la verdadera facilidad de uso del software. Por lo cual se propuso una tabla de comentarios (véase Apéndice A) que, aunado a una valoración cuantitativa establecida por el investigador permite realizar observaciones que potencien el análisis del sistema y por consiguiente enfoquen los requerimientos de la siguiente iteración para mejorar la capacidad del sistema para su fin planteado. En la segunda iteración se aplicó una Tabla de Verificación de Pruebas y Secuencias (Véase Apéndice B) que, además de comprobar el seguimiento del proceso experimental también recogió observaciones del uso del software por parte del investigador, así como los comentarios que el participante realizó al usar el sistema en tiempo real en un intento inicial para establecer una relación entre la objetividad de los datos biométricos con la subjetividad de los comentarios de cada participante.

5. Resultados

Gracias a la utilización de las herramientas de *Tobii Pro Lab* fue posible acceder a las métricas y patrones del participante mientras realizó la prueba. Para comparar objetivamente el grado de utilidad de cada elemento y por ende, del diseño en general se extrajeron los mapas de calor de las fijaciones que cada participante realizó sobre la disposición de estudio que le fue asignada con el fin de filtrar los niveles de atención visual para cada diseño planteado (Figura 7). Para cuantificar el nivel de utilidad y uso a través de la prueba se generó la Figura 8 dónde es posible consultar el número total de visitas a cada elemento de las disposciones.

Con el fin de establcer una relación entre la capacidad de los elementos para brindar información de valor con las respuestas generales de las disposciones se implementó una Tabla de Respuestas y Tiempos de la prueba (Véase Apéndice D), dónde para fines de éste trabajo no se revisó a fondo la redacción de los dos aspectos que se solicitaban para dar una respuesta correcta y compelta del ejercicio, en su lugar, se tomó como base la presencia del par de aspectos solicitados por el ejercicio para inferir el grado que cada disposición cuenta para desplegar toda la información necesaria para una respuesta. El primer aspecto (expresar conjuntos D, S, C y T) fue registrada en 5 de las 10 pruebas. El segundo aspecto solicitado (operación de conjuntos necesaria para obtener el área resaltada de color verde) fue expresado en 8 de las 10 pruebas mientras que en sólo 4 de las 10 se expresaron ambos aspectos solicitados en el ejercicio.

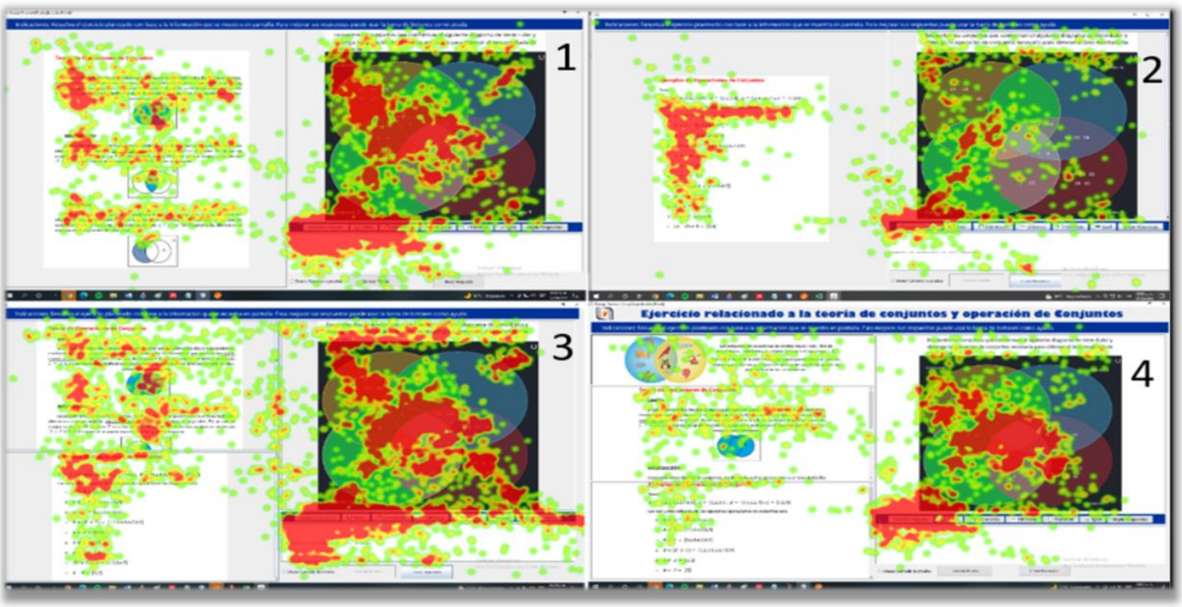
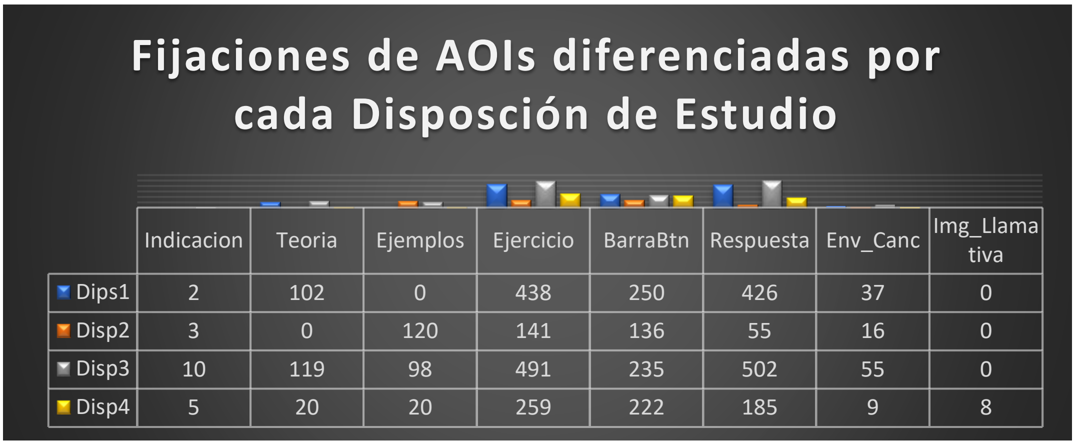


Figura 7: Mapas de Calor del Conjunto de Disposiciones
(Fuente: Elaboración Propia, 2022)



	Indicacion	Teoria	Ejemplos	Ejercicio	BarraBtn	Respuesta	Env_Canc	Img_Llamativa
Dips1	2	102	0	438	250	426	37	0
Disp2	3	0	120	141	136	55	16	0
Disp3	10	119	98	491	235	502	55	0
Disp4	5	20	20	259	222	185	9	8

Figura 8: Conteo de Fijaciones a cada elemento filtrado por disposición.
(Fuente: Elaboración propia, 2022)

5. Discusiones

Con base en (Díaz Herráez & Varona, 2017; López Orozco et al., 2019; L. Martínez, 2021) se realizó un análisis interpretativo de los diferentes resultados de las pruebas. En la Figura 7 de mapas de calor es posible determinar que el contenido teórico de las disposiciones 1 y 2 fue altamente revisado a comparación de la disposición 3 que presentaba a la par los conceptos teóricos y ejemplos. La poca utilización de estos elementos al presentarse juntos indica que la memoria de trabajo a corto plazo comenzaba a saturarse al intentar manejar mayores volúmenes de información, por lo que se centró en el análisis del ejercicio desestimando en gran medida el uso de los contenidos teóricos. Apoyando esta teoría, al observar la disposición 4, que fue pensada para sobrecargar cognitivamente al participante, presenta el área resaltada de rojo (área con mayor cantidad de fijaciones) exclusivamente en los elementos de ejercicio, barra de botones y zona de respuesta.

Observando el uso general de las disposiciones se pudo inferir que la barra de botones no fue en su totalidad un elemento de relevancia al buscar métodos para expresar una respuesta. Aunado a la comparativa de elementos más visitados por disposición es que se plantea la hipótesis de que la memoria de trabajo “descarta” automáticamente elementos para tener capacidad de procesamiento libre. Analizando los patrones de mirada y estudiando trabajos como los de (Martínez Gutiérrez, 2008; Parodi & Julio, 2016) se puede inferir que la barra de botones no es percibida como un elemento útil para resolver el ejercicio después del primer escrutinio general de la mirada sobre la interfaz.

Cotejando lo anterior con las respuestas se puede deducir que la disposición 2 que mostraba únicamente ejemplos de conjuntos resultó ser una fuente muy pobre para expresar información relevante para el entendimiento del tema. Por otro lado, la disposición 3 que presentaba tanto teoría como ejemplos fue la que obtuvo la mayor ratio de cumplimiento de los requisitos solicitados por el ejercicio y con una mejor calidad de las respuestas. También es la que presenta una mayor concentración de atención visual dentro del ejercicio y las áreas más importantes de la prueba. Es por esto que la disposición 3 fue seleccionada como la mejor opción para añadir una barra de botones mejorada y en una mejor ubicación. Generando así una disposición de estudio base para una posterior investigación.

Gracias a la utilización de herramientas de seguimiento de mirada para analizar la usabilidad de un sistema se observaron ventajas importantes con respecto a métodos más convencionales de pruebas (como la tabla de usabilidad planteada en la primera iteración) o la continua implementación de mejoras por parte del desarrollador. El análisis de los datos brindados y el estudio del comportamiento en tiempo real y posterior análisis de datos cuantitativos permitieron inferir con una alta precisión la capacidad del sistema para ser usado conforme a su fin planteado. Tomando en cuenta lo anterior y combinándolo con la propuesta de desarrollar sistemas diseñados para la docencia, es importante destacar que este estudio hizo uso del software para presentar un único ejercicio, por lo tanto, las variaciones de la carga cognitiva fueron diferenciables. Sin embargo, la necesidad por nivelar la carga cognitiva con los elementos y diseño de la disposición por cada tema a impartir a nivel licenciatura presenta un gran reto para el diseñador de software.

6. Conclusiones

Debido que la capacidad de procesamiento del cerebro tiene mecanismos para evaluar la relevancia de los elementos en pantalla es evidente que la utilización previa de las herramientas permite inferir el uso de las mismas (Tarouco, 2006). Cuando un estudiante se enfrenta a una evaluación en un ambiente desconocido para él, provoca un esfuerzo cognitivo extra para lograr identificar los elementos de dónde pueda obtener más y mejor información útil. Aunado a la “desatención auto inducida” que resulta muy beneficiosa para la no saturación de la memoria de trabajo, pero complica notablemente los estándares para el diseño de evaluaciones en medios digitales.

Dado que en el particular caso del área de las matemáticas la mayoría del contenido esquematizado, es decir aprendido, por el estudiante es producto de la presentación del docente es preciso fomentar la aplicación de herramientas de comunicación de conceptos desde la etapa de la impartición de los temas. Mientras el alumno más se relacione con las herramientas para expresar conceptos matemáticos más fácil le será relacionarlo con los temas vistos en clase. El uso reiterativo de las herramientas y su aplicación en la respuesta ayudan a identificar al estudiante los elementos más importantes incluso si son excluidos del primer recorrido de la mirada mejorando así tanto su interacción a través del canal cómo la aplicación del conocimiento a evaluar.

Esta investigación se centró en generar una primera aproximación a la aplicación de tecnologías biométricas en procesos de ingeniería de software para garantizar la calidad del producto. Para trabajos futuros se plantea expandir las capacidades del sistema propuesto para diseñar evaluaciones de diversos tópicos matemáticos mientras que se crean escalas como cantidad de reactivos, complejidad asociada al tema, dificultades para representación de notación, resultados de pruebas de usabilidad objetiva, entre otros para mitigar los efectos negativos de la carga cognitiva en el estudiante al ser expuesto a los elementos de cada disposición.

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Apéndice

Apéndice A: Tabla 1: Tabla propuesta para análisis de usabilidad.

https://1drv.ms/b/s!AtWNvmUnuxWzgZoylosts8J8F6wPEw?e=UXXj70

Apéndice B: Tabla 2: Tabla propuesta para verificación de pruebas y secuencias.

https://1drv.ms/b/s!AtWNvmUnuxWzgZox9pyiO2Yka81Neg?e=LwfE2w

Apéndice C: Tabla 3: Tabla propuesta para Respuestas y Tiempos de la prueba.

https://1drv.ms/b/s!AtWNvmUnuxWzgZowyHFNP-Rp6WhhDg?e=nhWwiE

Apéndice D: Repositorio Consentimiento Informado, Herramientas y Ficha Técnica.

https://1drv.ms/u/s!AtWNvmUnuxWzgZ1TWhyklwD0M2jQNw?e=XowdiF

13. Factors influencing the adoption of knowledge protection strategies by Australian SMEs in the Construction sector

Mandeep Dhindsa
Victoria University
Australia
Mandeep.dhindsa@live.vu.edu.au

Abstract

Small and medium sized enterprises (SMEs) are major contributors to economies. The construction industry sector is one of the largest contributors towards Australian GDP. This is a sector that has many small businesses who are required to share knowledge as part of their collaboration with business partners and suppliers. In some instances, this necessitates the protection of organizational knowledge to help construction SMEs to sustain competitive advantage and/or inhibit the leakage and spillover of critical knowledge outside the business. However, SMEs in 'low-tech sectors (such as the construction sector) do not typically pay much attention to the implementation of knowledge protection (KP) strategies. Thus, this study has identified factors that potentially influence KP adoption in construction SMEs, and the types of KP strategies they adopt. Qualitative semi-structured interviews were conducted with four SMEs in a metropolitan area of Australia. An important result of the study is the identification of the extent of KP strategies and their enablers and barriers. Various organizational factors (sector [in this case, construction], location, age, organisational structure) and SMEs characteristics (size, owner/manager characteristics, flexibility, relationships) are identified that can potentially influence the adoption of KP strategies in construction SMEs. The results suggest that size, age, flexibility, relationships and organisation structure impact KP adoption, as well as owner/manager characteristics which moderately impacts KP adoption. SMEs in general are inclined towards the implementation of informal and semi-formal protection methods, mostly due to the scarcity of the resources available to them.

Keywords: Knowledge management, Knowledge protection, Small and medium enterprises.

1. Introduction

The construction industry is Australia's third largest producing sector with around 8% of Australian GDP. It is mostly comprised of small and medium businesses (SMEs). Most construction business are sole operators with no employees (ABS, 2017). This is because of the traditional structure of sub-contractors in the sector. Hiring subcontractors is cost efficient for small businesses rather than hiring full time employees (AiGroup, 2015). Construction companies rely on knowledge sharing and collaborations with their business partners, which makes protection of their crucial knowledge (known as knowledge protection, or KP) critical. KP is one of the steps of knowledge management, and involves efforts made by an organisation to prevent knowledge "from being altered, transferred to other organizations, lost, or becoming obsolete" (Bloodgood & Salisbury 2001, p 57). KP assists an organisation to sustain competitive advantage, as well as protecting organisational knowledge from spill overs and leakages ('spill overs' being the exchange of knowledge among individuals and companies). Knowledge leakage is an unwanted knowledge transfer or deliberate or accidental loss of knowledge from an organisation to its competitors (Ahmad, Bosua & Scheepers, 2014; Annansingh, 2012). The smaller size of many construction businesses makes their use of KP more challenging (Estrada, Faems

& Faria, 2015) as the tools required for KP are often limited and costly (Päällysaho & Kuusisto, 2011). This study examines the factors that influence the use of KP strategies by SMEs. The study has the following research questions:

- What factors influence SMEs when adopting knowledge protection strategies?
- What strategies, if any, do SMEs use to protect their knowledge?

The study proposes a theoretical framework to examine these questions, using semi-structured interviews with Australian SMEs in the construction sector.

2. Knowledge Protection

KP strategies are broadly classified into three categories: formal, semi-formal and informal (Zins, 2007). Formal KP methods arise mostly from intellectual property protection legislation and are termed as 'formal' methods as they require legal authorization (Passi, Valkokari, Hytonen, Huhtilainen & Nysten-Haarala, 2012).). They are effective in protecting knowledge that can be codified and embodied in products and services, for example softwareOrganisations who produce new knowledge and innovative ideas apply for protection using these methods and government agencies evaluate the novelty of the knowledge and grant legal protection for exclusive use and licensing rights, usually for years (Olander, 2014). Examples of formal KP methods are: patents, design rights, trademarks, and copyright (which requires formal registration in some countries, but not in Australia, which makes it more of a semi-formal measure in that country). In Australia when something is documented then it is automatically protected under copyrights but if a design has to be commercialized then it can be protected under design rights (IP Australia, 2021). Informal methods of KP are methods which are based on companies' internal policies and processes rather than legislation (Passi et al., 2012). Informal methods of KP generally do not require extensive investments, validation or codification. The implementation of informal methods generally does not require special tools and technologies. These methods are often attractive to SMEs (Byma & Leiponen, 2006). They can be embedded into business routine operations. Sometimes organisations adopt informal KP methods without realizing it (Paallysaho & Kuusisto, 2011). Examples of informal KP methods are: authentication processes, authorization, cabinet locking, and division of work. Semi-formal methods of KP are methods that lie in between formal and informal methods. Examples are secrecy, restricting access to information and technical protection. The next section examines the factors that potentially influence KP strategies

2.2 Factors influencing knowledge protection

2.2.1 Organisational and other factors

KP strategies may differ across **industry sectors**. For instance, 'low-tech' sectors may be drawn to informal KP methods. Bolisani, Paiola and Scarso (2013) examined KP in knowledge intensive business services and found that the rate of usage of KP methods was low across these sectors. There is a direct link between knowledge reuse and protection as companies providing customized services like accounting or other financial services employ KP more frequently than others. The geographic **location** of an industry may have an impact on its use of KP strategies. Although there is no study specifically focusing on the relationship between geographic location and KP implementation, there have been differences in the use of digital technologies by SMEs in metropolitan and rural areas (Galloway & Mochrie, 2005).

2.2.2 SME factors

Smaller sized businesses face a scarcity of resources like finances, time, infrastructure and skills to know if and how to introduce KP effectively (Soto-Acosta & Merono-Cerdan, 2008). As noted by Faria & Sofka (2010), very large businesses tend to adopt a wide range of KP strategies. Päällysaho and Kuusisto (2011) investigated Intellectual Property (IP) protection and management practices in small service firms in Finland and United Kingdom. The study found that small firms prefer informal protection practices over formal methods. Olander, Laukkanen & Heilmann (2009) demonstrated the challenges of retaining core knowledge and capturing value by SMEs in choosing between knowledge sharing and protection. According to Byma and Leiponen (2009), formal KP mechanisms go through lengthy application processes and also require extensive resource commitment. SMEs with lesser resources may not invest in implementing them. Small businesses also face resource constraints with regards to the use of digital technologies (Sellitto et al., 2016). This can impact on their ability to use digital technologies as part of their KP strategies. Another characteristic of SMEs is their **informal management** style, where the owner of the business mostly acts as the manager. Managers should typically conduct long term strategic planning and ideally select strategies to be implemented based on challenges being faced (Keramati & Azadeh, 2007). However, SMEs are typically short-term planners and conservative adopters of information technology, which often reflects the characteristics of the owner/ manager (Sellitto, Banks, Bingley & Burgess, 2016). It is reasonable to assume that KP practices will also be related to the characteristics of the owner/ manager. Another consideration is that small businesses are **flexible** (Burgess, Sellitto & Karanasios, 2009) which makes it easier for them to introduce KP practices. They do not have to go through lengthy formal procedures to change approaches and may find it easier to adjust. Finally, strong **relationships** between SMEs and their suppliers and collaborators also make it easier for them to share information, but to protect their unique ideas and innovation from imitation they require KP strategies. (Chesbrough, 2011). The factors that potentially influence KP strategies in SMEs are summarised in Figure 1.

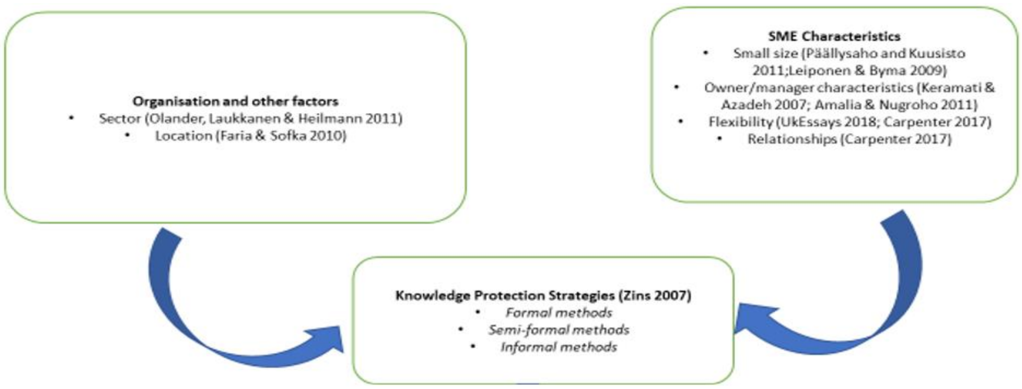

Figure 1: Proposed theoretical framework

3. Methodology

In this study, four selected SMEs are examined using semi structured interviews, which allow respondents to talk freely and let the conversation flow naturally (Hesse-Biber & Leavy, 2011). Interviews were conducted with the business owner/manager as SMEs do not typically have specific knowledge managers. Data was collected using various open-ended and on average each interview lasted for 45 minutes. Each interview started with some demographic questions first and then lead to questions targeted specifically on the research topic of Knowledge protection strategies such as what is age of the business, how many departments, what are the main services their business provide, whether they implement any protection strategies or not, if yes, then what protection strategies are adopted and why? Interviews help the researcher to understand respondent's perspective and seek in depth understanding through repeated interactions (Taylor & Bogdan, 1984). Also, semi structured interviews are the ability to rephrase or change the order of questions as required. For each interview, notes were taken by the researcher and each interview was written up and converted into a separate MS Word document. The researcher examined each interviewees' comments and classified them into themes matching the different sections of the research framework. For instance, comments made that related to business size were included in the business size discussion.

	Size (employees)	Departments	Type of Services	Age (years)
CON1	4	3	Multi-Unit Development, Knock Down, Rebuild residential/ commercial buildings	1.5
CON2	4	4	Multi-Unit Development, Knock Down, Rebuild single and double story buildings	1.5
CON3	19	7	Multi-Unit Development, Knock Down and Rebuild projects, Home & Land Packages and financial assistance.	9
CON4	150	9	Multi-Unit Development, Knock Down and Rebuild projects, Home & Land Packages, financial assistance.	36

Table 1: Detail of Construction sector cases

There are three main areas in construction: engineering construction, non-residential building, and residential building. This study has selected enterprises mainly working on the area of residential building. Residential building means any building which provides more than half of its floor area for dwelling purposes. They may or may not include cooking facilities. Some examples are houses, lodging rooms and apartments etc.

The study conducted interviews with four businesses in the construction sector. Two businesses were medium sized and the other two were small businesses. As Table 1 suggests, the small businesses were quite new in the market whereas the medium organisations were in operation between nine to 35 years. As the study has only interviewed four SMEs, data saturation has not been reached. However, at this stage the purpose of the study was to build theory (develop the research framework to be empirically tested at a later stage). This paper reports on the initial step of checking to see if the framework can be applied in 'real life' businesses.

4. Results

This section presents the findings for the four businesses, arranged according to the identified factors that influence the adoption of KP strategies.

4.1 CON1

CON1 is a micro business with three employees working across three departments (administration, accounts and purchasing). Most of their construction work is subcontracted. The types of services provided by the METCON1 relate mostly to residential developments. Along with this the company also builds new houses (from land preparation to building construction). At the time of the interview the organisation was quite new in the market, having been in operation for just one and a half years. Most of the construction to that time had involved *residential construction* and some commercial construction services. Under residential construction the company undertakes houses and multiunit single and double story homes. The company also provides 'custom' builds.

The discussion now moves onto different aspects of the framework. Due to their smaller ***size***, CON1 preferred to implement informal protection mechanisms over formal methods as informal methods do not require big investments and training. The business also did not have any information technology (IT) department dedicated for the implementation of KP strategies. Hence, the strategies are performed on a regular basis and are embedded in their regular business practices. The manager commented that "we do not need extra money to put a password on our computer and it's something we can do ourselves". Because of their small size the business cannot invest in extensive formal KP methods. Also, their small size requires them to share information across departments for seamless operations and let their employees cover a wider range of tasks by easily switching from one role to another. The ***owner manager characteristics*** also impacted the adoption of KP strategies as the owner of the business has a qualification in IT. He is capable of reaping benefits of informal protection mechanisms that can be embedded into routine business practices. The ***flexibility*** offered by CON1's size played an important role in the adoption of KP strategies. With only four employees the introduction and adoption of new strategies was an easy process. Thus, their size made it easier to introduce new KP strategies. As the manager said, "We can adopt new knowledge protection strategies as the demand arises, with only a few employees it is easy for us to update our strategies."

CON1 works closely with other SMEs in construction and aligned sectors (such as plumbing and painters), as well as with the suppliers of their raw materials. As they are relatively new to the market and still establishing their business, they also hire services from external SMEs. To build rapport and trustworthy ***relationships*** they are required to share some of their organisational knowledge with their suppliers and collaborators. This requires them to adopt and use protection methods against possible knowledge leakage. But it has also been identified that they do not need to share confidential information with external partners. For instance, the manager noted that "external companies do not require access to detailed cost estimations." The business operates in a ***sector*** where they provide customized residential building construction or construction based on existing in demand models. They build models of proposed developments in conjunction with client requirements. As the business is not developing them, these models are not protected by formal KP methods. The business relies on other informal means of protection such as authorization, authentication, cabinet locking, confidentiality, and trustworthy internal and external relationships. CON1 is a metropolitan based organisation and they do not have any non-metropolitan branches, so they are not affected by being in rural or remote ***locations***.The ***age of the business*** emerged from the data collection as having a major impact on the adoption of KP strategies. METCON1 is quite new in the market so their major focus is initially on establishing the business and strengthening their core activities. At the early stage of their growth, the business focus is to establish their 'roots' in the market and increase their customer base to make some revenue so they can later think of investing in other required strategies like KP. The manager commented that "we are too young to worry about any non-core business processes yet, At the stage our main focus is to extend our market share." The manager suggested that the business can protect explicit knowledge by implementing protection mechanisms such as passwords and restricted document access. CON1 uses a variety of informal methods like secrecy, restricted access, contracts and documentation. The manager noted that informal methods of protection do not require big investments and training. These strategies were performed on a regular basis and eventually embedded in business practices. The manager's educational background meant that he had studied about the layers of protection that can be implemented to protect organisation knowledge. He believes it is more effective to protect knowledge at different levels than using expensive protection strategies. For example, rather than applying for IP or trademarks, it is more economical to use a lock and a password.

4.2 CON2

CON2 is micro business. The business has four employees across four departments (administration, accounts, sales and purchase). It is a young business, only being in market for the previous one and a half years. Most of their work is in building residential buildings. The business mostly organizes several subcontractors to manage their construction work. This is to reap the benefits of specialized skill sets not possessed by existing employees. Their work requires a varied range of capabilities that is too diverse to be carried out by a single general contractor. The main services provided by the business are multi-unit development, knock down and rebuild single and double story buildings. However, most of their clientele is in new residential buildings under class 1A and 10.

CON2 has limited resources. The business's IT services are outsourced due to its small ***size*** and limited resources. Thus, the rate of usage of protection methods is quite low, especially usage of formal protection methods. The business wants to utilise the resources to establish the business first rather than focusing on the implementation of KP strategies. The manager indicated that they not currently be able to use their resources for such non-essential activities. Most of the business decisions are made by the *manager* of the company because of the small size and lack of hierarchical organisation structure. The manager of the business did not know much about the implementation of formal methods that he could use to protect company's knowledge assets but based on his earlier experience he believes that the early years of business can survive without focusing on the use of such protection mechanisms. The manager of CON2 said that, "I agree the company certainly requires KP for growth, but we must push the idea to the back of our mind because at this early age our focus is to establish ourselves and make better use of the revenues." The small size of CON2 provides much higher *flexibility* as compared to larger businesses. The business' flexible structure directly impacts its ability to adopt new business strategies including KP strategies. In the absence of strict organisation structural hierarchies, the manager can adapt KP strategies as needed without requiring formal approvals: adding that their "simple organisational structure enables easy adoption of new strategies, so if the need arises, we will start looking into protection strategies more seriously."

CON2's manager believes in sharing knowledge with other businesses in the sector where appropriate, even competitors as exchanging knowledge enables them to create new knowledge. The knowledge exchange and external business ***relationships*** imposes the threat of knowledge leakage along with providing ways to learn and grow. This calls for the implementation of KP strategies. But the business relies on working with other businesses that that they can trust will not leak their trusted knowledge, as the manager stated, "that trust is something we highly rely on." CON2 usually deals in construction based on existing 'in demand' models borrowed from other businesses. Every business in this industry ***sector*** publishes their designs online and other business can get inspiration and develop their own display properties from these. When clients approach the business with a particular design they like, the business suggests the changes and add-ons that can be added to the selected design. As the ideas are borrowed from existing market designs, they do not need to invest in formal protection methods. Another reason for not extensively using formal protection methods is their provision of customized designs for clients, and clients bring their designs and the business is only responsible for the construction without worrying about knowledge spillovers. The manager confused knowledge with information (which happened often with the interviews in this study as, despite the difference being discussed, interviewees did not differentiate between knowledge and information for SMEs. He commented that, "The type of information that could be protected is about their expenditures, sales and profit margins and this information could be easily kept in a safe place without requiring any formal protection method." CON2 mostly operates in metropolitan areas. The physical ***location*** of the business does not seem to have any impact on implementation of KP strategies. The current KP methods can be either implemented remotely (like file privileges) or can be building specific (cabinet locking), independent of the location. The manager mentioned that, "I believe that the adoption of KP strategies depends more on the business needs and resources rather than where its situated."

The ***age of the business*** seems to impact its ability to adopt KP strategies. The young age and less exposure have forced the business to focus on their core business activities and use their resources to expand and strengthen the business. The owner stated that, "As said earlier, I agree that the age of the business impacts the adoption of KP strategies. At this stage its more important for the business to establish itself by focusing on core business processes. It is not economical for us to spend our resources somewhere else." CON2 has only invested in informal and semi-formal ***protection methods*** like restricted access. Laptops are password protected and the documents are secured in locked cabinets. Knowledge sharing requirements of the business are secured with authorization and fragmentation of work. The owner of the business stated that, "the shared documents are mostly provided with read only rights, spreadsheet data is protected with data validation and locking mechanisms provided within the software" Hence, the business does not see the need for any formal protection mechanisms yet. The business uses informal methods as they are more like daily operational requirements rather than a rigid protection mechanism. Methods like passwords, user privileges, fragmentation of work usually does not impact collaborations and partnerships.

4.3 CON3

CON3 has ten departments and around 20 employees. The main departments are: sales, accounts, building coordination, estimating, construction, design, maintenance, administration, finance, and project management. CON3 is a well-established business with nine years in operation. The business has a web presence which enables their customers to find out about them. The main types of services provided by the business are residential. Generally, most new houses are built by property developers. CON3 operate in a similar manner, buying land when it is released by the government, building homes, and selling them as a complete house and land package. The business also organizes financial assistance for customers. They assist their clients to establish trusted partnerships with legal advisors and financial institutions to make obtaining a home loan easier for them. This is a free service, provided to make the entire project of building a new home easier for their customers.

CON3 have a well-established market. However, the business is at the lower range of mid-***size*** companies in terms of the number of employees. The business manager believes in the protection of organisational knowledge, but at the same time their limited resources (due to their size) inhibit them from the use and adoption of patents and trademark KP strategies. They believe that the process of acquiring formal protection methods is lengthy and costly which is why small businesses cannot afford them. The manager mentioned: "the business cannot indulge in the implementation of formal protection methods when it is more important to utilize the resources for our expansion." The ***manager*** of the business is responsible for its daily routine operations. The manager identifies the business needs and requirements based on his experience. He had previously worked and invested in few different businesses. The learning and experience gained from working across industry sectors enabled him to use his knowledge and experience in identifying, selecting and implementing protection strategies. He added, "as far as my experience various businesses survived competition without the need to invest in patents and trademarks." The ***flexibility*** offered by the small size of the business enables them to adopt varying business policies across their client base. The smaller size and the business manager being solely responsible for making major business decisions, enables CON3 to introduce and adopt protection strategies as per their need and requirements. The owner observed that sector is an industry ***sector*** where designs, architectural plans and diagrams are openly shared in the digital world. Businesses make their designs available on websites, use social networking for marketing and this makes it difficult to protect them.

The business believed that the roles of different departments and their flow of information has some inbuilt informal protection mechanisms due to adopted organisation structure of this business. Not all departments work with similar knowledge so access can be restricted within functional boundaries. They do not need to implement strict security measures that may slow down knowledge access across departments. CON3's manager did not believe that ***location*** had any impact on the use and implementation of KP methods. Their business operates in the metropolitan region and in some rural areas. No differences were reported operating from these different locations, as the remote access to the centralised database (with the same restrictions) enabled the business to follow the same informal and formal protection mechanisms in their regional offices. The ***age of the business*** is believed to be a factor that has a direct impact on the use and adoption of KP strategies. The manager felt that at the earlier stage every business has a smaller knowledge base which require lesser protection mechanisms in place but as the business grow so does their knowledge base. The manager commented that, “We might invest into patents once we grow more mature and start inventing our own designs and products.” With the growth in the business strategies and acquisition of knowledgeable resources the need for extensive protection methods might also expand. CON3 uses design rights to protect their business knowledge, as well as a mixture of semi-formal and informal methods, such as: copyright, secrecy, restricted access, contracts and documentation, fragmented division of labour and access privileges. Organisation structure also impacts the adoption of ***KP*** strategies. Hardcopy documents are kept to a minimum, and important files are mostly kept in digital format in a password secured system. Large, important projects are under restricted access. All soft copies are password protected. Architecture blueprints, any new design ideas and sketches are protected under copyright. The manager believes that copyright is a weak protection method as people today can easily edit images, remove copyright symbols, and use them as their own: “we don’t really know how we can track the access and usage of our images in this digital world.” The business has not invested in specific KP strategies for tacit knowledge. Contracts and documentation contribute towards KP. They also rely on state government authorities/ tribunals to deal with disputes/ complaints with suppliers, partners, and customers.

4.4 CON4

CON4 is a part of a large group of companies and is a well-established business, 36 years in operation and has built over 2,000 houses in Australia. The selected business is a franchise business. The company best fits the definition of a large medium business with around 150 employees and eight departments. The main departments are Sales, Operations, Construction, Maintenance, Displays, Interior Design, Human Resource, and Accounts. The company has offices in various states of Australia. The major type of construction services provided by the business are residential. CON4 belongs to the ***SME*** sector but believes strongly in organisational KP. Building over 2,000 houses and with extensive customer base, the business makes larger profits than most other smaller businesses in the sector and can thus invest in adoption of KP strategies. The business believes that “it doesn’t matter if you are a big business or small, it is important that every organisation employ protection strategies.”

The ***manager*** of the business has more than 40 years of experience. He has owned and operated his own construction company in the past. He is not only qualified in business management, and marketing but also holds a certificate in contract law. His knowledge and experience enable him to understand, analyse and adopt KP strategies according to business needs. The business has a group of subsidiary businesses to fulfill all necessary construction requirements of their customers. The size of the business does not offer much ***flexibility***, however the organisational structure and availability of different websites for each business group enables efficient adoption of KP strategies. Each business group can have their choice of KP strategies implemented depending on their needs and structure. The manager added that, “being a franchise we are legally bound with the company policy and procedures but still our small size and flexible organisational structure allows us to implement our own protection mechanisms internally.” CON4 is a business comprising various business groups and has a large database of contractors. They do not just have to maintain strong and trustworthy ***relationships*** with all their inter-organisational groups but also with external business partners. One of the most important things to build such relationships and grow the business is knowledge sharing within and outside organisational boundaries. Whilst sharing knowledge, specific attention is paid to the level and extent of knowledge that is shared.

In the construction industry ***sector***, the business processes, designs and ideas are remarkably similar and thus do not require extensive formal protection. The manager commented that, “Every business should protect their organisational knowledge. The only thing which differs is the type of knowledge you are protecting in different sectors. And knowledge is an important asset for every business organisation." CON4 utilises the digital world to advertise its services to potential new customers. In addition to their business website, they also have individual websites for each of their group of companies. The business also uses other means of digital networking such as social media. Their web presences enable their customers to do research on them, select designs and contact them for quotes. This helps in extending their business and attaining customers, but also poses security threats in the digital world. Competitors can access their online information, but the business is not concerned about knowledge leakage as such access does not give away any vital organisational knowledge. The participant commented "We are in an open business and there is no harm in sharing design ideas. Accessing pictures will not give any information about how specific business operations are performed. They are just static pictures." The ***location*** does not appear to have a significant impact on the adoption of KP strategies, but this is difficult to determine from the results. Due to their long ***time in the business***, CON4 has established a strong customer base. Working as a group of companies for a long time, sharing knowledge and working with contractors enabled them to learn about newer and more efficient protection mechanisms. Over time they have learnt that instead of using expensive and time-consuming protection mechanisms it is important to use multiple layers of informal and semi-formal protection methods. The ***KP strategies*** adopted by CON4 are copyright, secrecy, restricted access, contracts and documentation, fragmented division of labour and access privileges. There is functional division of work across departments and the business makes effective use of restricted access and fragmented division of labour across departments along with authentication and authorization. Registered design rights are the preferred formal way to protect the business designs.

5. Discussion

The results support the notion that Australian SMEs in the sector generally do not invest in formal KP strategies. The main KP strategies implemented were a mix of informal and semi-formal mechanisms such as secrecy, restricted access, authentication, authorization, cabinet locking and documentation. Table 2 provides an insight into the findings and data analysis.

The results suggest that the implemented protection strategies are impacted by the smaller size and revenues of the business. Formal protection methods require large investments and long processing times which is a constraint for most of the SMEs. Only two of the businesses (CON3 and CON 4) use design rights to protect their construction designs as they are comparatively larger than CON1 and CON2 and also have more market exposure and financial resources. The findings were very similar to the study performed by Leiponen and Byma (2009), which identified that the smaller firms with lesser resources do not invest in formal KP methods because of lengthy application processes and extensive resource requirements.

Category	Factor	Business				Overall
		CON1	CON2	CON3	CON4	
Organisation and other factors	Sector (construction)	Moderate	Moderate	Moderate	Moderate	Moderate
	Location	Not sure	Unsure	No impact	No impact	Unsure

	Age (in years)	Yes	Yes	Yes	Yes	Yes
SME characteristics	Small size	Yes	Yes	Yes	Yes	Yes
	Owner/manager characteristics	Moderate	Minor	Yes	Yes	Likely
	Flexibility	Yes	Yes	Yes	Moderate	Yes
	Relationships	Yes	Yes	Moderate	Yes	Yes
KP Strategies adopted (informal; semi-formal; formal)		Mostly informal	Mostly informal	Mix of formal, semi-formal, informal	Mix of formal, semi-formal, informal	Mix of semi-formal and informal

Table 2: Findings and analysis

The owner/manager characteristics seems to have a moderate impact on KP adoption as they have different experience, knowledge and skill set. Also, their flexible organisational structure allows them to adapt their protection mechanisms to respond to changes in organisational policies and strategies. Flexibility enable these businesses to change organisational policies and procedures without going through a formal procedure. Relationships with external partners and suppliers seems to have a considerable impact on the adoption of KP strategies. As SMEs relies on these external businesses to perform their core business processes efficiently. They mostly use outsourcing to get their work done by contractors. The external knowledge exchanges require protection against accidental knowledge spillovers. It can also be said that the industry sector likely impacts the selection of protection methods. The construction sector operates like an open business where ideas are easy to access and copy. Internet and social presence have made the information available at ‘one click’ which influences the business’s decision in the adoption and implementation of KP strategies. Even the designs that are protected with design rights are susceptible to theft. The competitors are required to change only 20% of the design before they are legally allowed to use someone else’s registered design. So even though the design ideas can be replicated, the services provided are very hard to replicate and/or copy illegally, so this does not require strict KP which coincides with the findings of the study performed by Xu and Tan (2010). The age of the business has a role to play in the adoption of KP strategies. New businesses concentrate more on expanding their business by sharing and collaborating with internal and external business partners rather than protecting their organisational knowledge. So, instead of investing in costly and time-consuming formal methods SMEs are more inclined towards informal and semi-formal protection methods. Päällysaho and Kuusisto (2011), also concluded that small businesses prefer informal methods over expensive formal methods in their study performed on small service firms in Finland. It was not evident from the findings if the location of the business impacts the KP adoption as most of the selected businesses operate in metropolitan regions. Those that did have rural operations did not find much difference in KP strategies. Informal and semi-formal protection strategies are not highly impacted by the availability of ICT tools.

The businesses believed that both formal and informal ways of protection are important to protect knowledge spillovers and attain competitive advantage. However, their smaller size and limited turnover had mostly restricted them to informal mechanisms. They certainly require KP for growth, but at their early age their focus is to establish themselves and make better use of their revenue. Once the businesses start innovating new ideas and plans, then they plan to invest in more formal and stronger protection strategies. For instance, CON3 and CON4 use design rights to protect their architectural blueprints and designs. Overall, it can be said that the results generally support what was stated in the literature, but some factors seem to have a greater influence on KP strategies than others. There were enough common answers across the businesses to suggest that some of the findings could potentially be specific to the sector.

6. Conclusion

This paper has summarized the factors impacting the adoption of KP strategies by SMEs. Four Australian SMEs in the construction industry sector were interviewed to gather data and identify their adopted KP strategies. The construction industry has been one of the highest GDP contributors towards Australian economy, so it was worth investing them. Various factors such as size, Owner/manager characteristics, flexibility, relationships, sector, age and other SME characteristics have been identified as factors effecting K adoption. The protection mechanisms were categories into three categories: formal, informal and semiformal protection strategies. The results have shown that generally SMEs are inclined towards informal and semi-formal protection methods due to their smaller size (flexibility and relationships), limited resources and age of the business. At present the biggest limitation of the study is in terms of data saturation and case study focused on one industry sector. In the next phase of the study the data collection will be extended to more industry sectors and regional areas to investigate if location and industry sector have any significant impact on KP adoption.

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14. How Top Managers Utilize Dynamic Capabilities to Digitally Transform Their Business: Evidence from European Firms

Research-In-Progress

Dennis Renee Metzler
Chair of Financial Data Analytics
University of Augsburg
dennis.metzler@uni-a.de

Abstract

Digital Transformation remains one of the most important topics on the agenda of researchers and practitioners alike. The intelligent orchestration of existing organizational structures and new emerging digital technologies is vital to stay competitive in an increasingly digitalized world. Since a successful digital transformation needs specific competencies to adapt to rapidly changing environments through digitalization, the development and use of so-called dynamic capabilities plays an important role in the process of digital transformation. Whereas existing research primarily focuses on dynamic capabilities for digital transformation at an organizational level, this study sheds light on the use of dynamic capabilities at an individual level. By conducting a qualitative interview study with top managers of several firms across different traditional industries, this study aims to analyze the role of dynamic managerial capabilities in digital transformations and investigates how top managers utilize these capabilities to digitally transform their business. The preliminary findings of this research in progress paper indicate that dynamic managerial capabilities play an important role at the individual level of top managers and that managers use different ways of utilizing sensing, seizing, and transforming capabilities to orchestrate digital transformation. In that regard, this study provides various important implications for practitioners and researchers alike.

Keywords: Digital Transformation, Dynamic Managerial Capabilities, Top Managers, Qualitative Research.

1. Introduction

The rise of new digital technologies, such as smart connected devices and digital platforms, is incrementally affecting societies and businesses. To keep pace in an increasingly digitalized world, firms across industries and geographical regions need to undergo a substantial process of transformational change (Vial, 2019; Hanelt et al., 2021). Described as "*a process that aims to improve an entity by triggering significant changes to its properties through combinations of information, computing, communication, and connectivity technologies*" (Vial, 2019, p. 121), digital transformation remains one of the most relevant issues for researchers and practitioners alike. Since a successful digital transformation requires specific competencies to adapt to rapidly changing environments (through digitalization), the development and use of so-called dynamic capabilities play an important role in digital transformations (e.g., Konlechner et al., 2018; Warner & Wäger, 2019; Soluk & Kammerlander, 2021).

Dynamic capabilities can be defined as "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*" (Teece et al., 1997, p. 953). In information systems research, this theoretical construct is mainly used as a theoretical lens to find possibilities on how firms can best master conditions in turbulent circumstances, such as digital transformations (e.g., Konlechner et al., 2018; North et al., 2020). Nevertheless, research at the intersection of dynamic capabilities and digital transformation is still at an early stage. For example, Warner & Wäger (2019) investigate factors that influence the building and maintaining of dynamic capabilities for digital transformations. Vartiainen (2020) explores the influence of digital transformation on the development of dynamic capabilities. Other research examines the way how dynamic capabilities trigger and enable digital transformations (Soluk & Kammerlander, 2020; Marx et al., 2021; Matarazzo et al., 2021; Ellström et al., 2022) or how digital transformations can be managed with the use of specific dynamic capabilities (e.g., Iden & Bygstad, 2021).

All existing research at the intersection of dynamic capabilities and digital transformation have in common that they focus on dynamic capabilities at an organization level. However, another important focus-level of dynamic capabilities is the individual manager that uses these capabilities at an individual level (Adner & Helfat, 2003; Teece, 2012). These so-called dynamic managerial capabilities, which can be seen as an analogy to the more general dynamic capabilities at an organizational level, are defined as "*the capabilities with which managers build, integrate, and reconfigure organizational resources and competences*" (Adner & Helfat, 2003, p. 1020). Since existing research agrees that managers play an overriding role in the digital transformation of firms (e.g., Heavin & Power, 2018), further investigations on the role of dynamic managerial capabilities in the context of digital transformation are needed. To address this important research gap, the following research question was formulated: *How do top managers utilize dynamic capabilities to enable and drive digital transformation?*

To answer this research question, an in-depth interview study with top managers (mostly chief executive officers (CEOs)) of several incumbent firms active in various different traditional industries was conducted. By analyzing the role of dynamic managerial capabilities in digital transformations and explaining how top managers utilize these capabilities to digitally transform their business, the preliminary findings of this study extend the current knowledge at the intersection of (managerial) dynamic capabilities and digital transformation significantly.

The remainder of this work is structured as follows. Starting with the theoretical and conceptual foundations, the main concepts and theories of interest are introduced and brought together. Afterward, the methodological foundation of the conducted study will be demonstrated. This is followed by a presentation of first initial findings of the study. Finally, a conclusion including a discussion and a presentation of the next steps will complete this work.

2. Theoretical and Conceptual Foundations

Dynamic capabilities are derived from the Resource-Based-View and can be defined as "*the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments*" (Teece et al., 1997, p. 516). Over the last years, the body of literature concerning dynamic capabilities has increased significantly, especially in the strategic management and information systems literature (Steininger et al., 2022). Dynamic capabilities are a rather crude framework that explains a complicated issue; namely how a business can spot opportunities and execute them accordingly (Teece, 2007). They involve higher-level activities that enable a business to direct its ordinary activities toward high-payoff endeavors. To achieve this, firms must manage their resources to react to rapidly changing business environments (Teece, 2007; Teece, 2012; Teece, 2018). Dynamic capabilities are undergirded by micro-foundations, which include distinct skills, processes, procedures, organizational structures, decision rules and disciplines (Teece, 2007).

A more recent definition of dynamic capabilities states that these capabilities "*can be disaggregated into the capacity (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise's intangible and tangible assets*" (Teece, 2007, p. 1319). Consequently, dynamic capabilities can be divided into (1) sensing capabilities, (2) seizing capabilities, and (3) transforming capabilities (often referred to as reconfiguring capabilities) (Teece et al., 1997; Teece, 2007; Teece, 2012). Sensing new opportunities can be seen as a scanning, creation, learning, and interpretive activity, where organizations, for example, must explore new technologies and markets (Teece, 2007; Teece, 2012). Once new opportunities are sensed, they must be addressed through new products, processes, or services (Teece, 2007; Teece, 2012). This includes maintaining and improving technological competencies and dismissing established practices (Teece, 2007; Teece, 2012). Finally, transforming capabilities are needed to maintain an evolutionary fitness. This includes changing routines, which can be costly and lead to heightened anxiety within the organization unless the culture is shaped to accept high levels of internal change (Teece, 2007). In order to enable this, the redesign of routines should be crafted in a way that old and new practices can complement. The ability to recombine and reconfigure assets and organizational structures as markets and technologies change is a key to sustained profitable growth (Teece, 2007). The ability to sense, seize, and transform is multi-faceted, and firms will not necessarily be strong across all types of dynamic capabilities (Teece 2018). However, a firm with strong dynamic capabilities will be able to continuously innovate itself and respond to rapidly changing market environments.

Recently, research started discussing dynamic capabilities in the context of digital transformation (e.g., Warner & Wäger, 2019; Marx et al., 2021; Matarazzo et al., 2021). Existing research found that dynamic capabilities are an enabling factor for successful digital transformations by enabling firms to create a competitive advantage in quickly changing environments (e.g., Soto Setzke, 2020; Marx et al., 2021). Further, strong dynamic capabilities have the potential to shape a firm's proficiency at business model design by identifying unmet customer needs and specifying technologies that will address them (Teece, 2018). Interestingly, research at the intersection of dynamic capabilities and digital transformation only focuses on dynamic capabilities at the organizational level. However, existing research indicates that dynamic capabilities at the individual level of managers (i.e., dynamic managerial capabilities) can also play an important role in transformation projects of firms. For example, Basile & Faraci (2015) show that dynamic managerial capabilities serve as a basic requisite for organizational transformation processes. Further, dynamic managerial capabilities positively influence the development of organizational ambidexterity which is vital for information technology-driven organizational transformations (Gregory et al., 2014; Dahlmann & Grosvold, 2018; Nguyen, 2018). By approaching this research gap, this study aims at expanding existing research on dynamic (managerial) capabilities in the context of digital transformation and, thereby, pursues the claim of other researchers who have made calls for additional research to further investigate dynamic capabilities, for instance, in the context of business model innovation (Teece, 2018) and in the context of digital transformation (Vial, 2019).

3. Methodology

To analyze how top managers utilize dynamic capabilities to enable and drive the digital transformation of their business, an exploratory in-depth interview study was conducted (Myers & Newman, 2007). The advantage of such studies is that they directly focus on the topic under investigation. Further, interview data provides more sensitive information than publicly available documents. Figure 1 gives an initial overview of the methodological approach.

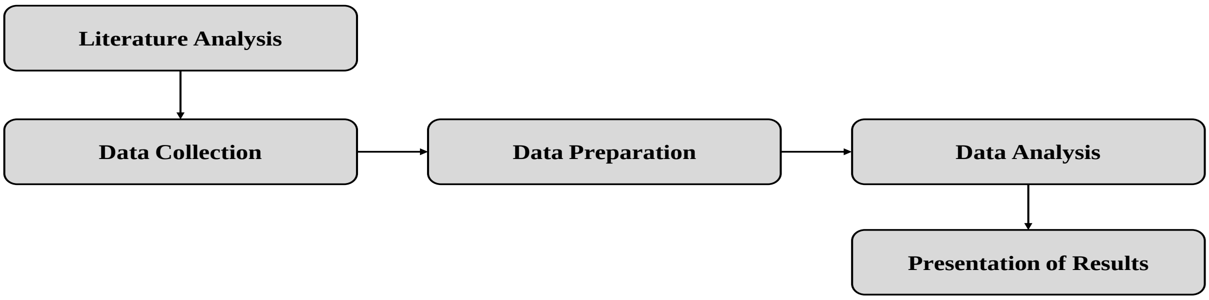

Figure 9: Overview of Methodological Approach

Inspired by the extant literature on digital transformation (e.g., Vial, 2019; Hanelt et al., 2020) and dynamic capabilities (e.g., Teece et al., 1997; Teece 2007; Teece, 2012), a semi-structured interview guideline was developed. This guideline aimed at nudging the interview partners to reflect on the digital transformation processes within their firms, whether they have specific dynamic managerial capabilities at all, and how they utilize these capabilities to enable and drive digital transformation in their firms.

#	Job Title	Industry	Age (years)	Revenue (EUR)	Length (min.)
1	CEO		> 20	> 1 mn.	50
2	CEO		> 45	> 10 mn.	40
3	CEO	Automotive	> 35	> 5 mn.	60
4	CEO		> 40	> 5 mn.	50
5	Head of IT		> 50	> 100 mn.	80
6	CEO		> 120	> 1 mn.	80
7	CEO		> 25	> 1 mn.	60
8	Transformation Officer	Manufacturing	> 30	> 100 mn.	45
9	CEO		> 100	>1,000 mn.	60
10	Strategy Officer		> 70	> 600 mn.	70
11	CEO		> 40	> 500 mn.	70
12	CEO	Industrial Services	> 60	> 1 mn.	65
13	CEO		> 20	> 25 mn.	50
14	CEO		> 20	> 1 mn.	90
15	Head of Digitalization	Pharma & Life Science	> 20	> 10 mn.	55
16	CEO		> 20	> 1 mn.	55
17	CEO	Consumer & Retail	> 35	> 5 mn.	55
18	CEO		> 75	> 5 mn.	65
19	CFO		> 200	> 100 mn.	80

Table 7: Overview of Conducted Interviews

As illustrated in Table 1, the sample of this study comprises interviews with 19 top managers. Thereby, a wide bandwidth of different viewpoints of top managers from different firms and industries is included. All interviewees are active as a chief executive officer (CEO) or in a similar position in the top management team with a minimum of five years experience in their current position. The case firms are all pre-digital firms (i.e., established before the digital revolution with a business model which is not originally based on the use of digital technologies). Further, all case firms are active in a traditional industry (i.e., an industrial-age industry). Finally, all case firms have a minimum revenue of one million euros. Hence, this study does not only focus on large firms, but also considers small and medium-sized firms. This broad bandwidth of firms and industries allows making statements on a cross-firm and cross-industry level. All firms operate worldwide and have their headquarters in Europe (primarily in Germany).

The interviews were conducted either virtual or face-to-face. Each interview was transcribed and uploaded to the qualitative data analysis software MAXQDA. Within the scope of data analysis, a qualitative content analysis was conducted in a two-step approach as a mixture of deductive and inductive category development. The theory of dynamic capabilities served as the main theoretical framework for the data analysis. In a first step, the role of dynamic managerial capabilities in the digital transformation of the interviewees' firms was analyzed in a very general manner. To this end, the interview transcripts were analyzed with regard to statements referring to dynamic managerial capabilities. These statements were assigned to the specific dynamic capability (i.e., seizing, sensing, transforming capability). Consequently, the three specific dynamic capabilities served as main categories. The second step included analyzing how the specific dynamic capabilities are designed and how the interviewees utilize each capability in the context of digital transformation.

4. Preliminary Findings

An important finding of the qualitative content analysis is that all of the interviewed top managers have dynamic managerial capabilities and use them (either consciously or unconsciously) to enable and drive digital transformation. The initial findings additionally indicate a highly relevant role of dynamic managerial capabilities in the process of digital transformation. Further, the results show that all three specific types of dynamic managerial capabilities are of great importance for managers to enable and drive digital transformation. Table 2 illustrates the main characteristics of each capability. It gives a first impression on how top managers utilize dynamic managerial capabilities to enable and drive digital transformation.

<table>
<tr><th>Capabilities</th><th colspan="12">Characteristics</th></tr>
<tr><th>Managerial Sensing Capabilities</th><td colspan="3">Engaging in open exchange with different parties</td><td colspan="3">Actively tracking industry and market developments</td><td colspan="3">Actively pursuing digital transformation-related self-education</td><td colspan="3">Transferring relevant insights from private life to business</td></tr>
<tr><th>Managerial Seizing Capabilities</th><td colspan="4">Formulating and selecting the right endeavors for digital transformation</td><td colspan="4">Mobilizing resources to enable digital transformation</td><td colspan="4">Providing the necessary work environment to build commitment and loyalty concerning digital transformation</td></tr>
<tr><th>Managerial Transforming Capabilities</th><td colspan="6">Transforming mindset and culture towards developing new digital transformation-driven business model configurations</td><td colspan="6">Providing open innovation and cross-collaboration to enable digital transformation</td></tr>
</table>

Table 8: Overview of Dynamic Capability Utilization of Top Managers Towards Digital Transformation

Managerial Sensing Capabilities: The initial findings indicate that top managers utilize managerial sensing capabilities in four different ways to enable and drive digital transformation. All sensing capabilities are mainly about identifying opportunities for digital transformation. Managers ideally do not only focus on a single capability, but rather combine all four capabilities into their working routine. Engaging in open exchange with different parties, for example, means cross-hierarchical exchange with colleagues, intensive exchange with customers, and utilizing cooperation with academia. Actively tracking industry and market developments means tracking industry developments and tracking direct and indirect competitors. Actively pursuing self-education can be done by following the press, attending seminars, and teaching things autodidactically. Transferring relevant insights from private life to business means following trends within the private life and exchanging with befriended entrepreneurs and executives.

Managerial Seizing Capabilities: Once sensed, opportunities should be seized. In that regard, three different seizing capabilities could be identified. Formulating and selecting the right endeavors for digital transformation is about precisely assessing added value for the firm's business model, internally discussing opportunities among relevant stakeholders, and using work shops and agile methods to identify value. Mobilizing resources to enable digital transformation means creating task forces to pursue opportunities, utilizing internal and external expertise, and establishing idea generation and management processes. The necessary work environment can be provided by involving affected staff to provide solution input, reducing complexity in ideating processes, and reducing fear of staff.

Managerial Transforming Capabilities: Finally, two main activities how top managers utilize transforming capabilities in the process of digital transformation could be identified. First, top Managers need to transform mindset and culture towards enabling digital transformation. This is done by promoting the use of new methods (e.g., agile), embracing a culture of trial and error, and removing old and antiquated ways of thinking. Second, the provision of open innovation and cross-collaboration is done by embracing cross-collaboration within firms and balancing personal contact and increasing digitalization.

5. Conclusion and Next Steps

The initial findings of this research in progress paper show that top managers use a broad range of dynamic managerial capabilities to pursue the digital transformation of their firms. Further, the initial findings illustrate how specifically top managers utilize these capabilities. However, this study is not completed yet. The next step aims at diving deeper into the data to gain a better understanding how top managers utilize dynamic capabilities and to precisely link the interview data to the final results. Another goal is to analyze whether there exist different circumstances in which specific utilizations of dynamic capabilities are more appropriate than others. The final goal of this study is to derive a skillset for top managers that helps to understand which skills are needed to utilize dynamic managerial capabilities in order to enable and drive digital transformation.

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16. It Loves Me... It Loves Me Not: Towards Implementing Artificial Love in Companion Robots

Priya Asse
INSA Rennes
Rennes, France
priya.asse@insa-rennes.fr

Miguel Vargas Martin
Ontario Tech University
Oshawa, Canada
miguel.martin@ontariotechu.ca

Abstract

We describe our prototype implementation of Chapman's theory about the five love languages into a humanoid robot. This implementation has the objective of fostering a relationship that nurtures love, and that could lead to the human feeling loved by the robot. This special bond could potentially serve as a non-pharmacological intervention to aid in patients' treatment or wellbeing during prolonged hospitalizations. At the same time, the robot could monitor the patient in case abnormal behaviour is detected such as anxiety or depression.

Keywords: Artificial Love, Love Languages, Companion Robots.

1. Introduction

As described by Jin and Kim (2019), a nurse would expect that the robot become friends with the child patient, and encourage the child to cooperate with the caregivers. The robot can also help reduce the child's fear of hospitals and caregivers. We speculate that a robot featuring artificial love could contribute to such expectations. We use the five love languages theory of Chapman (Chapman, 2009). Chapman claims that humans have five ways to express love to another human: acts of service, physical touch, words of affirmation, quality time, and gift-giving. Our project consists of building a prototype and a methodology to implement these languages into a robot; in our case, the Asus Zenbo robot (see Figure 1). We have chosen this robot because, as described in (Roland, 2021), Zenbo is one third human and two thirds machine, so the child can feel that they are interacting with a machine that is capable of love, and understand them like a human, although fully aware that it is not a real human and the love in it is only artificial. The robot comes with built-in artificial intelligence functions, including natural language processing, which we use to make our prototype able to speak and understand the five love languages in a natural (as possible) exchange with a human.

2. Related Works

We have chosen to make a loving robot, because as the research of Payne (2006) points out, when someone is loved, their wounds are going to heal 60% faster. And if the child heals faster, they are likely to spend less time in the hospital. Also, in their study, Sanson and Lobefalo (2021) claim that if we can bring love into the hospital, especially into the intensive care unit, we would be able to drastically improve the patient's experience. To implement that, we have chosen to use Chapman's (Chapman 2009) love languages, which have drawn the attention of researchers and readers in general since their first appearance back in 1992. Chapman built a model with five love languages: "act of services", "quality time", "physical touch", "words of affirmations" and "gift-giving".

Figure 1: Zenbo Robot

Two decades after, Nicole Egbert and Denise Polk (2006) conducted a study with 110 participants to try to validate Chapman's model. They compared three models, one with the five love languages, another one with only four combining the language's word of affirmation and time together. The third language had only three languages, as they combined together words of affirmation and quality time in one part and receiving gift and physical touch in another part. They concluded that Chapman's model was the best of the three models. A similar research with 410 participants was made in Indonesia by Surijah and Septiarly (2016) who came up with the same conclusion. Salas (2009) also validated Chapman's languages of love through a study involving couples in Spain.

Our choice to use the Zenbo robot was inspired by the work of Valle, Martin and Horsburgh (2021) who aimed at developing artificial empathy using Zenbo, as well as the work of Ritvik, Martin and Kritika (2022) who suggested an emotion recognition framework for the same robot.

3. Prototype

For our project, we used two development environments: the Dialogue Development Environment (DDE) Editor and the Zenbo App Builder. Both are tools provided by Asus to build applications that work on the robot.

3.1 Dialogue Development Environment Editor

The DDE Editor was used for the dialogue part, as depicted in Figure 2. The human sentence is categorized as an intent. The intent is a collection of sentences that convey the same idea. For instance, "yes" and "that would be lovely" can be in the same acceptation intent. This intent is going to trigger the plan that is linked to an action depending on the robot's state, thus determining the robot's response. For example, if the robot's state indicates that the robot has asked before if the human wants a joke, and the human says something that is in the acceptation intent, the robot will tell a joke to the human. For the same sentence, if the robot state indicates that the robot has asked before if it can tell a story to the human, it will then tell a story.

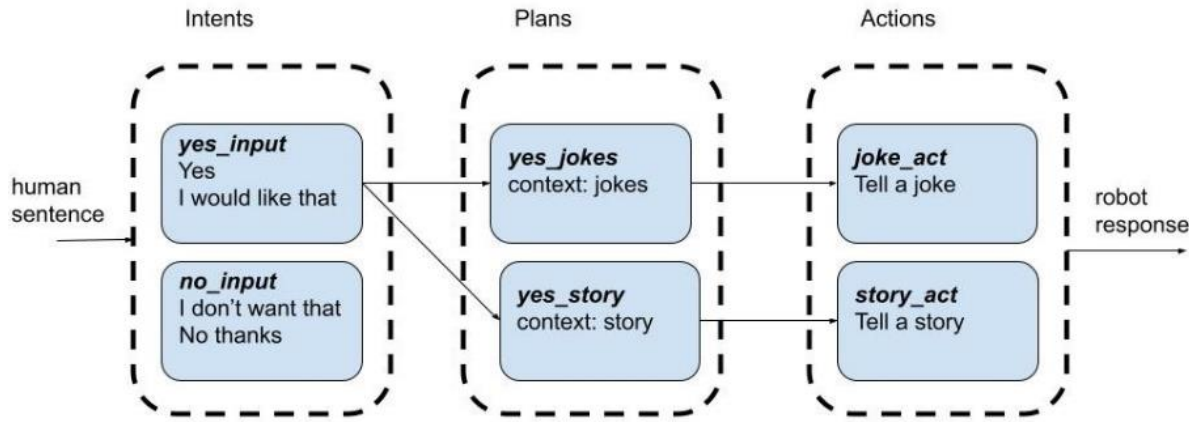

Figure 2: DDE Methodology

We used this structure to allow the robot to speak the language of "words of affirmations". This language unites the abilities to give accurate compliments and recognize when the interlocutor gives compliments. We began our work by creating a dataset of compliments by coding a compliment's generator based on the compliment syntax formulas of (Iwashita & Katagami) (see Figure 3). Which is based on the research of Holmes (1986) in which the author listed words and expressions that we can use to compliment someone.

We also enriched our dataset with sentences from the TV shows Friends and The Simpsons. These datasets consist of 39,000 sentences for Friends and 150,000 sentences for The Simpsons. We filtered the compliments using text blob, which is a Python package that can extract the general feeling of a sentence based on the feeling carried by the words of the sentence. We have only kept the sentences that carry a positive feeling. Then we selected the complimenting sentence containing at least one intensifier from our list.

The second part of our project was to make the robot say these compliments at the right time using the DDE Editor.

The quality time language is the act of giving someone our undivided attention. We implemented that by making the robot able to tell jokes, stories, or perform some dance show with its body movement and illuminated wheels. The robot can also listen and react if the human wants to tell a joke, a story, or just talk about anything. The goal was to make the human feel that the robot is happy to share a moment with them and giving them all its attention.

3.2 Zenbo App Builder

Because the DDE Editor allowed us to only managing what the robot says, we needed the Zenbo App Builder to make the robot move or else show different facial expressions on its screen. Fortunately, we can make the two environments communicate, so that a plan in the DDE Editor can link to an intent and add a context to perform an action within the Zenbo App Builder. For example, if we had asked the human if they wanted the robot to dance, we were into the dancing context. Thus, if the robot hears a sentence that is categorized into the "yes" intent of the DDE Editor, it would trigger the software routine that makes the robot dance in the Zenbo App Builder. All these features were used to implement the three remaining love languages.

1. NP BE (LOOKING) (INT) ADJ
2. I (INT) LIKE/LOVE NP
3. PRO BE (a) (INT) ADJ NP
4. What (a) (ADJ) NP!
5. (INT) ADJ NP
6. You (V) (a) really ADJ NP
7. You (V) (a) really ADJ
8. ADJ NP!
9. Isn't NP ADJ ?

Figure 3: Compliments Syntactic Patterns

(Source: Iwashita & Katagami, 2020)

The act of service is the act of making tasks for the person we love: vacuuming the house, cooking their favorite meal, etc.… This love language is harder to implement directly, because the robot doesn't have extremities and even if it had, its dexterity and the difficulty of performing these tasks would be significantly challenging. Nonetheless, the robot could control some electronic devices and give expressions to the caregivers. For example, it could play the patient's favorite show, control the room's temperature, or ask the floor chef to cook the patient's favorite meal.

As per physical touch, since the robot doesn't have extremities, it can't extend to touch the human. However, to overcome this barrier, the robot would ask the human to touch it, or hug it.

The last language we studied was gift-giving. While the robot can't offer material gifts, this language is not about the gift itself but the meaning of the action of giving. For example, showing photos of the human's loved ones, favorite landscapes, or playing the human's favorite music. To know the human's preferences and enable Zenbo to give "accurate gifts", the human would need to fill up a survey before meeting with the robot for the first time.

4. Proposed Experiments

The goal of our proposed experiment is to see if we have successfully created a bond between the robot and the human. To quantify this bond, we would use a metric such as the Lovotics Love Attitude Scale (LLAS), a 42-item questionnaire used to measure attitude towards love, proposed by Samani (2016), or relevant questions from the Rubin's Liking and Loving Scale questionnaire (Rubin 1970), or a combination of these and other relevant questionnaires available in the literature. We would recruit a number of participants to come to our Human-Machine Laboratory for a number of continuous days (e.g., for a week), and spend a certain amount of time (e.g., 30 minutes) each day interacting in private with Zenbo using our love languages implementation. We will use a control group which will interact with Zenbo through an interface other than our love languages implementation.

After each session, each participant would respond to our questionnaire (e.g., LLAS, Rubin's). We would then report if there was an increased bonding and whether this effect was a result of our love languages implementation.

5. Conclusion

We have described our prototype implementation of the five love languages in a humanoid robot, along with a suggested experiment to measure the level of the human-machine bonding formed as a result of our implementation.

It remains for us to continue developing and refining the love languages implementation, while considering potential ethical issues arising from the false impression of love a robot may project on a human. We will also investigate the development of feelings other than love such as compassion, indifference, affection, etc.

Acknowledgements

This work was developed while the first author was visiting Ontario Tech University under the Mitacs Globalink Research Internship program.

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17. It's more than memes: User risk appetite and app enjoyment predict simulated mobile trading app behavior

Harsh M. Gawai
Faculty of Computer Science
Dalhousie University
harsh.gawai@dal.ca

Colin Conrad
Faculty of Management
Dalhousie University
colin.conrad@dal.ca

Vlado Keselj
Faculty of Computer Science
Dalhousie University
vlado@cs.dal.ca

Abstract

Mobile trading application users have rocked the financial world and are becoming a noteworthy for their ability to contribute to financial uncertainty, often at great risk to their personal wealth. While participation in meme stock culture likely contributes to this risky behavior, other factors such as personal risk appetite and enjoyment could also explain a user's willingness to engage in risky actions on these platforms. In this paper, we describe the results of an experiment whereby participants engaged in a simulated financial trading task designed to mimic the Robinhood trading app. We took a mixed method approach to investigating users' experiences, using time-series machine learning clustering as well as questionnaire measures. We identified distinct clusters of users based on app usage data which reflected degrees of risky behavior and found that these features were associated with a user's perceived risk appetite and the degree to which they enjoyed the simulated technology. Taken together with past evidence that suggests that risk appetite and enjoyment are associated with application use, we posit that these factors play a role in explaining risky behavior on mobile trading platforms, which has implications for financial application design and future research on financial technology applications.

Keywords: Financial Technologies, Hedonic Information Systems, Risk Perception, Time Series Clustering, Simulation

1. Introduction

In January 2021, financial markets were rocked by an unexpected cause. Over the course of two weeks, millions of Reddit users leveraged popular financial trading apps such as Robinhood to propel the stock value of GameStop, a failing company, by more than $1500 (Li, 2021). Though many app users profited from this activity, it also had a negative impact on hedge funds which had bet on the stock failing. Millions of Reddit users also lost money as the stock price subsequently crashed (Brown, n.d.). This activity subsequently caused stock hysteria in various similar assets, ultimately culminating in market volatility and calls for regulation of these apps (Stewart, 2021). Today in 2022, stock markets continue to face increased volatility, and many internet influencers continue to promise gains, which has even prompted action from the Securities Exchange Commission cautioning the public about investing money in meme stocks and related cryptocurrencies which are popularized by social media (Cachero, 2022)

What factors explain this investing behavior? A possible explanation is that users who are most apt to invest in meme stocks and meme cryptocurrencies (hereafter referred to as “meme stocks” for short) are risk takers. Economists have long understood that risk appetite is a personality trait that can predict attitudes towards investments, as well as actual investment behavior such as saving for retirement (Barksy, 1997; Kam & Simas, 2010). This observation has also been observed in the context of information systems (IS) research in the context of cybersecurity notifications (Vance et al., 2014), suggesting that it could generalize in other related contexts. It is thus possible that risk appetite predicts meme stock investing behavior.

Another possible explanation is that people enjoy using the application. Hedonic factors such as enjoyment are known to influence users’ satisfaction and propensity to use applications, especially when they involve social media (Agarwal & Karahanna, 2000; Li & Chen, 2012). Users who enjoy the mobile investing experience may be more apt to use the application and be more engaged with interesting and exciting trends. This was posited by both media (Cachero, 2022) and academic sources (Costola, 2022) as a predictive factor in whether people participate in risky activity on mobile investing platforms.

In this paper we describe the results of an exploratory experiment which provides insights into factors that predict risk taking when using trading apps. Inspired by approaches employed by behavioral economics (Geezey & Potters, 1997) and new directions related to experience simulation being undertaken by IS researchers (Labonte-LeMoyne et al., 2017; Beese et al., 2018), we constructed a simulation of a financial trading application to facilitate the analysis of risk taking and enjoyment factors in investing app behavior. Simulation provides some advantages of alternative approaches, such as surveys, when few participants have direct experience with the information technology artifact in question. By providing a shared experience that is similar to the Robinhood application, we can make inferences about factors that influence behavior which may generalize to the actual technology. Simulation applications also allow us to analyze actual use behaviors in way that we would not otherwise be able to without access to the application itself. The approach that we take to our research methods leverages machine learning clustering of the behavioral data, designed to answer a recent call among IS researchers for new approaches to computationally intensive research (Berente et al., 2019; Miranda et al., 2022). We also conducted standard linear regression of the survey to complement the machine learning findings and help interpret the results. We have articulated our research question as follows:

RQ1 – Does risk appetite predict risky trading app behavior?

RQ2 – Does platform enjoyment predict risky trading app behavior?

RQ3 – Do clusters of user data will exhibit differences in trading behavior?

The remainder of this paper is structured as follows. We begin by discussing the theoretical framework, complete with the research questions that we seek to pursue. We then describe the methodology, detailing the psychometric, behavioral and machine learning analysis approaches to the research question. The results are provided along with a discussion about the theoretical and methodological contributions of this work. We ultimately conclude by discussing ways to improve this approach, with attention to future research directions.

2. Theoretical Framework

2.1 Risk appetite & Enjoyment

Risk appetite and enjoyment are social factors that have been studied in social sciences broadly, and in IS research specifically. For example, researchers have explored factors that contribute to collective social behaviors on social media such as those exhibited on Reddit (TsaI & Bagozzi, 2014). There are also well-established theories that investigate the role that enjoyment plays in information technology use such as cognitive absorption (Agarwal & Karahanna, 2000), as well as the role that risk perception may play in driving risky and impulsive IT behavior (Vance et al., 2014). More recently, e-commerce researchers have applied similar techniques to the assessments of the effects of gamification on online shopping behavior, finding that they influence online shopping trends (Garcia-Jurado et al, 2021). These social scientific approaches can offer considerable insight into the latent causes of risky behavior, though offer relatively little insight into specific design factors that influence it in the context meme stocks traded on popular platforms such as Robinhood, which are purported to influence the behavior (Li, 2021).

The meme stock phenomenon can be conceptualized in light of a mobile trading information technology artifact. Mobile applications have been extensively studied in the literature, perhaps most influentially from the perspective of a hedonic/utilitarian dichotomy (Wakefield & Whitten, 2006). In this conceptualization, hedonic applications (e.g. social media) are primarily designed to promote user enjoyment, while utilitarian applications (e.g. trading apps) are primarily designed to promote practical or business needs (Wakefield & Whitten, 2006; Sledgianowski & Kulviwat, 2009; Li & Chen, 2012). Mobile trading applications blur this dichotomy, as the affordance of the application seems to be practical gain, while the antecedents of use may be hedonic influenced by factors such as enjoyment.

While there are many factors that could influence risky trading, we were led to investigate two: *risk appetite* and *enjoyment*. Risk appetite has been previously investigated by IS researchers often in the context of cybersecurity notifications, finding that it predicts disregard for cybersecurity warnings (Vance et al., 2014) and plays a role in the wider context of protection motivation theory, which explains a users' motivation to protect their computer assets (Haag et al., 2021). Building on the work of Vance et al. (2014) as well as Kam & Simas (2010), we explore the ways that risk appetite influences a users' interest in taking risky decisions over less risky ones.

By contrast, enjoyment is often explored in the context of hedonic IS, especially in the context of social media (Li & Chen, 2012; Turel & Serenko, 2012). Enjoyment is often associated with positive impacts on IS use, such as through increased engagement with a system or the experience of cognitive absorption (Agarwal & Karahanna, 2000), though it has also been found to predict negative aspects of social media (Turel & Serenko, 2012). In the case of the study described by Turel & Serenko (2012), enjoyment of social media was found to play a role in forming bad habits and dependence on the information technology; we can similarly conceptualize a way that enjoyment influences risky trading behavior.

2.2 Machine learning approaches to IS research

Even from its earliest days, the IS discipline has drawn from mixed methods approaches, ranging from qualitative to quantitative; the discipline is now drawing from increasingly computationally intense methods to advance theory (Miranda et al., 2022). While machine learning is certainly not new and has been applied to IS research in the past, many of these applications have not advanced IS theory (Berente et al., 2019). More recently however, IS researchers are employing such methods to make advancements in the application of grounded theory and the advancement of theories of information technology use (Miranda et al., 2015; Tidhar & Eisenhardt, 2019; Vaast et al., 2017). Machine learning can contribute to IS theory not just by providing descriptive analysis, but also exploratory analysis into factors that could explain IT use behaivour by leveraging large amounts of data that cannot be easily analyzed using conventional techniques (Miranda et al., 2022).

In the context of trading apps, machine learning analysis can similarly yield insights into risk behavior that might not be captured by conventional technique such as interviews or surveys. By observing use data that is collected from actions generated by a computer application, we can observe organic behaviors that mimic real use behavior, similarly to how a researcher may do observations in grounded theory approaches to social science (Berente et al., 2019; Miranda et al., 2022). In an ideal world, we would gather data directly from a mobile trading application such as Robinhood, which would contain transactions that reflect actual users' behavior. Instead, as academics not associated with the popular trading platforms, we build on past IS research which leverages behavioral data gathered from simulations in order to make inferences (Labonte-LeMoyne et al., 2017; Beese et al., 2018). By applying machine learning clustering, we may discover clusters of behavior that reflect patterns of IT use, which can in turn be corroborated with an alternative method, such as questionnaires.

3. Methodology

3.1 Application Description

The first step for our study was to develop a web application which can simulate a mobile trading app where people can buy and sell stock. We used the Python programming language to create the web app, specifically the Plotly Dash library (Plotly, n.d.) for building interactive dashboards and SQLAlchemy (SQLAlchemy, n.d.) for managing database operations. The application was hosted on Heroku the cloud platform. The simulation leveraged stock market indices, equities and cryptocurrency data and a central display. Asset prices were updated every second during the simulation, with one second simulating a single trading day. The interface leveraged buttons to ease the purchase and selling of the virtual assets. The application was called "Nottingham" to demonstrate that the purpose of the simulation was to reflect the Robinhood trading application.

In Figure 1, we illustrate two interfaces from the application. Users landed on the welcome screen and when they click the 'Participate' button, took them to a Consent procedure, followed by a pre-session survey which asked questions related to risk appetite. The second screen demonstrates the main simulation page where there were two tabs: 'Instructions' and 'Invest'. Former gives information about the assets available in the simulation and the available actions they can perform. The later has sub-tabs of all the assets and those assets are based on their volatility and the reward one can get after investing on them.

The assets were always based on historical stock or cryptocurrency data, though the names of the actual assets were not known to the users and the specific assets and time periods that they were presented were generated randomly every time user starts a new session. Assets were limited to five options and were placed in order of volatility: government bonds (lowest volatility, lowest reward), a major stock index fund, a single bank stock, a meme stock (e.g. Gamestop, Blackberry), and a cryptocurrency (e.g. Bitcoin, Litecoin; most volatile, highest reward). Users could see the status of each asset by touching the related tabs. The graph updated every 1500 ms and the simulation consisted of four rounds, each corresponding to 46 to 47 days of real data. To help manage cognitive load and quick decision making, users were given a quick buy option where there were several buttons with the number of stocks they want to buy. Apart from this there was a 'Sell' button where one can sell any number of stock they want to sell from the asset and another is 'Sell All' button through which one can sell all their asset from their portfolio. After all the rounds complete, the user was prompted with a post-session survey regarding the enjoyment they had using the simulation. The submission of survey takes them to debriefing page where the top-3 performers on the simulation were displayed along with their portfolio data.

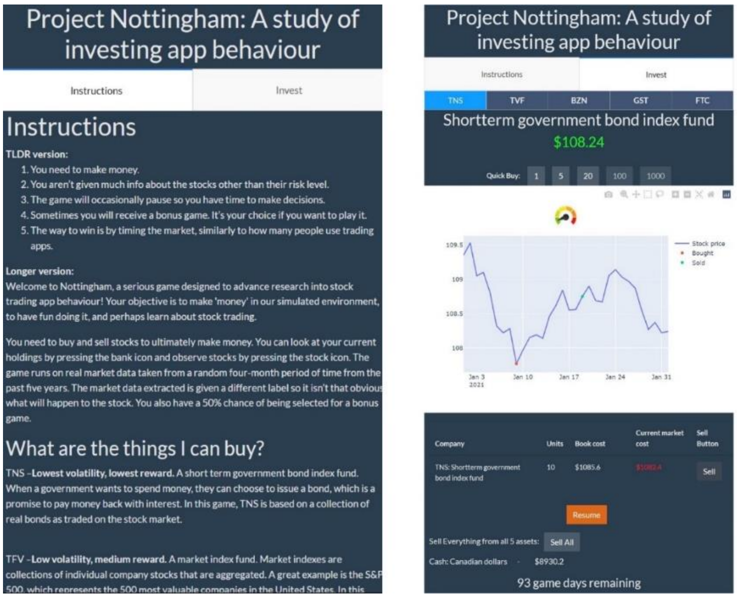

Figure 10: Sample screens of the web app, designed for mobile. Left: Instructions Right: Stock Simulation

3.2 Survey Development

There has been well-established theories that investigate the role that enjoyment or cognitive absorption plays in information technology use (Agarwal & Karahanna, 2000) as well as the role that risk perception may play in driving risky and impulsive IT behavior Vance et al. (2014). We thus incorporated two surveys in our web simulation i.e. the user profile survey in the beginning and the session survey at the end. The profile survey consists of 9 questions which included 7 previously validated questions about general risk appetite from (Barksy et al., 1997), as well as control variables: age and demographics. The session survey concerned the enjoyment that participants experienced and consisted of 11 questions based on a well-known enjoyment measure known to be associated with technology use (Agarwal & Karahanna, 2000).

3.3 Participants and Procedure

All procedures were reviewed and approved by our university's research ethics board and was found to adhere to the Canadian Tri-Council Policy Statement 2 on Ethical Conduct for Research Involving Humans. We took several approaches to recruit participants for our study such as email, social media, and paid panel. We contacted students via our lab and faculty mailing lists and offered them to enter for a chance to win a random draw of $50 CAD gift voucher as well as a competitive award for the best three performers. We also used the Prolific platform to find volunteers, who were paid £2 for their time and were compensated whether or not they finished the activity. Though 214 consented to participate and conducted at least more than a minute of interaction with the app, due to technical difficulties, only 147 completed the entire simulation and answered all of the questionnaire items.

When the participant clicked the link to the application, they were presented with a consent screen, and consent was given by agreeing to get to the pre-session survey. Participants then completed the risk questionnaire and completed the stock trading simulation, which consisted of four rounds consisting of 46-47 seconds during which participants could buy and sell simulated assets, which were arranged in order of volatility. The simulation was paused in between each round and resumed by the participant at will which gives them chance to analyze their portfolio and take actions based on it for their future investments.

3.4 Data Description

The data that were collected from the application was comprised of 4 different tables: ‘Userinfo’, ‘Sesioninfo’, ‘Postsurveydata’ and ‘Playbehavior’. The first had information about the user’s age and gender along with the survey about their risk-taking decisions. The second one consisted of the data about the session played such as start-time of the session, number of times user played the session, amount left in their account, portfolio value including all the assets they invested on, and profit/loss. The third one contained information about the survey on enjoyment of the simulation they played and the last one contained the data of transactions they did on the simulation such as buy/sell with company name, on which simulation day they did transaction, number of stocks bought, market value of single stock and total value of the stocks purchased.

We calculated and extracted the relevant features that would be useful for our Machine Learning models from tables ‘Sessioninfo’ and ‘Playbehavior’. Those features are summarized in Table 1. As our application had 3 pauses on 31st, 62nd and 93rd simulation day, we had a total of 4 rounds. We thus refined the data into 5 different tables as Round 1 - data between game day 1 to 31, `Round 2' - data between game day 32 to 62, `Round 3' - data between game day 63 to 93, `Round 4' - data between game day 94 to 124 and 'Total Rounds' of the mentioned features where the last table ‘Total Rounds’ contains the summation of all four rounds of extracted data.

3.5 Data Mining Approach

We took an unsupervised learning approach to data mining, so that we did not have to presuppose anything about the data as we conducted exploratory analysis. The algorithm that we've selected for our experiment is Time Series K-Means, which was implemented using the tslearn Python library (Tavenard et al., 2020). We selected this approach because the simulation had four rounds in and we treated each round data as time series to monitor how they performed. Using the data described in Table 1, we generated two clusters, to identify high risk-taking and lower risk-taking simulation users based on the behavioral data.

Feature	Description
TRANSACTIONS_PER_MINUTE	Number of transactions users made per minute
STOCKS_PER_MINUTE	Total number of assets bought per minute (e.g. stocks or cryptocurrency)
COSTBUY_PER_MINUTE	Total amount of assets bought per minute
BOUGHT	Total number of assets bought in a single session
NUMBER_OF_TRANSACTIONS	Total number of transactions made in a session
BUY_VALUE	Total value of assets bought in a session
MIN_BUY_AMOUNT	Minimum value of assets bought in a session
MAX_BUY_AMOUNT	Maximum value of assets bought in a session
RISK_METER	Most frequently bought asset of the five assets
TNS_AVGTIME	Average time taken between buy and sell of lowest volatility, lowest reward asset
TFV_AVGTIME	Average time taken between buy and sell of low volatility, low reward asset
BZN_AVGTIME	Average time taken between buy and sell of moderate volatility, moderate reward asset
GST_AVGTIME	Average time taken between buy and sell of high volatility, high reward asset
FLIPCOIN_AVGTIME	Average time taken between buy and sell of highest volatility, highest reward asset
PROFIT/LOSS	Profit or loss at the end of the simulation
RISE_BUY	Number of times a user bought assets when it increased versus previous day
FALL_BUY	Number of times a user bought assets when it decreased versus previous day

Table 11: Extracted features used in machine learning analysis

3.6 Survey Data Analysis

In addition, we analyzed the survey data using a separate linear regression approach, in an effort to evaluate the validity of the clustering algorithm. We investigated the risk appetite and enjoyment survey instruments using Chronbach's alpha and all items demonstrated an alpha of at least 0.7, so were aggregated. We ran simple ordinary least squares linear regression models on extracted features from the simulation and the survey data to predict the risk appetite and enjoyment, to establish a link between the play behavior and the established survey-based measures.

4. Results

4.1 Clustering

Figure 2 demonstrates the results of our clustering approach. The time series k-means identified two distinct clusters: one "low risk" cluster which contained 143 participants which exhibited lower risk activities and one "high risk" cluster of 71 participants which largely exhibited higher risk activities. The clusters are illustrated based on their average values from seven of the indicators previously mentioned in Table 1. Six of these indicators are illustrated below. In Figure 3, we filtered out the unique sessions of users and then took the ones who played full session and it is clear that most of the people around 40% of the users that we've analyzed were 'Low Risk' takers and made profit whereas only 16% of the users that were detected as 'High Risk' takers but made loss on simulation.

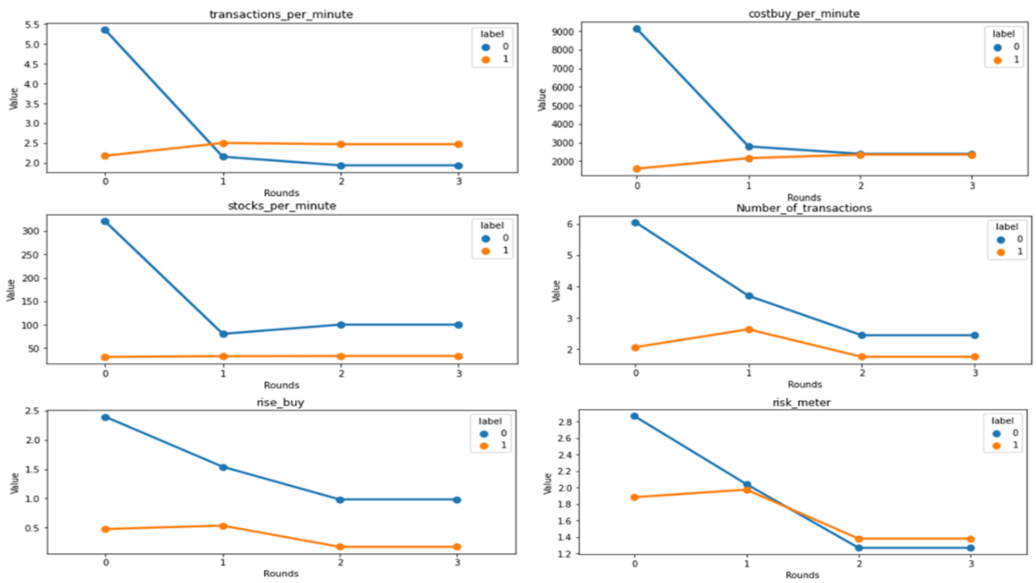

Figure 2: Comparison of the Time Series K Means clusters

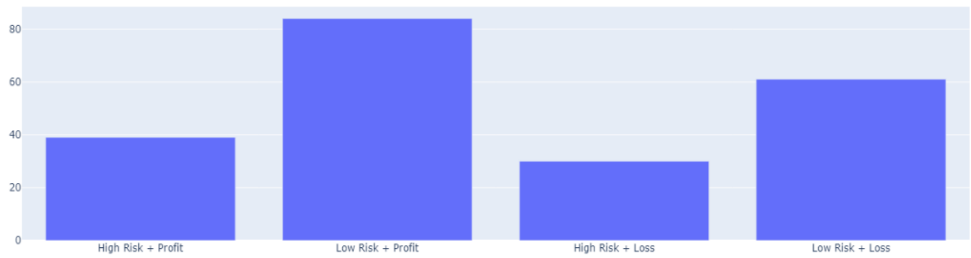

Figure 3: Type of Risk takers and Profit/Loss

4.2 Survey Analysis

Figure 4 provides a correlation table of the various survey instruments and behavioral features measured. We analyzed the seven of the features that most differentiated the clusters using the risk and enjoyment survey data using linear regression. Figure 4 provides a correlation table of the various features. Seven of these features (risk_meter, counts, max_buy_amount, buy_value, costbuy_per_minute, number_of_transactions, and avg_buysell_time) were found to be significantly correlated with both the enjoyment and risk surveys.

5. Discussion

5.1 Implications

To get the insights about the users risk taking decisions, we used ‘TimeSeriesKMeans’ algorithm to distinguish the clusters which helped in identifying their behavior. There were total 69 sessions in ‘Cluster 1’ while 145 sessions identified in ‘Cluster 0’. The clusters that we obtained clearly reflected two distinct behaviors: Cluster 0 which can be described as high risk taking, and Cluster 1 which can be described as low risk taking. While high risk-taking players tended to purchase a large number of risky assets at the outset of the simulation, they continued to trade throughout the session, and tended to maximize on rising asset prices. By contrast, low risk-taking players purchased fewer, less risky assets early on and traded less frequently, as illustrated by Figure 2. Though all players tended to interact with the application less as the simulation proceeded, the differences between the two clusters are clearly defined. The reason we selected 2 clusters for the algorithm is less data and increasing the clusters resulted in highly imbalanced clusters and uninterpretable b their features compared to 2 clusters.

Importantly, we can be confident that these clusters reflect more than just engagement with the application because we observed significant relationships between behaviors and the surveys. We observed associations between the seven behavioral features that were identified by the clustering algorithm and both the risk and enjoyment survey measures. The measures were also closely associated, suggesting that there was a strong relationship between a user’s risk appetite, how much they enjoyed the simulation, and their risk-taking behvior, as described in Tables 2 and 3.

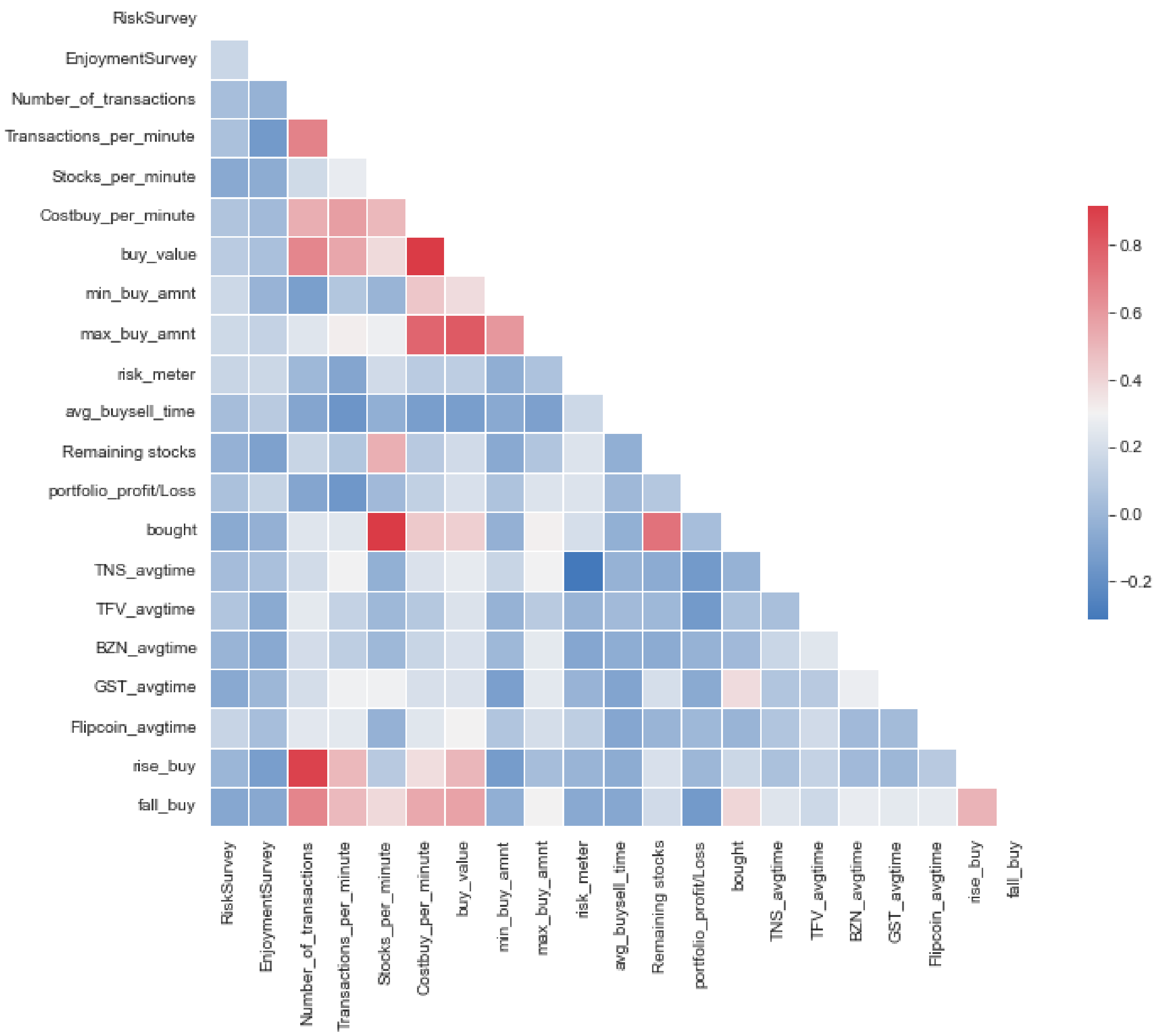

Figure 4: Correlation table of the various measured features

These findings have interesting theoretical contributions. They suggest that social factors such as risk appetite and enjoyment had influence on risk taking behavior of users on stock trading simulation, which could generalize to the meme stock phenomenon. User enjoyment has is known to be key factor in predicting hedonic information system use (Wakefield & Whitten, 2006; Sledgianowski & Kulviwat, 2009) and risk appetite is known to influence decision making (Vance et al. 2014). We are led to assert that these findings generalize to the case of investing applications.

Finally, there are also practical implications. Investing applications such as Robinhood incorporate design features which encourage users to take risky decisions and reinforce hedonic affordances. For example, Robinhood features a referral program and a rewards system that mimic features of mobile games and social media. Depending on their goal, application designers or other stakeholders can limit or encourage features that either identify risk-taking, encourage enjoyment, or limit these things. Future work could refine these findings to assess specific features that either encourage or limit the risk or hedonic factors.

5.2 Limitations

Our findings are limited by challenges with recruitment and data quality. While 214 participants consented to participate, many of the participants were recruited from Prolific, which is a platform of convenience, who were extrinsically motivated by payment. In addition, much of our data was incomplete, as only 147 participants completed the full task and answered both the pre and post survey. The results described in this paper can be considered complete, though an uncomprehensive analysis.

Secondly, there are theoretical challenges with drawing conclusions from a simulation task. While the task was designed to mimic the Robinhood trading application, participants in the study may not be similarly motivated as individuals who actually use the real-life trading application. Future work can overcome this limitation by collecting opinions from people who use the Robinhood application in addition to drawing inferences from the behavioral task. Alternatively, future work can improve on the generalizability of these findings by grounding future experimental work in a well-developed theory, such as the theory of planned behavior (Ajzen, 1991).

6. Conclusion

In this paper we explored possible factors that motivate individuals to engage in risky trading behavior when using mobile trading platforms. The approach that we took was to create a simulation of a mobile trading platform, through which we identified clusters of risky behavior, and that perceived risk appetite and reported enjoyment predicted people's engagement with risky behavior. We are ultimately led to conclude that while memes and hype can explain some of the engagement with these apps, people's risk appetites and experienced enjoyment during the application use predict risky behavior.

7. Acknowledgements

This work was supported from funding by Mitacs awarded to Vlado Keselj and the SSHRC Insight Development Grant program awarded to Colin Conrad.

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18. Making Robotic Dogs Detect Objects That Real Dogs Recognize Naturally: A Pilot Study

Dingtao Hu, Zhizun Wang
Benjamin C. M. Fung, David Meger
McGill University, Canada
{dingtao.hu, zhizun.wang}@mail.mcgill.ca
{ben.fung, david.meger}@mcgill.ca

Rupendra Raavi, Patrick C. K. Hung
Ontario Tech University, Canada
rupendra.raavi@ontariotechu.net
patrick.hung@ontariotechu.ca

Hidenori Mimura, Kamen Kanev
Shizuoka University, Japan
mimura.hidenori@shizuoka.ac.jp
kanev@inf.shizuoka.ac.jp

Abstract

The recent advancements in artificial intelligence (AI) and deep learning have enabled smart products, such as smart toys and robotic dogs, to interact with humans more intelligently and express emotions. As a result, such products become intensively sensorized and integrate multi-modal interaction techniques to detect and infer emotions from spoken utterances, motions, pointing gestures and observed objects, and to plan their actions. However, even for the predictive purposes, a practical challenge for these smart products is that deep learning algorithms typically require high computing power, especially when applying a multimodal method. Moreover, the memory needs for deep learning models usually surpass the limit of many low-end mobile computing devices as their complexities boost up. In this study, we explore the application of lightweight deep neural networks, SqueezeDet model and Single Shot Multi-Box Detector (SSD) model with MobileNet as the backbone, to detect canine beloved objects. These lightweight models are expected to be integrated into a multi-modal emotional support robotics system designed for a smart robot dog. We also introduce our future research works in this direction.

Keywords: Robotic dogs, Smart toys, SqueezeDet, MobileNet, Object detection

1. Introduction

Demographic transition is regarded as one of the motivators of technological development in the twenty-first century. Millions of individuals are negatively affected by population ageing and the epidemic of loneliness, which have caused damage to their psychological and physiological health (Cacioppo et al., 2006; Luo et al., 2012; Anderson et al., 2018). While addressing these issues will take significant work, the industry has already developed smart robots as novel solutions. For example, a social robot, defined as an autonomous robot that communicates with humans by following the social rules attached to its role, could provide individuals with emotional support, make routine activities easier, link distant family members, and be employed in various professional jobs. The Japanese technology start-up Groove X developed a home robot named LOVOT (*GROOVE X* n.d.), which is advertised as a product that “stirs your instinct to love”. Boosted by 50 surface sensors, the robot can remember the faces of its close partners, warm up when embraced, and move closer to the door when its owner arrives late. Sony also created a dog-shaped social robot named AIBO with a variety of sophisticated functions (Melson et al., 2005). The robot maps out the space ahead of it with a forward-facing camera and has Wi-Fi and Long Term Evolution (LTE) connectivity, allowing it to work inside and outside the home. Four microphones detect speech instructions, while two Organic Light-emitting Diodes (OLED) panels act as its eyes.

Intelligent emotional-support robots involve multiple modalities as they need to react to the external environment and interact with individuals in collaborative activities. Huge volumes of sensory-motor data, such as raw RGB image frames, joint angles, and voice commands, are merged to generate higher-level multimodal representations based on deep learning algorithms. The method of integrating data from various input modalities into a compact multi-modal representation is referred to as multi-modal fusion. The efficient multi-modal fusion of data from different sensors helps the model learn important tasks and exhibit robustness against noise. For instance, a significant application of this fusion method lies in the area of Physical Human-robot Interaction (PHRI), where the modalities of force, torque and tactility are recognized as direct contact modalities (Xue et al., 2020). They need to be efficiently detected and integrated to conduct collision avoidance between humans and robots. Indirect contact modalities in PHRI include vision and natural language, which are crucial for modeling and inferring the space-time relationship between the perception and operation domains for interaction tasks.

To make a robot dog more intelligent, it is natural to apply multi-modal fusion to it. By combining different modalities and taking advantage of the complementary information in multi-modal data, the robot dog is expected to show behaviours similar to a real dog. If objects that catch the attention of a real dog are placed inside the field of view of the robot dog, it should also react to those objects. In this paper, we focus on the object-detection task in the emotional-support robotic system, to identify items such as dog feeders, dog cushion beds, chew toys, treat balls and human faces in the frames extracted from real-time videos. We will utilize the AIY Vision Kit from Google (*Vision kit* n.d.) as the camera to be installed on the robotic dog. Due to the constraints on the memory of the device, the major goal of this study is to elaborate on the accuracy of SqueezeDet (Wu et al., 2016) and SSD-based detection with MobileNet (Howard et al., 2017) as the backbone on the customized item dataset.

2. Literature Review

Nowadays, we see a vast improvement in the creation and usage of robotic dogs, such as Sony AIBO. For example, Bruno et al. (2019) developed a robotic dog that guides visually impaired people. They used technologies such as ultrasound sensors, vision sensing, etc., to help robotic dogs navigate the visually impaired. The robotic dog they developed initially detects the obstacles with the help of ultrasound. Once an obstacle is detected, the images are taken, and the object-detection algorithm You Only Look Once (YOLO) is used to detect the objects and then guide without colliding. Schellin et al. (2020) surveyed the dog likeness of Sony's AIBO, where they performed a study by considering two factors: putting fur on the robot and keeping it as it is. Thirty-three participants were recruited with 12 of them being females, and all the participants had previously owned a pet. The final result was that, except for three participants, all other participant liked the dogs. Robotic dogs are also used in therapy for treating loneliness. Banks et al. (2008) conducted surveys to check the loneliness of older adults in three scenarios: one with a robotic dog. another one with a real dog, and the last one with no dog. The results showed that elderly residents living with either a real or a robotic dog felt substantially less lonely than residents without a dog. Interestingly, it was also found that there was no significant difference between using a robotic dog and a real dog. Next, Jones & Deeming (2007) discussed how an emotional interaction of a dog would affect humans, making them more alive. They created software capable of differentiating users' emotions based on their speech properties. With such a software we, a robotic dog would not be able to obey users based on their words. Instead, it follows the user based on the emotion used to speak those words. This is done on the top Sony AIBO robotic dog, which was able to differentiate anger, sadness, happiness, boredom, surprise and perform actions based on emotions. After the survey, most of the participants were enthusiastic about this robot. Stanton et al. (2008) conducted a study to see whether children would prefer to interact with the Sony robot AIBO or with a simple mechanical toy dog called Kasha. Where authors noted the time, of each child spent in interacting with kasha and AIBO and based on the results, children spent an average of around 72 percent with AIBO and more minor of 52 percent with Kasha. The results also show that the number of words that children spoke to the robotic dog was higher compared to spoken to the simple mechanical toy dog. In an earlier study, Melson et al. (2005) surveyed 72 children to see whether they would interact more with the robotic dog AIBO or with a living Australian shepherd. It turned out that children were more interested in interacting with the real dog than with the robotic dog. Still, the survey also showed that many children tried to interact with the robotic dog AIBO similarly to the way they treat a real dog. Further, Weiss et al. (2009) conducted a survey in a shopping mall for three consecutive days as a voluntary free exploration case study where 147 participants were selected. According to their study, all 129 children among the participants showed a lot of enthusiasm, expresses by statements such as 'That's cool', 'May I play with it?', and actions to run towards AIBO to play with it. But researchers would also report children saying that AIBO was not responding properly, which as mentioned in the paper was due to the multiple voice commands issued simultaneously. As a result, most of the children, on average, spent around 20 minutes and interaction was stopped just because their parents wanted them to go.

3. Project Pipeline

The semantic perception of canine beloved objects involves a number of development phases and a customized training dataset. A collection of images of dog supplies from various online pet stores (Amazon, JD, Chewy, etc.) and royalty free stock photography providers (iStock, Getty Images, etc.) was established in this work. The images were annotated by Computer Vision Annotation Tool (CVAT) (Sekachev et al., 2019) in the PASCAL VOC format with the assistance trained deep learning models provided by the open-source tool. Furthermore, our pipeline can automate multiple image augmentation operations and the process of labeling augmented images, which expands the volume of the original dataset and enhance the effectiveness of annotation. The labels and the coordinates of bounding box in the augmented images were automatically generated by transformation processing based on those in the original images. Given these materials, lightweight neural network models were trained utilising the TensorFlow framework (Abadi et al., 2015). We used the model with better performance on image prediction in the preliminary experiment to conduct real time inference on the video captured by laptop webcam and will integrate it with into the AIY Vision Kit from Google (*Vision kit* n.d.) and robotic dog in the further study. Figure 1 demonstrates the pipeline of canine beloved object detection object.

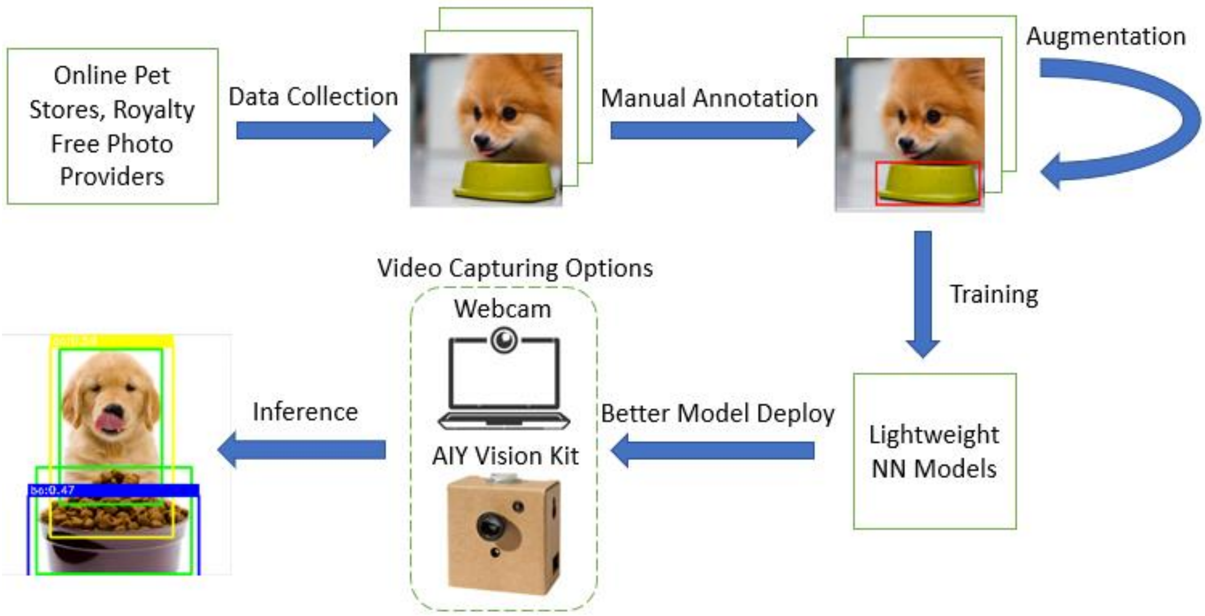


Figure 1: Canine beloved object detection framework. The process begins with data collection from online pet stores and royalty free photography providers, which is followed by the manual object annotation. To expand the dataset size, multiple data augmentation techniques are utilised. Furthermore, the lightweight neural network model with better performance in the preliminary experiment is integrated into the dedicated hardware devices.

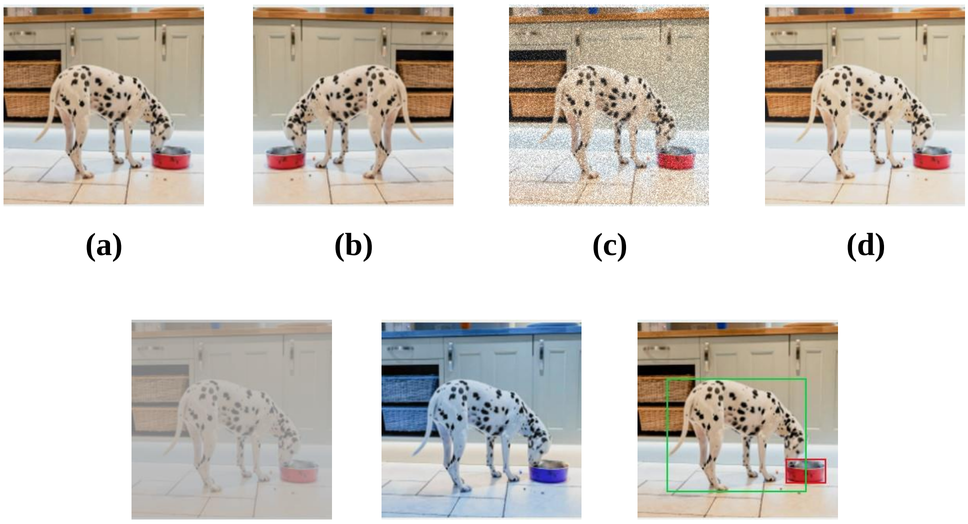
4. Data Processing

We created our dataset from scratch. We collected 1400 images from online pet stores and galleries for three categories of canine beloved items: dog feeders, dog beds and dog toys. Eight labels were defined: dog, cat, human face, hand, treat ball, chew toy, dog bowl and dog bed. All images were resized to 256 × 256.

We applied the following five image data augmentation techniques to improve the performance and the generalization capabilities of the model:

- Flipping: each image is flipped horizontally;
- Gaussian Noise: the noise from the distribution $N(0, 0.1\times255)$ is added to images. Specifically, the noise value is different per pixel and channel (i.e. adding different noise values to red, green and blue channels of the same pixel) ;

Figure 2: An example of a training image to which we apply data augmentation or data annotation. Images (a)-(g) are the original image, the flipped image, the image with Gaussian Noise, the image with Sigmoid Contrast, the image with Linear Contrast, the image with Channel Shuffle, and the image with bounding boxes, respectively.



(a) **(b)** **(c)** **(d)**

(e) **(f)** **(g)**

- Sigmoid Contrast: we adjusted the image contrast by scaling pixel values to the size of $255\times\frac{1}{1+e^{gain\times(cutoff-\frac{v}{255})}}$, where *v* is the original single pixel value, the *gain* is uniformly sampled from the interval [5, 20], and *cutoff* is uniformly sampled from the interval [0.25, 0.75];
- Linear Contrast: we modified the image contrast by scaling pixel values to $127+\alpha\times(v-127)$, where *v* is the original single pixel value, and α is uniformly sampled from the interval [0.4, 1.6] for each image;
- Channel Shuffle: we rearranged the RGB channels of each of the images at random.

We annotated the objects in the original images using Computer Vision Annotation Tool (CVAT), an open-source interactive video and image annotation tool for computer vision research developed by Intel (Sekachev et al., 2019). CVAT supports a list of shapes with which we can annotate the images, such as bounding boxes and polygons. We conducted data annotation by looking at an image in our dataset, finding the objects that belong to one of the 8 labels we defined above, and manually annotating them with bounding boxes. CVAT allows us to export the annotated data in different formats, including PASCAL VOC, TFRecord and KITTI, which we can directly feed into our models. CVAT also provides trained deep neural network models, such as Mask R-CNN and YOLOv3, to assist the users to improve the annotation efficiency.

5. Lightweight Neural Networks

5.1 SqueezeDet

SqueezeDet is one of the smallest lightweight, fully Convolutional Neural Networks (CNNs) for object detection, which integrates SqueezeNet as the backbone network for feature extraction into the YOLO framework. It has been verified that SqueezeDet could achieve good performance in single-shot object detection tasks on many benchmark datasets (including KITTI, VOC 2007, COCO) with significantly smaller model size than other networks. In particular, it is valid to employ SqueezeDet in low-end edge devices or embedded systems within a short running time.

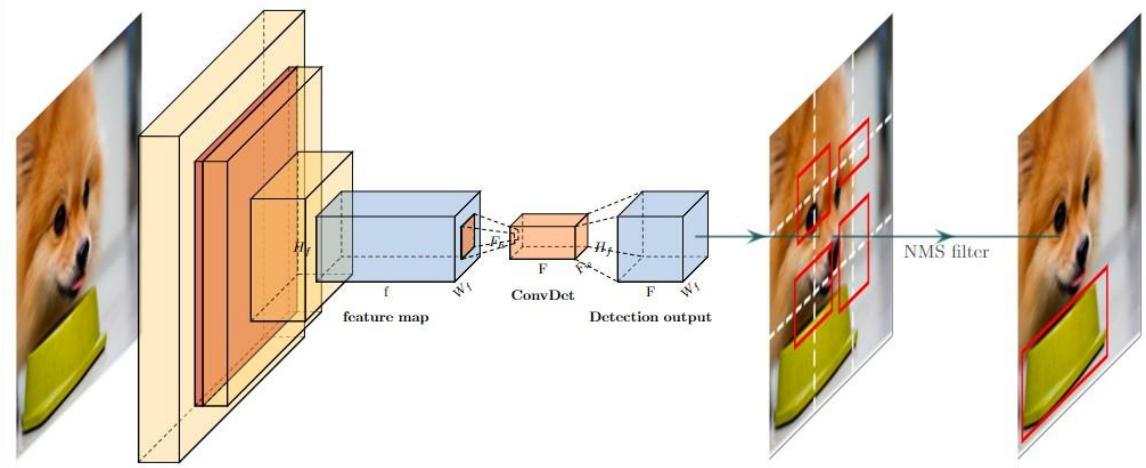


Figure 3: SqueezeDet pipeline. The feature map is of size W_f,H_f,f, where W_f and H_f refer to the width and height of the feature map, respectively, and f represents the number of channels. The output of the ConvDet, a $F_w \times F_h$ convolution, is of size $F := K \times (5 + C)$. It is then trained to compute the class probability and the values associated with the bounding box at each grid center.

Inspired by the Region Proposal Network in Faster Region-based Convolutional Neural Network (RCNN) and YOLO, SqueezeDet employs a single-shot object detection pipeline to achieve region proposition and classification by one network stream concomitantly. First, the convolutional neural network takes the input image and extracts feature maps, which act as the backbone of the object localization network. Then, the ConvDet layer takes the feature maps as inputs, overlays a uniformly distributed $W \times H$ spatial grid on top of them, where W and H represent, respectively, the number of grid centres horizontally and vertically, goes across each spatial position as a sliding window and computes K reference bounding boxes (termed as anchors) with preset shapes at each grid center. Each anchor is represented as 4 scalars, (x_i,y_j,w_k,h_k), where (x_i,y_j) is the spatial coordinate of the grid center (i,j), and w_k and h_k refer to the width and height of the k-th reference bounding box. Besides, each anchor is also associated with C conditional classes and a confidence score Pr(Object)*IOU, where IOU denotes Intersection of Union. A high confidence score indicates that the probability of the existence of a targeted object is high and the intersection between the candidate anchor and the corresponding ground truth is large. As a result, SqueezeDet's fixed output is $W \times H \times K(4+1+C)$. Finally, the most appropriate bounding box for the object is obtained by filtering out redundant bounding boxes by Non-Maximum Suppression (NMS).

5.2 MobileNet-SSD

MobileNet, also referred to as MobileNetV1, is a type of CNN specifically designed for embedded vision applications and mobile devices (Howard et al., 2017). Using depthwise separable convolutions, it builds lightweight deep neural networks on top of a streamlined architecture. Depthwise separable convolution is a form of factorized convolution. In other words, it factorizes a standard convolution into two separable convolutions: a depthwise convolution, which applies a single filter per input channel, and a pointwise convolution, which is a 1× 1 convolution combining the outputs of the depthwise convolution and changing the dimension. Two non-linearities, Batch Normalization (BN) and Rectified Linear Unit (ReLU), are applied to the depthwise separable convolutions. In the complete network structure of MobileNet, there are 28 layers in total, if the depthwise convolutions and the pointwise convolutions are counted as separate layers. Each layer is followed by both BN and ReLU, with the exception of the final fully connected layer which feeds into a softmax layer.

Because MobileNet splits the standard convolution operations into two types of steps, namely filtering steps and combination steps, via the use of depthwise separable convolutions, it can achieve substantial reduction in computational cost. Single Shot Multi-Box Detector (SSD) is a novel architecture with a single deep neural network (Liu et al., 2015). In the object detection task, this feed-forward convolutional network detects the presence of instances that belong to the specified object classes. It produces a fixed-size collection of bounding boxes and scores for these instances. Then it uses a method of non-maximum suppression to yield the final detection results. The structure of the SSD model is based on a truncated version of the VGG-16 network; a CNN commonly used for high quality image classification (Simonyan & Zisserman, 2014). A set of convolutional feature layers is added to the end of the truncated network, allowing predictions of object detection at multiple scales. The SSD model is able to complete the tasks of object localization and classification in a single forward pass of the network, which is exactly the meaning of “single shot”. The SSD training objective is inspired by the objective of MultiBox (Erhan et al., 2014), an approach for the bounding box coordinate proposal generation.

MobileNet-SSD is essentially an SSD model that uses MobileNetV1 as a base network, or a backbone, in its structure. The original backbone, the truncated VGG-16 network, is replaced by a truncated version of MobileNetV1. The models reduce the computation cost while exhibiting a similar object detection accuracy. It is suitable for situations where we have only low computing power devices to perform object detection tasks in real time. For example, if MobileNet uses 3×3 depth-wise separable convolutions, its computational cost is between 8 to 9 times less than that of the full standard convolutions, while the accuracy of MobileNet is only about 1% less than that of the standard convolutions (Howard et al., 2017).

6. Experiments

6.1 Implementation Details

Our preliminary experiment focused on training the lightweight models to recognize dog bowls mainly. The 301 images containing at least one dog feeder were expanded to 1806 images by the five data augmentation techniques listed earlier. The input size of the original SqueezeDet model is 1242 × 375, which is too large to run on Google Vision Kit. So, we changed the input size to 256 × 256 and reduced both the number of vertical anchors and the number of horizontal anchors to 16 to make SqueezeDet model fit the supported configuration of the device. We implemented the network in Keras and did the training with the Adam optimizer, employing an initial learning rate of 0.001, learning rate decay factor of 0.5, decay step size of 10000 and a batch size of 4. A Tesla T4 GPU was adopted to train SqueezeDet in the experiment.

The input to the original MobileNet-SSD model was in the size of 300 × 300. We resized the input image to 256 × 256 and set depth multiplier to 0.125. When training MobileNet-SSD, we set the batch size to 24, the initial learning rate to 0.004 (with exponential decay), the decay factor to 0.95, and the number of decay steps to 800720. A single NVIDIA GeForce RTX 3090 GPU was employed.

The model with better performance in the preliminary experiment would be trained by larger dataset with more objects and deployed to the hardware devices. The training dataset was boosted by 500 images of dog beds, 600 images of dog toys (treat ball and chew toy) and their corresponding augmented images. The annotations of augmented images were generated automatically based on the labels on the original images.

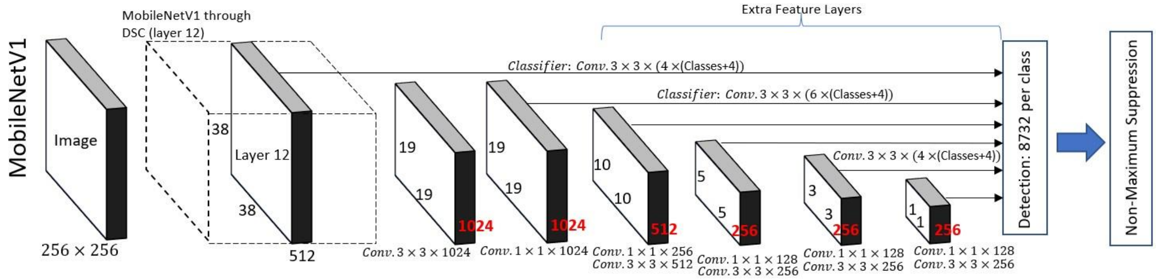
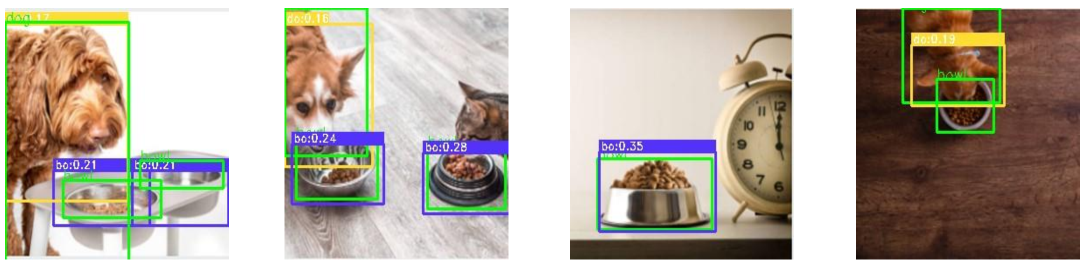


Figure 4: MobileNet-SSD architecture. To integrate MobileNetV1 within the original SSD framework, we truncate the last three layers of MobileNetV1 because the part of MobileNetV1 is not responsible for classification. It only needs to extract the features describing the contents of the images from the input images and pass them along to the other layers of the framework.

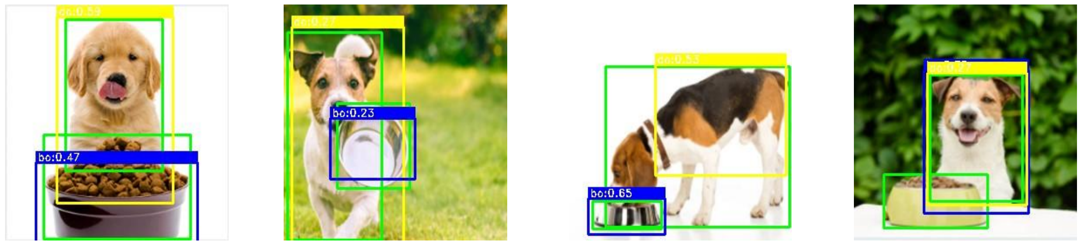
6.2 Experiment Results

In this subsection we demonstrate qualitative results of the bounding box detections produced by SqueezeDet and MobileNet-SSD on the categories *dog* and *dog bowl*. First, we analyze the performance of SqueezeDet. In Figure 5, we show the predictions of SqueezeDet. The ground truth bounding boxes are in green, while the prediction boxes of the *dog* and *dog bowl* are in yellow and blue, respectively. The threshold for the probability of detection is set to 0.13. According to Figures 5(a), 5(b), and 5(c), the trained multi-class object detector correctly localizes and labels the objects in the testing images with high (>0.7) IOU, but relatively low (approximately 0.3) probability scores. And some of the views, such as the top view of the partially occluded dog bowl, are challenging for the model to detect as Figure 5(d) displays. Besides, the detector tends to localize the main part with distinctive features of dog, for instance, in some cases the prediction boxes include the dog head but ignore the feet or trunk of the dog. While the prediction boxes of the dog bowl usually exceed the boundaries of the corresponding ground truth boxes. Furthermore, we examined the performance of MobileNet-SSD. The examples of MobileNet-SSD prediction are presented in Figure 6. In general, the probability scores are higher than those obtained by SqueezeDet. In particular, while the majority of the probability scores of MobileNet-SSD are between 0.4 and 0.6, the probability scores predicted by SqueezeDet are mostly between 0.2 and 0.4.



(a) **(b)** **(c)** **(d)**

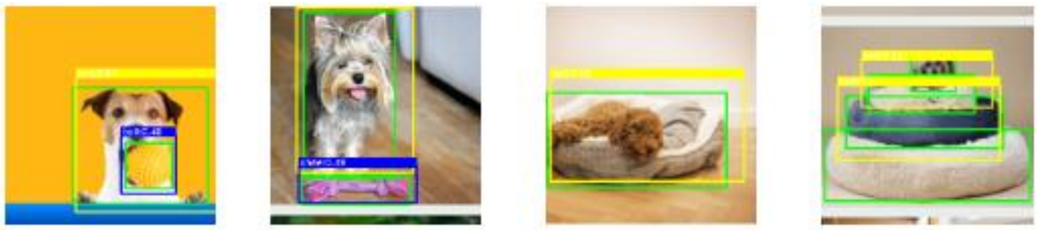
Figure 5: Examples of SqueezeDet prediction. In images (a)-(c), the detector successfully localizes and labels the objects. In image (d), the model fails to detect the occluded bowl from the top-down view.



(a) **(b)** **(c)** **(d)**

Figure 6: Examples of MobileNet-SSD prediction. Generally, the probability scores are higher than those obtained by SqueezeDet. Image (c) shows a localization error, while image (d) shows a classification error and a missed bowl object.

Therefore, MobileNet-SSD was selected to be trained by the boosted dataset with labeled dog toy and bed objects. Figures 7(a), 7(b) and 7(c) exhibit the detections of treat ball, chew rope and dog cushion bed with relatively high confidence scores (above 50%) compared to the results in the preliminary experiment. Both Figures (c) and (d) show a detection error in which the missed bed and dog are highly truncated and over-lapped with other objects.



(a) **(b)** **(c)** **(d)**

Figure 7: Prediction results of the MobileNet-SSD trained by boosted dataset. Images (a), (b), (c) show the detected treat ball, chew toy and dog bed respectively, while image (d) displays the missed objects.

7. Discussion & Future Work

In this research project, we explored the possibility of implementing lightweight neural networks to help robotic dogs recognize objects that real dogs recognize naturally. Trained by small-scaled low-resolution images from scratch, the low power networks could localize and label multiple items with an acceptable accuracy of probability scores and a relatively high IOU. The experiment results show that the small-sized models under the configuration constraints have the potential to detect the objects in the real time video stream even if the input frames are of low quality. Further improvements in object detection may be achieved by leveraging supplementary sharpened images during the training process to encapsulate more details about objects of interest and improve the accuracy of the confidence and probability scores. Additionally, the trained model will be integrated into the Vision Bonnet by exporting the generated checkpoint as a frozen graph, using the compiler to convert the frozen graph into binary format, and copying it onto the Vision Kit. The feasibility of the models will be tested on the intelligent camera.

Our continuing work on the robotic dog system will explore a machine learning model aiming at specific hand sign language features based on the YOLO object detection algorithm (Redmon et al., 2015). With respect to this we have collected over 1,500 images from different angles to see the hand signs from a robotic dog perspective. Currently, those images are being augmented using noise and blur techniques that increase the size of the training dataset. While some training experiments with the model have been carried out, detailed evaluations and comparisons to other algorithms such as Single Shot Detector and Efficientnet (Tan & Le, 2019) are still to come. For this, we are designing further experiments with different distances and angles from a dog perspective.

An alternative approach that is also being explored is the employment of direct h4444and and finger motion tracking devices such as data gloves. While the camera-based tracking and recognition of hand signs require clear views, proper lighting, and suitable backgrounds, and is thus highly dependent on the environmental conditions, the direct data glove-based tracking is fundamentally more robust. With respect to this, we have conducted experiments with a deterministic low computing power model for data glove-based tracking and recognition of hand signs employing an extension of the Malossi alphabet (Gelsomini et al, 2022). The advanced Data Glove incorporating highly stretchable Carbon Nanotube sensors developed at the Research Institute of Electronics that was commercialized by Yamaha was used in the experimental work (Gelsomini et al, 2021). Further experiments are planned with newer Data Glove models incorporating haptic feedback and employing machine learning models evolving from the camera-based approach discussed in this paper.

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20. Present a feature selection technique based on machine learning in order to increase the detection rate of classifiers using CHOA algorithm

Hassan Ghaedi
Department of Computer, Khormuj Branch,
Islamic Azad University, Khormuj, Iran
hassan.ghaedi@iau.ac.ir

Sahar Soleimani
Department of Computer, Khormuj Branch,
Islamic Azad University, Khormuj, Iran
s.soleimani@samabushehr.ac.ir

Abstract

In creating a pattern classifier, feature selection is often used to prune irrelevant and noisy features to producing effective features. Feature selection algorithms; try to classify an instance with lower dimension, instead of huge number of required features, with higher and acceptable accuracy. In fact an instance may contain useless features which might result to misclassification. An appropriate feature selection methods tries to increase the effect of significant features while ignores insignificant subset of features. In this paper, an efficient feature selection algorithm based on Cheetah optimization algorithm and support vector machine (CHOA-SVM) was used. First a population of cheetahs (feature subsets) were randomly generated, and then optimized by CHOA-SVM wrapper algorithms; finally the best fitness feature subset was applied to SVM classification. Experiments over a standard benchmark demonstrate that applying CHOA-SVM in the context of feature selection is a feasible approach and improves the classification results. The simulation experiment results have proved that the feature subset selection algorithm based on CHOA-SVM is very effective.

Keywords: Feature Selection, Machine Learning, Data Mining, Pattern Classification, Cheetah Optimization Algorithm.

1. Introduction

In many pattern classification problems, using a large number of features does not increase the accuracy. Furthermore, sometimes using some features even decreases the prediction accuracy. Therefore, feature selection is used as a valuable pre-processing tool before solving the classification problem. The purpose of the feature selection is to reduce the number of irrelevant characteristics so that the classification accuracy remains acceptable. A good feature selection method can reduce the cost and increases the classification accuracy as well as efficiency (Khalid et al., 2014). The best subset includes the fewest features that have the most of collaboration in the accuracy. The remaining and immaterial features are ignored because many of them are either useless or have little information load. Deleting these features does not cause information problems but raises the computational load for the desired application as well as saving much useless information along with useful information (John et al., 1994). One of the problems related to categorizing is the high dimensionality of the feature space. Some of the features are irrelevant and redundant, and negatively affect the functionality of the classifier. Therefore, feature selection is required to reduce the feature space and increase the efficiency of classifier. A lot of work has been done in the field of feature selection in recent years. (Palanisamy & Kanmani, 2012) used the Artificial Bee Colony (ABC) algorithm for feature selection. The aim is to increase the speed of classification operations and extract useful information among the features. The extracted features have been evaluated by the j48 Decision Tree (DT) algorithm. (Nakamura et al., 2012) have proposed a new feature selection technique inspired by nature. The purpose was to solve the optimization of feature selection. In order to find the features that maximize the accuracy, the power of Bat exploration is combined with the speed of the Optimum-Path Forest (OPF) classifier. To evaluate the results, the algorithm was tested on 5 datasets. (Banati & Bajaj, 2011) have explained the problems related to high-dimensional, noisy and unrelated data, and the objective was to provide a new nature-inspired feature selection algorithm. In this paper, RST combined with the Firefly algorithm is used to find a subset of the features. The proposed hybrid algorithm was applied in the medical fields to find the minimum set of features. Four different medical databases were used as well as different methods for evaluating performance. (Forsati, 2012) proposed a new feature selection method using the ABC algorithm. The purpose was to formulate the feature selection as an optimization problem and provide a new feature selection process to achieve better classification results. In their study, the ABC algorithm was used to solve the feature selection problem. The proposed algorithm has experimented on 6 reference datasets. (Rodrigues et al., 2013) presented the finding a set of features to help the higher detection rates and faster extraction of features. The goal was providing a new feature selection based on binary Cuckoo search. In this paper, a binary version of Cuckoo's search for the purpose of the feature selection is presented. (Pritom et al., 2016) proposed a method to investigate the probability of breast cancer as well as the probability of recurrent breast cancer using various data mining techniques. Cancer patient data was collected from Wisconsin dataset of the UCI machine learning. Tis dataset contains 35 features, which are selected using the feature selection methods and are computed using classification algorithms. According to the results, Naive Bayes algorithm and decision tree provide better and higher accuracy. (Kamel et al., 2019) were used the GWOs and SVM for feature selection and data classification in order to increase the accuracy of breast cancer diagnosis, respectively. The best results were obtained from a hybrid of the SVM algorithm and the GWO to select the subset of the efficient features. (Ghaedi et al., 2022) were used a two-level stacking technique to detect power theft. To increase the correct detection rate of this technique, the CHOA algorithm was used to select the features of the base classifiers. The results of the proposed framework were showed that the efficiency of the proposed framework was higher than other studies. (Saranya & Pravin, 2021) focus on the use of an analysis of feature sensitivity to determine the optimum feature subset using Matlab with improved accuracy and sensitivity for classification. In comparison to the already well-known algorithms for wrapper selection, filter and embedded method, the effectiveness of the proposed algorithms is evaluated. The feature selection methods are more preferred than the feature extraction methods since they preserve the originality of the dataset. Based on this motivation, (Ceylan & Taşkın, 2021) were accordingly modified an evolutionary based optimization algorithm utilizing self-organization map to provide a new feature selection method for the classification of hyper-spectral images. (Baruah et al., 2020) attempt to introduce a PSO based feature selection method using mutual information (MI). Feature-class MI has been used to select a subset of features based on its relevancy. A wrapper-based method is used to find the productiveness of the method by evaluating with different classifiers in different datasets. (Arunadevi & Ganeshamoorthi, 2019) have concentrated on prediction of the breast cancer with few attributes. They have employed feature selection as the preprocessing step for the classification. They used three classifiers and two feature selection strategies for this paper. This work is mainly focused on using the minimal number of attributes for the prediction of cancer in order to reduce the data handling overhead.

Therefore, the main objective of previous works is to familiarize with the new algorithms used in the area of feature selection and introduce a more effective algorithm that improves the performance by focusing on their drawbacks. In order to obtain better accuracy for classification problems, an efficient feature selection process is required. In this study, the CHOA (Ghaedi et al., 2022) algorithm is applied to implement a feature selection problem, and also the SVM along with the one-versus-rest approach used as classifier.

This paper is organized as follows: Section 2 elucidates the CHOA and proposed algorithm. Section 3 clarifies the design of the proposed system. The results of experiments and their evaluations will be explained and discussed in section 4. Finally, the conclusions of the paper will be presented in section 5.

2. Cheetah optimization algorithm (CHOA)

This algorithm was presented by (Ghaedi et al., 2022). In this algorithm, cheetahs are expert hunters built for speed. They have small heads, long legs, and muscular tails to maintain balance. Their hearts and lungs are larger than usual to supply oxygen to the running muscles. Half of their muscle mass is placed around the spine so that they can be as flexible as a spring. This lengthens their strides, which helps them reach their maximum speed (Wilson et al., 2013). For cheetahs, only three strides are enough to reach a speed from zero to 65 km/h, and it only takes 3 seconds to reach a speed of 110 km/h. Cheetahs need coordinated senses to hunt. Although cheetahs are very fast, they must be close enough to their victim before attacking. When they see victim, they are completely focused (Van der Weyde et al., 2016). Teamwork increases the likelihood of success in hunting. When one gets tired, the other continues to chase. Male cheetahs usually hunt in groups (Farhadinia et al., 2012). The CHOA algorithm is a population-based meta-heuristic algorithm in which the location and velocity of the $object_i$ ($cheetah_i$ or $victim_i$) in the search space are specified as follows:

$$location_{object_i} = [location\_object_1^i, location\_object_2^i, \ldots, location\_object_d^i]$$

$$velocity_{object_i} = [velocity\_object_1^i, velocity\_object_2^i, \ldots, velocity\_object_d^i]$$

where d is the dimension of the search space.

Figure 1 shows the steps of the CHOA algorithm. All cheetahs choose a direction according to the movement of the victim, and the victim chooses its direction according to the cheetah leader.

Based on the current velocity of a cheetah and its distance from the victim, a new velocity is calculated for a cheetah. To find the best solution by $cheetah_{leader}$, firstly, all of the N cheetahs and M victims are initialized at random locations in the search space. Because the cheetahs are not far apart in a group, they are located in a range with a radius $R_{Hunting}$(10 meters). At the beginning of the movement (first step), the velocity of all cheetahs and victim is considered zero. In the next steps, the velocities and locations are updated. Figure 2 shows the vectors that determine the movement path of the cheetahs.

As shown in Figure 2, vector 1 represents the coefficient of the previous movement of the $cheetah_i$. Vector 2 represents the coefficient of the vector of the current location to the victim. Finally, based on the results of the two vectors, the new velocity of $cheetah_i$ is determined as vector 3.

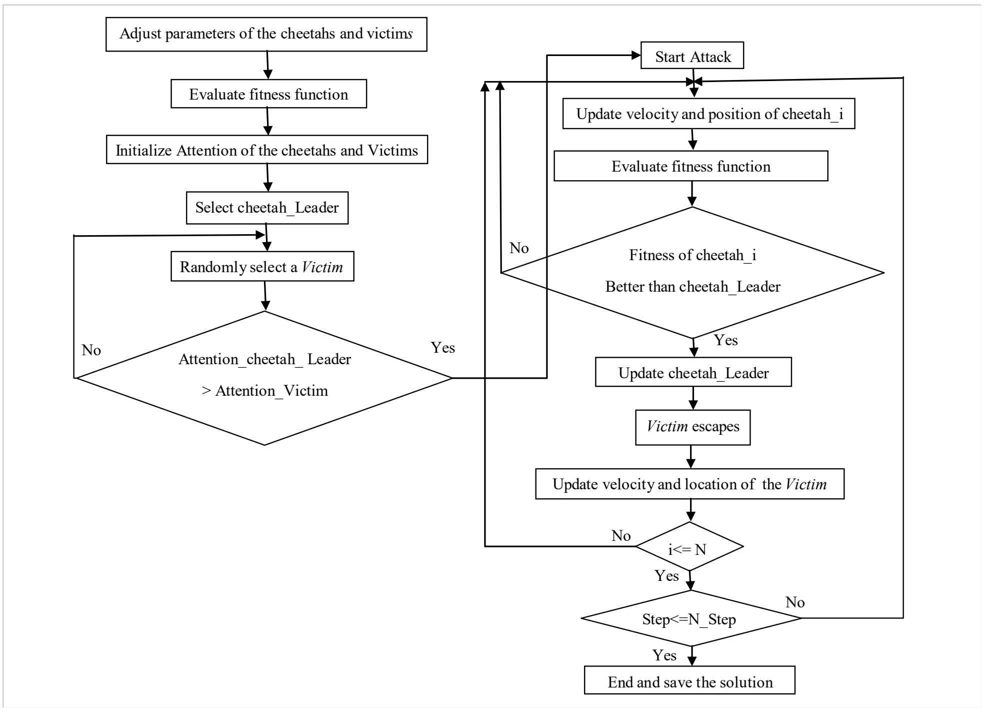

Figure 1: The steps of CHOA algorithm

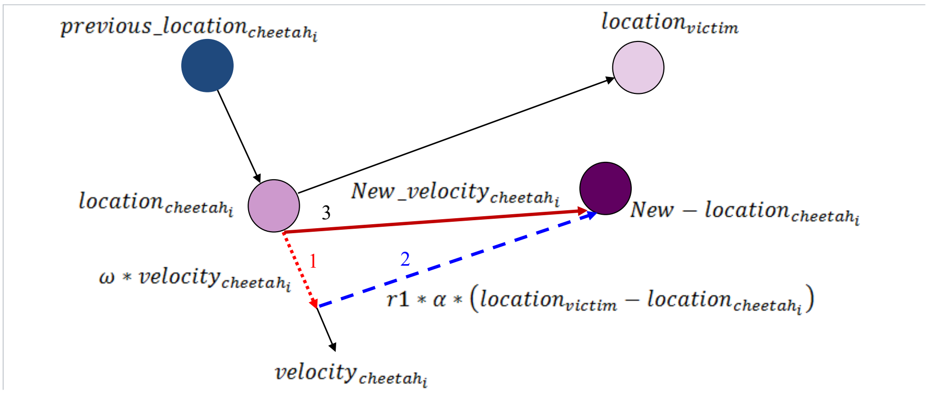

Figure 2: The direction of the cheetah movement

For each cheetah, the fitness of the new location is evaluated, and depending on the obtained value, the cheetah_(Leader) may be updated. If the cheetah_(Leader) improves, the victim will escape and its velocity and location will be updated.

Figure 3 also illustrates the movement pattern of the victim with respect to the changes in the movement of the cheetah_(leader).

As shown in Figure 3, vector 4 represents the coefficient of the previous movement of the victim. Vector 6 represents the coefficient of the vector of the current location to the cheetah_Leader. Finally, based on the result of the two vectors, the new velocity of the victim is determined as vector 6. To attack, the distance of cheetahs to the victim must reach a certain threshold. The best distance is between 30 to 100 meters. Therefore, the locations of the victims are randomly adjusted in the mentioned range. One of the important criteria for starting an attack is Attention.

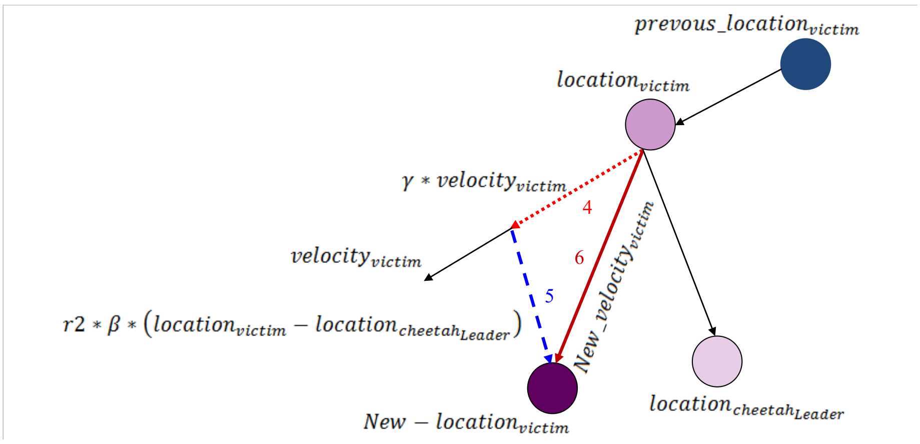

Figure 3: The direction of the victim movement

The Attention of each object (cheetah or victim) is calculated as follows:

$$\text{Attention\_(object\_i)} = \text{(Fitness(object\_i))/(\_i} = \text{1\^{}N)MAX(Fitness(object\_i))} \quad (1)$$

where $\text{Fitness}(\text{object}_i)$ is the fitness value of object_i and $(_i = 1^N \text{MAX}(\text{Fitness}(\text{object}_i))$

represents the highest amount of fitness among objects. In fact, values of the Attention are between 0 and 1. To attack, the cheetah_Leader must have more Attention than victim. The cheetah with the highest fitness is known as cheetah_Leader. The movement of each cheetah is affected by movement of the victim and is updated as follows:

$$\text{velocity\_(cheetah\_i)} = 〚\omega * \text{velocity}〛\text{\_(cheetah\_i)} + r1 * \alpha(〚\text{location\_victim} - \text{location}〛\text{\_(cheetah\_i))} \quad (2)$$

$$\text{New} - \text{location\_(cheetah\_i)} = \text{location\_(cheetah\_i)} + \text{velocity\_(cheetah\_i)} \quad (3)$$

where ω is the inertia weight. The weight of inertia controls the effect of past velocities on present velocities. In this study, the weight of inertia decreases linearly. The algorithm usually starts moving with a large amount of the weight inertia, which causes a large search space at the beginning of the algorithm, and this weight decreases over time, which causes the search within a small space at the final steps. In fact, inertia indicates how much the cheetah wants to maintain its current state of motion. A lower amount of inertia results in faster convergence of the algorithm, and increasing the amount of inertia increases the number of sudden movements of the cheetahs. velocity_(cheetah_i) represents the velocity of the cheetah_i. α indicates the influence of the location of the location_(victim) on the location of the cheetah_i. location_victim shows the location of the victim. Location_(cheetah_i) represents the current location of the cheetah_i. r1 is a random function with a uniform distribution between 0 and 1 that is used to increase random search and maintain the random nature of the algorithm. During the hunting process, if cheetah_(Leader) improves its fitness, it will not be able to catch the victim and the new location of the victim will be updated as follows:

$$\text{velocity\_victim} = 〚\gamma * \text{velocity}〛\text{\_victim} + r2 * \beta * \left(\text{location}_{\text{victim}} - \text{location}_{\text{cheetah\_Leader}}\right) \quad (4)$$

$$〚\text{New} - \text{location}〛\text{\_victim} = \text{location\_victim} + \text{velocity\_victim} \quad (5)$$

where γ is the inertia weight, location_victim is the current location of the victim,. β is the change percentage in the fitness improvement of cheetah_Leader,. and r2 is a random function with a uniform distribution between 0 and 1. The fact that cheetah_Leader is selected based on the distance and attention factors prevents the algorithm from falling into the local optimization. A local optimum of an optimization problem is a solution that is optimal (either maximal or minimal) within a neighboring set of candidate solutions. The two most important factors in meta-heuristic algorithms are diversification and intensification. In the CHOA algorithm, with increasing the attention of the victim, the cheetah has to search a wider space, and diversification increases. Also, if the attention of the victim is low, the cheetah will hunt locally, which means that the intensification will increase.

3. System Design

This study developed a PSO approach, termed CHOA + SVM, for feature selection in the SVM. For the feature selection, if n features are required to decide which features are chosen, then n decision variables must be adopted. The value of n variables ranges between 0 and 1. If the value of a variable is less than or equal to 0.5, then its corresponding feature is not chosen. Conversely, if the value of a variable is greater than 0.5, then its corresponding feature is chosen. Figure 4 illustrates the solution representation.

Figure 5 shows the flowchart for CHOA + SVM. First, the population of particles is initialized, each cheetah having a random position within the D-dimensional space and a random velocity for each dimension. Second, each cheetah's fitness for the SVM is evaluated. The each cheetah's fitness in this study is the classification F-measure. If the fitness is better than the cheetah's best fitness, then the position vector is saved for the cheetah. If the cheetah's fitness is better than the global best fitness, then the position vector is saved for the global best. Finally the cheetah's velocity and position are updated until the termination condition is satisfied.

F1	F2	…	Fn
1	0		1

Figure 4. Solution representation.

In order to provide a basic idea of the proposed approach performance, a comprehensive plan is presented on how to select features from the initial datasets, as well as the evaluation of these sub-features, as shown in Figure 5.

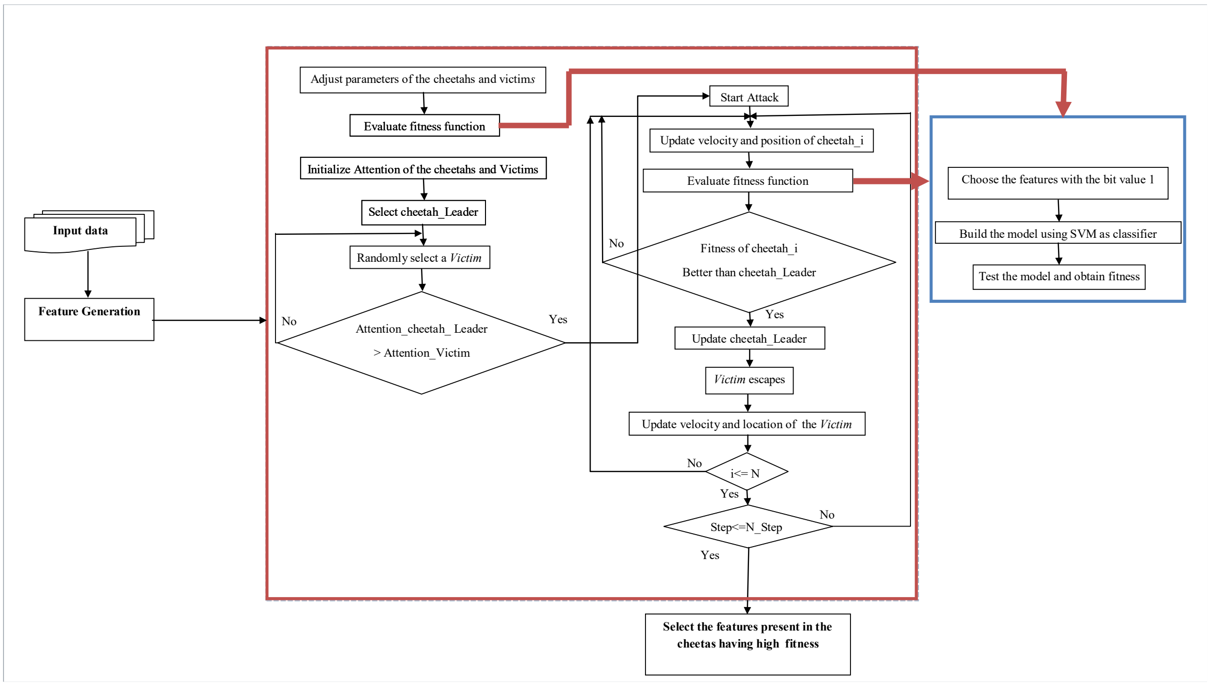

Figure 5: The Proposed Feature Selection based on CHOA

As shown in Figure 5, after feature generation, a subset of the features is selected by using the CHOA algorithm. Then, a model is constructed based on the selected features, and their performance criterions are evaluated by the SVM classifier along with the one-versus-rest approach as well as evaluation methods such as the K-flod Cross-Validation and Booting.

3.1. Feature Selection

The feature selection is used to identify a subset of features that maintain the predictive efficiency at an acceptable level. In order to compare the results of the CHOA algorithm with other algorithms, the common and well-known ACO and PSO algorithms are used in this study. All three algorithms are in the category of evolutionary algorithms inspired by the natural selection process.

3.2. Evaluation of Classifier

Two methods of K-Flod Cross-Validation and Bootsting (Kohavi, 1995) are used to evaluate the performance of the classifiers. The K-Flod method is used for problems with a low number of features, and the Bootsting method is also used in cases where the number of features is moderate or high. In the K-Flod method, the dataset is divided into k equal parts. The k-1 section is used as a training dataset to build the model and evaluation operation is carried out with one remainder part. The process will be repeated to k times. The evaluation of the final accuracy of the classifier is equal to K average of calculated accuracy. Unlike the K-Flod method, in the Bootsting method, a record has previously used in training phase, can be reused for training. That is, the training records are selected by sampling with inserting from the original datasets.

3.3. One-Versus-Rest method

In cases where the number of clusters is more than two clusters, finding the boundaries of classification is more complicated. One of the methods that makes binary classification possible for classifying multi-class problems is the one-versus-rest approach (Rocha & Goldenstein, 2014). The use of this method in multiclass classes such as decision trees and neural networks often reinforces classifier. In this paper, a SVM classifier is used along with the one-versus-rest approach to better evaluate the model.

3.4. Evaluation criteria

In this section, the most important criteria for evaluating the performance of classification are introduced. The concept of confusion matrix is described before examining a variety of classification criterions. This matrix classifies the algorithm as for the input dataset according to the type of problem clusters, and Table 1 presents a confusion matrix for the two-classes classification problem.

		Predicted Label	
		Positive	Negative
Actual label	Positive	True Positive (TP)	False negative (FN)
	Negative	False Positive (FP)	True negative (TN)

Table 1: Confusion Matrix for the two classes classification

In many articles, the accuracy criterion is used as a performance criterion for classification. However, this criterion solely is not an appropriate criterion for evaluating the performance. The reason for this is that in the accuracy relationship, the value of the records of different clusters is considered the same. Therefore, if in a specific application, the value of a cluster differs from that of another, then the correct or wrong prediction of the label of that cluster will have a different benefit or disadvantage relative to the records of the other clusters. Therefore, Precision, Recall, F-Measure and ROC criterions along with Accuracy (Hossin & Sulaiman, 2015) are used to measure performance, as shown in Table 2.

Criterion	Formula
Accuracy	(TP+TN)/(TP+TN+FN+FP)
Precision	TP/(TP+FP)
Recall/Sensitivity	TP/(TP+FN)
Specificity	TN/(TN+FP)
F-Measure	(2×Pre×Recall)/(Pre+Recall)
ROC Area	Cumulative distribution function between Sensitivity and 1- Sensitivity

Table 2: Performance criteria

Accuracy indicates the number of samples that are properly classified. Precision checks whether the number of correct examples is categorized, how many to the positive category. Sensitivity and Recall indicate that the number of positive samples is properly classified. The F-Measure is, in fact, an average between the accuracy and Recall parameters, and is used in cases where the importance of each Recall and Pre cannot be significant. The Specificity states how many negative samples are correctly classified. The ROC curve is derived from the cumulative distribution function between sensitivity and 1-specificity and in the modeling, the surface under the ROC curve is used to measure the accuracy of the model. If the ROC sub-curve is closer to 1 the model's accuracy at a good situation and closer to 0.5 is indicative of the low accuracy of the model and the inappropriate prediction of the model.

Therefore, by studying the CHOA algorithm, its use in feature selection and clustering customers, as well as the use of feature correlation, local search and hybrid structure of collective learning, a framework, is proposed that aims to increase the recognition rate of customers who theft electricity.

4. Adjustment of Experiments

In order to experiment the proposed method and compare the results with the results of other methods, adjusting the parameters and using reference datasets are required. In this section, these experiments are performed using reference datasets.

4.1. Dataset

To evaluate the efficiency of the CHOA + SVM combination method, Vowel, Wine, WDBC, Ionosphere, Sonar and Glass datasets are used. Table 3 shows the characteristics of these datasets. These datasets are available from the UCI data repository.

Dataset	Number of instances	Number of classes	Number of features
Vowel	528	11	10
Wine	178	3	13
WDBC	569	2	32
Ionosphere	351	2	34
Sonar	208	2	60
Glass	214	6	9

Table 3: The characteristics datasets

Attributes represent the number of table columns related to data. Instances represent the number of records in each table. The number of classes also indicates the number of classes and categories of each record in the table. If the number of features is between 10 and 19, the sample groups are considered as small, if the number of features is between 20 and 49, the sample groups are regarded as medium, and if the number of features is more than 50, the sample groups are as large. In cases where the number of features is small, the K-Flod Cross Validation method is used to evaluate the classifier, and if the number of features is moderate and large, the Bootstrap method is used.

4.2. Experimental Results and Evaluation

To select a classifier in combination with the CHOA algorithm, the initial experiment of the reference datasets without a selectable feature is firstly evaluated by the SVM, KNN and DT algorithms. Algorithm with better performance is selected as fitness function in the CHOA algorithm. First, without the feature selection, on the primary datasets, the result of the classification algorithms is calculated, as listed in Table 4.

No.	Dataset	Number of class	Number of features	Number of instances	Performance evaluation	Classification algorithm (%)		
						KNN	Decision Tree	SVM
1	Vowel	11	10	528	F-Measure(%)	77.40	81.90	83.25
					ROC-Area(%)	63.80	74.63	76.62
2	Wine	3	13	178	F-Measure(%)	88.15	88.69	97.87
					ROC-Area(%)	60.11	65.23	98.54
3	WDBC	2	32	569	F-Measure(%)	89.65	87.26	86.65
					ROC-Area(%)	76.69	78.36	71.13
4	Ionosphere	2	34	351	F-Measure(%)	84.45	92.23	91.12
					ROC-Area(%)	76.66	89.68	88.36
5	Sonar	2	60	208	F-Measure(%)	91.58	90.36	94.36
					ROC-Area(%)	80.06	86.41	88.87

Table 4: The values of evaluation criteria for algorithms without the feature selection

The method of evaluating the performance of the classifiers for the Wine and Vowel datasets is K-Flod method, and that of the WDBC, Ionosphere, and Sonar datasets is Boosting. The brown color indicates the best result of the F-Measure criterion for classification algorithms. Gray color represents the best result of the ROC criterion. According to Table 4, among the classification algorithms, in four datasets, the SVM algorithm shows the best result, so that the values of F-Measure and ROC curves for Vowel dataset are 83.25 and 76.62, respectively, for Wine dataset, respectively equivalent to 97.87 and 98.54, and for Sonar data are 94.36 and 88.87, respectively.

In the second experiment, all three ACO, PSO, and CHOA algorithms use the SVM classifier together with the one-versus-rest approach, which performed better at the previous stage compared to the two classifiers of KNN and Decision Tree. Table 5 presents the comparison results of three algorithms such as ACO, PSO and CHOA. As can be seen from Table 5, CHOA algorithm had the highest value for ROC curve in all datasets and the best value of F-Measure in five datasets. The results show that the CHOA algorithm reduces the number of selected features compared to other algorithms and, at the same time, increases the values of the F-Measure and ROC curves.

No.	Dataset	Number of features	Feature selection								
			ACO			PSO			CHOA		
			Number of features	F-Measure(%)	ROC area(%)	Number of features	F-Measure(%)	ROC area(%)	Number of features	F-Measure(%)	ROC area(%)
1	Vowel	10	8	78.63	80.06	7	80.11	84.32	4	98.23	97.36
2	Wine	13	10	90.18	89.97	8	98.17	98.65	2	100	100
3	WDBC	32	25	86.11	84.44	20	88.69	87.36	10	98.25	98.04
4	Ionosphere	34	30	89.32	90.45	20	91.69	94.74	14	98.87	97.38
5	Sonar	60	48	90.11	90.29	38	89.36	88.74	11	99.32	98.89

Table 5: Comparison of evaluation criteria for ACO, PSO and CHOA algorithms

In another experiment, the proposed method was compared with (Shojaee et al., 2021) research. Table 6 shows the results for Vowel, Glass and Wine datasets. According to Table 6, the CHOA-SVM has higher accuracy.

Dataset	Proposed method(CHOA)	(Shojaee et al., 2021)
Vowel	98.23%	91%
Glass	99.46%	98%
Wine	100%	93%

Table 6: Comparison of Prediction Accuracies of three datasets

In the last experiment, the performance of proposed method has been compared with (Zhang et al., 2020) work. The evaluation criterion is Accuracy. According to Table 7, the Accuracy of proposed method for all three datasets is higher than the (Zhang et al., 2020) work.

No.	Dataset	(Zhang et al., 2020)	Proposed method (CHOA)
1	Sonar	98.08%	99.34%
2	Wine	100%	100%
3	WDBC	97.92%	98.21%

Table 7: Comparison of the Accuracy of the proposed method with (Zhang et al., 2020)

According to the obtained results, it was proved that the proposed method classified the data with high efficiency.

5. Conclusion

This study used the CHOA algorithm to select the features so that accuracy was maintained at its highest level. Initially, without the feature selection, the F-Measure and ROC criterions were computed using the SVM, KNN, and DT classification patterns. The results revealed that The SVM classification had the best performance. Then, F-Measure and ROC criterions were measured using the feature selection algorithms of CHOA, ACO, and PSO. In order to evaluate the classification algorithm, the K-Flod method was used for small sample group testing problems and for the problems of testing medium and large groups, the Bootstrap method is used. The comparison of three ACO, PSO, and CHOA algorithms showed that the CHOA algorithm improved the F-Measure and ROC curves by decreasing the number of selected features. Therefore, the CHOA algorithm is suitable for the feature selection problem and can handle datasets with a high number of noisy and unrelated features. Nevertheless, the CHOA-based approach is not restricted to SVMs and can be easily extended to work in combination with other kernel methods, such as Gaussian process regression and classification. Future works include improving the convergence properties of CHOA on the feature selection problem, perhaps investigating an alternative selection strategy.

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21. Providing an efficient framework for power theft detection based on combination of Raven roosting optimization algorithm and clustering and classification techniques

Hassan Ghaedi
Department of Computer, Khormuj Branch,
Islamic Azad University
hassan.ghaedi@iau.ac.ir

Sahar Soleimani
Department of Computer, Khormuj Branch,
Islamic Azad University
s.soleimani@samabushehr.ac.ir

Abstract

One of the main concerns of power generation systems around the world is electricity theft. One of the goals of the Advanced Measurement Infrastructure (AMI) is to reduce the risk of electricity theft in the electric smart grids. However, the use of smart meters and the addition of a security layer to the measurement system paved the way for electricity theft. Nowadays, machine learning and data mining technologies are used to find abnormal patterns of consumption. The lack of a comprehensive dataset about abnormal consumption patterns, the issue of choosing effective features, the balance between consumer's normal and abnormal consumption patterns, and the choice of type and number of classifiers and how to combine them are the challenges of these technologies. Therefore, a detection system for electricity theft that is capable of effectively detecting theft attacks is needed. To this end, a framework including data preparation phases, feature selection, clustering, and combined modeling have been proposed to address the aforementioned challenges. In order to balance normal and abnormal data, 6 artificial attacks have been created. Moreover, with respect to the Chief element in the Raven optimization algorithm and its two-step search feature, this algorithm has been used in feature selection and clustering phases. Stacking as a two-step combined modeler has been used to strengthen the prediction of accuracy. In the second step of this modeler, the meta-Gaussian Processes algorithm is used due to the high accuracy of detection. The Irish Social Science Data Archive (ISSDA) dataset has been used to evaluate performance. The results show that the proposed method identifies dishonest customers with higher accuracy.

Keywords: Power theft Detection, Classification, Feature selection, smart power grid, Clustering.

1. Introduction

In smart power grids, it is important to know the amount of power consumed by customers in a moment is necessary so as to accurately predict and plan the electricity demand in the future. In the smart power systems, if a user by a normal consumption is detected as a dishonest user, the system is not damaged, however, if a dishonest user is detected as a right user, the system will be damaged so that if the total number of these users is high, the system will be damaged more. Many studies have been done to explore electricity theft using machine learning and data mining technologies through customer consumption patterns, but each has some kind of challenge. One of these challenges is the lack or deficiency of existing samples of abnormal consumption of electricity customers. For example, there are no or a few abnormal samples for a customer. The existence of abnormal and manipulated samples of consumption can make it easier to identify dishonest customers for classification. Thus, the lack of a comprehensive Dataset, which includes both normal and abnormal samples, limits the discovery rate of theft. That is why a comprehensive and balanced Dataset is required. Another challenge is the lack of attention to the issue of feature selection. Removing some features may not have any effect on the final result of detection, and the failure to select some of the important features can have a significant effect on the correct detection of the classification result. By converting the property selection issue into an optimization issue, it can be solved by a meta-heuristic algorithm and extracted important features. The selection of type and number of classifiers and how to combine them are other challenges of using data mining techniques in the issue of electricity theft detection, in which often one classifier or sometimes two classifiers have been used. Therefore, an electricity theft detection system that is capable of effectively detecting theft attacks is essential. Several studies have been carried out to detect electric theft using data mining techniques through customer consumption patterns, however, each has some challenges, as mentioned before. One of these studies has done by (Jokar et al., 2016) the strength of their research is the use of single-class and multi-class support vector machines to detect theft. Moreover, the abnormal samples of customer consumption were also slightly produced in their research. One of the weaknesses of this research is the imbalance between normal and abnormal samples of customer consumption. In fact, the low number of abnormal samples has challenged classifiers to detect electricity theft. The use of the support vector machine (SVM) classifier alone and the lack of use of other methods, especially the combination methods, have challenged their research study. Therefore, the main goals of this research are to create a balance between normal and abnormal examples of customer consumption and increase the accuracy of electricity theft detection using combined classification methods and selecting important and effective features. This research study is organized as follows: Section 2 reviews the previous works. The Black Raven Optimization algorithm is reviewed in Section 3. Section 4 describes the proposed framework. Examinations and evaluations are discussed in Section 5 and Section 6 is dedicated to the research conclusions.

2. Related Works

Considering the importance of detecting and discovering electricity theft from smart grids, many research studies have been carried out over the past few years. In this section, some of them which have used data mining techniques are discussed. (Jeyakumar & Devaraj, 2018) proposed a new approach to identifying suspect customers using a consumption pattern. So that, if there is a difference between the produced electricity and the consumed electricity in a district, all customers belonging to that area are considered a suspect. In their research, customers were classified into the K cluster using the k-nearest neighbors (KNN) algorithm and by using the normal customer profiles, three types of abnormal customers were generated. A readout was made for each customer every half hour, and the customer profiles were categorized using the artificial neural network (ANN) algorithm. To evaluate the efficiency of the proposed method, the Accuracy and Error Rate parameters were used. The drawback of the proposed method is that electricity theft is based on the assumption that suspected customers are fraudulent customers. As reported by (Sowndarya & Latha, 2017), AMI provides two-way communication between the power industry and customers, which eliminates manual intervention in reading the meter. In spite of the advantages of smart meters, there are some disadvantages related to these meters. Manipulating smart meters may not be possible, however, electricity theft is still possible by bypassing smart meters. In their research, a new framework detects fraudulent customers based on customer consumption patterns. Because the KNN algorithm has the ability to retrain, it reinforces the proposed framework against unwanted changes in the consumer pattern. The disadvantage of this method is the lack of existing examples (samples) related to customer’s abnormal consumption patterns. (Yeckle & Tang, 2018) stated that AMI is a major component of grid networks that is responsible for collecting, measuring, and analyzing customers' energy consumption. Despite the advances, new problems have arisen in AMI, particularly electricity theft. To cope with these challenges, Dataset related to consumption data was analyzed. Their research provides the possible use of outlier data detection algorithms to increase AMI security. The performance of the proposed algorithm is examined on a real Dataset, and a data preprocessing method is also performed by the K-means clustering algorithm with the aim of reducing the number of sample measurements per day. (Jokar et al., 2016) used single-class and multi-class support vector machines to discover fraudulent customers. They create a balance between true and dishonest data by creating a new dataset using manipulated data by customers. (Feng et al., 2020) presented an algorithm for detecting abnormal power consumption patterns based on local matrix reconstruction (LMR). Five daily load characteristics were used instead of high daily amplitude load curves and PCA technique to calculate weighted regeneration errors. (Zhang et al., 2020) proposed a feature engineering-based method for detecting abnormal power consumption behavior. First, the main features were created by brainstorming. Then, the optimal features were obtained based on the variance and similarity between the selected features. (Nazmul Hasan et al., 2019) proposed a hybrid power theft detection system that combines a convolutional neural network (CNN) with long short-term memory (LSTM). Since power consumption is time-series data, the CNN-LSTM model was used for classification, and a technique based on local values was employed to calculate missing items. In their study, Li et al. (Li et al., 2019) proposed a hybrid model based on CNN and random forest (RF) to detect power theft. In this model, CNN was first used to learn features between different hours of the day and different days extracted from smart meter data. A dropout layer and a back-propagation algorithm were used in this model to reduce over-fitting and update network parameters in the training phase, respectively. The RF was then trained based on the characteristics obtained to determine whether the customer was robbing or not. Although much research has been done in identifying and detecting theft by using data mining, the challenges still are there such as not paying attention to abnormal` samples of customers in datasets, the issue of effective feature selection as well as the type and number of classifiers and so on. In the light of the above-mentioned facts, this research tries to address the aforementioned challenges with the help of Raven roosting algorithm in combination with other methods.

3. Raven Roosting Optimization (RRO) Algorithm

The Raven Roosting optimization (RRO) algorithm is inspired by the process of feeding and gathering a bird called the common Raven, developed by (Jokar et al., 2016). According to RRO algorithm, after selecting an accumulation place, the algorithm parameters are set. The location of the Ravens is then randomly selected (a potential food location) and the fitness value of each N Raven is evaluated, and the Raven located in the best location is selected as Chief. After that, a percentage of the Ravens (PERCfollow) is used to leave the roosting site randomly within a radius of Rchief and others will look for food at their best location.

All Ravens memorize one of their searches (SEARCH) for the source of food during the flight to the destination. Ravens perform this process by dividing their flight into Nstep so that the length of each step is randomly selected. Each Raven at each step senses the quality of its step point and searches for a range within the radius of Rpcpt. If amongst these locations, it finds a better location than its best personal one, there is one percent chance of Probstop that the Raven stopped flying at that point and doing a search at that new location; otherwise, it performs the next flight stage and keeps moving on to its destination. In Ravens' foraging algorithm, a feeling mechanism has been embedded whereby followers perceive other locations on the path, and if they find a better location than their own, they will accidentally stop in these locations. For ravens that reach their destination (in the vicinity of the Chief or the best own), if the best personal locations need to be updated, they will be updated and fitness function will be evaluated for each Raven. Finally, if the location of the best solution also needs to be updated, it will be updated.

4. The Proposed Method

Given the importance of detecting electricity theft and the existence of challenges mentioned in the previous sections, it is necessary to provide a method for addressing and solving these challenges. Here, the RRO algorithm is used in the phases of feature selection and clustering in order to better identify and increase the accuracy of electricity theft detection. According to Figure 1, the proposed method involves several executive phases. In the first phase, which is known as the data preparation phase, pre-processing operations are performed. The electricity may not be consumed during the hours of night or days of the year and the value of 0 is sent to the control center. Using preprocessing techniques, appropriate data is placed instead of empty values. Moreover, to improve the classification accuracy, the linear normalization of features is done in this phase. In order to improve classification performance, effective features are selected in phase 2. Nowadays, in many aspects of feature selection, meta-heuristic methods, for example, genetic algorithm (GA), ant colony algorithm (ACO) and particle swarm optimization (PSO) algorithms are used to select effective features. Each of these methods suffers from weaknesses.

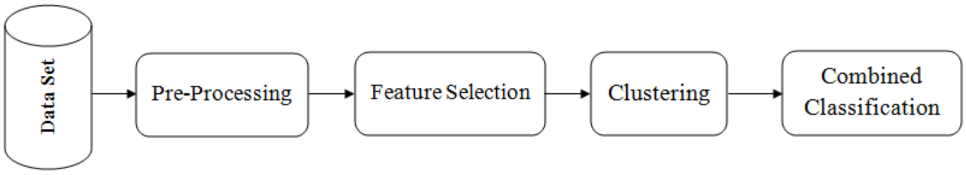

Figure 1: Steps of the proposed algorithm for theft detection

To overcome these problems, a new and more efficient way is needed. Correlation information of features is an important factor in helping the search process. In this phase, an effective 6-step method is proposed based on the RRO algorithm that uses the correlation information of features (Monirul Kabir et al., 2010) to guide the search process in the RRO algorithm. In order to determine the size of the subset of features, a random probability function is used, according to the following Eq.(1):

$$p_s = \frac{f - s}{\sum_{i=1}^{p}(f - i)} \quad (s \le f) \tag{1}$$

Where f and s are the number of initial Dataset features and selected features, respectively; p is the difference between f and s (p = f-s), and ps is the probability value of determining s as the initial number of features. According to Eq.(1), the probability value of the ps increases, if s value is lower. The value of s is randomly selected in the range of [3, k] (k=∊×f). Indeed, the grouping of features is the division of features into groups of similar objects with the aim of finding the relationship between features, so that the algorithm is capable to select the privileged features (Monirul Kabir et al., 2010). In this research, the Pearson correlation coefficient is used to measure the correlation between different features of a Dataset. The greater the correlation coefficient between the two features, the more similar the two features. The correlation coefficient between the two features i and j are shown by rij and is obtained according to Eq.(2):

$$\mathrm{rij} = \frac{\sum_{k=1}^{m}(\mathrm{xi(k)} - \overline{\mathrm{xi}})(\mathrm{xj(k)} - \overline{\mathrm{xj}})}{\sqrt{\sum_{k=1}^{m}(\mathrm{xi(k)} - \overline{\mathrm{xi}})^2)}\sqrt{\sum_{k=1}^{m}(\mathrm{xj(k)} - \overline{\mathrm{xj}})^2)}} \tag{2}$$

where m is the number of samples, and xi(k) and xj(k) are the values of the features i and j for the sample kth, respectively. The variables $\overline{xi}$ and $\overline{xj}$ are, the mean of xi and xj for the m sample, respectively. After calculating the correlation coefficient for all possible components of features, the correlation of each feature i is calculated according to Eq.(3).

$$cori = \frac{\sum_{j=1}^{f} |rij|}{f-1} \quad if \;\; i \neq j \tag{3}$$

where f is the total number of features. A higher correlation value indicates the higher similarity of the feature with other features. To build two groups of features, RRO-LS algorithm arranges features ascending based on their correlation values. The first half with less correlation is placed in the unlike group(U=unlike) and the second half in the Alike group(A=Alike). In the proposed method, each Raven is identified by a binary vector. The length of each vector is equal to the number of initial features, and if the values of one cell of the vector are equal to 1 or 0, it means that the corresponding feature has been selected or not been selected, respectively. Firstly, the initial location of each Raven is randomly initialized. In the RRO algorithm, on each flight, the location of each Raven changes in a Rpcpt radius of a circle according to Eq.(4).

$$\mathrm{NewLoc} = \mathrm{Rv}(\mathrm{j},:) + \mathrm{rand}(1,\mathrm{D}) + \mathrm{Rpcpt} \tag{4}$$

where Rpcpt is the radius of the flying circle and Rv(j, :) is the initial location of the Ravens.

Then, according to the group Chief, the location of the follower Ravens, in a circle with the Rchief radius, is expressed according to Eq.(5).

$$\mathrm{NewLoc} = (\mathrm{Chief} \; - \; (1 - 2 \; * \; \mathrm{rand}\,(1,\mathrm{D}) \; * \; \mathrm{Rchief}) \tag{5}$$

With a local search strategy, a classifier can learn all important information about a Dataset and plays a key role in the proposed algorithm (Kabir et al., 2011). To carry out local search operations, two stages are considered including the segmentation of features and Ravens displacement. For each Raven, the Add and Dell operators are used so as to improve their local search. In this way, a Raven uses the Add operator to add a number of desirable features and uses the Dell operator to remove a number of features from its location. In this strategy, firstly, the number of bits 1 generated from a newly Raven, for example, 01101011, is identified and is placed into a subgroup called F.

$$F = \{F_2, F_3, F_5, F_7, F_8\} \tag{6}$$

Then each element of F is compared with members of A and U sets and divided into two subgroups FA and FU. FA means that all alike features are located in both A and F sets. FU means that all unlike features are located in both U and F sets. Then all FA and FU features are arranged in ascending order based on their correlation values. The most important step is the Raven displacement. At this stage, the number of bits 1 generated in Raven must be managed. For this purpose, according to Eq.(7), the values of nA and nu, which represent the number of alike and unlike features, respectively, are calculated as follows:

$$n_u = \alpha . S, \qquad n_A = (1-\alpha)S \tag{7}$$

where α the control parameter controlling the nu; s is the size of the subset of the selected features. With two Add and Dell operators, the features are added to or removed from the Raven. Whenever $|FU| < n_u$, then, the number of (nu-FU) features in (U-FU) is added to Raven by Add operator, otherwise, with the Dell operator, the (FU-nu)features in FU should be removed from the Raven. Besides, if $|\mathrm{FA}| > \mathrm{n_A}$, the number of (FA-nA)features in FA is removed from the Raven by Dell operator, otherwise, with the Add operator, the (nA-FA) features in (A-FA) arebeing added to the Raven. Then, the new Dataset is divided into two teaching and testing groups, and the 10-flod cross-validation method is used to evaluate each Raven using the KNN classifier. At the end, the value of the fitness function is compared to the best overall value and Chief, and updates are done. In the third phase, data clustering is performed in such a way that the data is clustered using the proposed RRO-CL algorithm. The goal of this phase is to label the normal and abnormal data in order to build appropriate models for the classification of new customers. In this algorithm, data is split into the desired clusters using the RRO optimization algorithm. Figure 2 illustrates the proposed algorithm for data clustering. In the following, the steps of the proposed algorithm for clustering RRO-CL are explained. Step 1: Adjustment of the parameters including the number of Ravens; the domain of the problem, the perception radius of the Ravens, the group Chief radius, the number of execution stages, the number of followers, and so on. Then each Raven is randomly assigned an initial location of Xind. Since each Raven is represented as vector with k cluster centers, Xind is shown as:

$$Xind = (Ci1, Cij, \dots, Cik) \tag{8}$$

Cij represents jth cluster center for the ith Raven.

Step 2: Each Raven will randomly be initialized with the initial location x. Step 3: At the start, the values of pbest and Chief are initialized with an infinity value of inf, then for each Raven the fitting value is calculated according to Eq.(9)

$$Fitness = \sum_{j=1}^{k} \left[\sum_{x \in mij} |x - Cij| \right] \tag{9}$$

where x is the input data vector; mij is the number of data for jth cluster from the ith Raven, and Cij represents jth cluster center for the ith Raven. Step 4: Regarding the obtained fitting value, the values of pbest and Chief are updated and the location of each Raven is updated according to Eqs. (10) and (11):

$$\mathrm{NewLoc} = \mathrm{Rv(j,:)} + \mathrm{rand(1,D)} + \mathrm{Rpcpt} \tag{10}$$

$$\mathrm{NewLoc} = (\mathrm{Chief}\ -\ (1 - 2\ *\ \mathrm{rand}\ (1, \mathrm{D})\ *\ \mathrm{Rchief}) \tag{11}$$

Step 5: The Kmeans algorithm calculates the Euclidean distance of the input data to all cluster centers for each Raven and the cluster of each data is specified. Step 6: The cluster centers are re-calculated and the location of each Raven is calculated based on the new centers. If the result is desirable, the algorithm is finished otherwise the third step is returned.

In the fourth phase, data modeling is done. For data modeling, there are several modelers including logistic regression(LR), support vector machine (SVM), decision tree(DT), neural network(NN), and k-nearest neighbors. The combined structure of collective learning is also an effective way of machine learning, in which the results of several simple modelers are combined together to improve the learning accuracy.

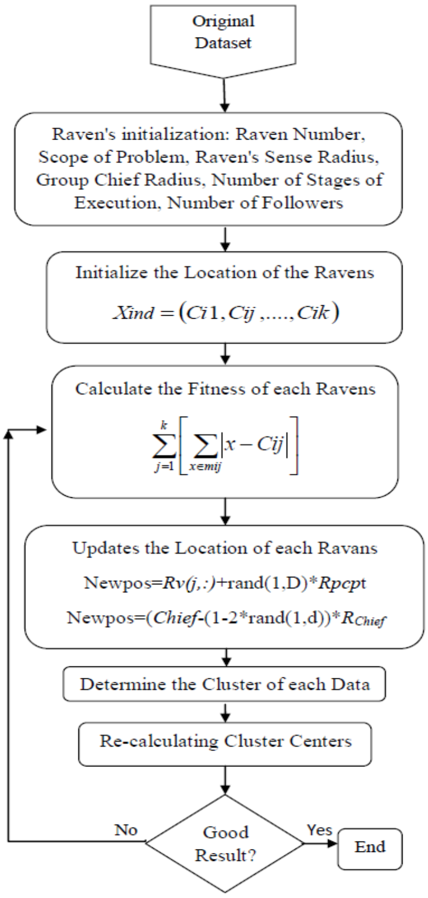

Figure 2: The proposed clustering algorithm

The classifiers'composition consists of 2 sections. The first part involves the creation of classifiers with an appropriate basis, the election of type, and the number of classifiers. The second part involves combining the output of classifiers in order to obtain the best result for the classification of patterns. In this research, the hybrid stacking algorithm (Wolpert, 1992) is used to increase the recognition rate of the hybrid classification system. Stacking consists of two phases. In the first phase, a set of basis classifiers is produced and in the second phase, a meta classifier is trained to combine the output of the basis classifiers. The most important issue in the stacking method is selecting features and an appropriate algorithm for learning at meta-level. Various algorithms such as SVN, NN, KNN, etc. are used at the meta-level. In this research, meta-level Gaussian accumulations (Xu et al., 2009) are used due to the nature of flexible non- parametric, providing predictive distribution and a simple and effective learning process. Due to study limitations and shortcomings associated with electricity theft discovery, it is highly required a method to cover these problems. Therefore, by studying the RRO optimization algorithm, its use in feature selection and clustering customers, as well as the use of feature correlation, local search and hybrid structure of collective learning, a framework, is proposed that aims to increase the recognition rate of customers who theft electricity.

5. Experiments and Analysis

In this section, according to the proposed framework, various tests are conducted in each phase, and the results are analyzed. Furthermore, the results of the proposed algorithm are compared with literature data.

5.1. Dataset

The ISSDA dataset was used to conduct tests and analyze the results by considering the importance of electricity theft and the need for a reference dataset with customers' power consumption data. The ISSDA (*Irish Social Science Data Archive*, 2012) is the consumption data of 5,000 smart meters for domestic and commercial Irish consumers, released by SEAI in 2012. The most important reasons for using this dataset in the present study are the large number of customers and their variety, as well as the length of the measurement time. In this dataset, for every customer, consumption data are saved every half an hour during the day, reducing the sampling rate per hour. The consumption data of 535 days are saved for each customer. One of the challenges of the discovery of electrical theft based on the pattern of customer consumption is the lack of a reference dataset from customers' abnormal consumptions. The ISSDA dataset only includes normal data from customers' consumption. In the first phase, after the data preprocessing, artificial attacks are created and an abnormal data sample of each customer's consumption is added to this dataset. These artificial attacks are in some way an indication of the possible manipulations of submitted data by customers in the declaration of their actual consumption. These artificial attacks can be made using the equations presented in Table 1. For example, for the ISSDA dataset in which the sampling rate is computed per hour, each sample is represented as y = {y1, ..., y24}, and 6 attack types are created.

Attack Formula	Description
$f_1(y_t)=a*y_t$, a=random(0.1,0.9)	Multiply all attributes in a constant random amount a
$f_2(y_t)=a_t*y_t$, a_t=random(0.1,0.9)	Multiply each attribute in a random amount
$f_3(y_t)=a_t*mean(y)$,a_t=random(0.1,0.9)	Multiply the mean of readings in a random amount
$f_4(y_t)=mean(y)$	Average readings during a day
$f_5(y_t)=y_{24-t}$	Changing the readings of a day.
$f_6(y_t)=\begin{cases} 0 & \forall t \in [ts, tf] \\ y_t & otherwise \end{cases}$	It is a by-pass attack that sends a value of zero at a specified time interval [ts, tf], otherwise, it sends the actual amount of consumption.

Table 1: Artificial attacks to generate the unusual samples in the ISSDA dataset

The artificial attack example created for each customer is added to the original dataset as manipulated and abnormal data.

5.2. Experiments

In this section, the experiments related to the phases of the proposed framework are explained. After normalizing and pre-processing data in the first phase, the effective features in the final detection are extracted in the second phase. The RRO-FS (raven roosting feature selection) technique is applied to the ISSDA dataset. Table 2 shows the accuracy of each algorithm on this dataset. It can be seen that the accuracy of the RRO-FS algorithm is better than the other algorithms. Table 3 presents the features extracted from the ISSDA dataset by GA, ACO, PSO, and RRO-FS algorithms.

Dataset	GA	ACO	PSO	RRO-FS
ISSDA	78.30%	75.82%	81.32%	88.11%

Table 2: The Accuracy of RRO-FS algorithm compared to GA, ACO, and PSO algorithms

Algorithm	Selected attributes
GA	f7,f10,f12,f13,f15,f18,f19,f20,f21,f23
ACO	f4,f6,f7,f8,f14,f15,f16,f22,f23,f24
PSO	f7,f8,f9,f12,f13,f14,f19,f20,f23,f24
RRO-FS	f11,f12,f14,f15,f19,f20,f21,f22,f23,f24

Table 3: Selected attributes from ISSDA using GA, ACO, PSO, and RRO-FS algorithms

In the third phase of the proposed framework, after selecting the desired features, the normal and abnormal data were clustered into three different clusters using the RRO-CL (raven roosting-clustering) technique, and the assigned cluster number represents the class label of each data. In this phase, in order to evaluate and analyze, the results of the proposed clustering algorithm RRO-CL were compared with the K-means, SOM, and PSO clustering algorithms. In our study, the Squared Euclidean distance (SED) index which is stronger and more robust than other indicators, was used to evaluate the cluster efficiency. The lower the SED value, the better result. Each test was carried out 30 times and the average was considered the final SED value, as shown in Table 4.

Dataset	Clustering algorithm			
	KMEMNS	SOM	PSO	RRO-CL
ISSDA	163.68	174.32	156.35	121.97

Table 4: The SED for clustering algorithms K-means, SOM, PSO, and RRO-CL

From the data presented in Table 4, the SED value of the proposed RRO-CL algorithm is lower than other algorithms. For example, the SED value is 121.97. This indicates a better efficiency of the RRO-CL technique in comparison to SOM, PSO, and K-means algorithms. After clustering the data and identifying the cluster number of each data, it is necessary to build a model for the classification of new data. A stacking hybrid algorithm that includes two phases was used in the proposed framework. Before using the hybrid method, the accuracy of the simple modelers such as NN, SVM, LR, and KNN for the ISSDA dataset is calculated. Table 5 elucidates the results of these predictions.

Algorithm / criterion	NN	SVM	LR	KNN
Accuracy (%)	89.67	91.45	86.17	78.7

Table 5: The Accuracy of NN, SVM, LR and KNN Classifiers

Stacking is now used to predict the Accuracy of the ISSDA dataset with different meta-algorithms. Table 6 shows the prediction accuracy of different meta-algorithms in stacking.

In the proposed framework, the basic algorithms were used such as LR, SVM, KNN, and NN, and meta-Gaussian Processes. According to Table 6, its accuracy is higher than hybrid methods with KNN and NN meta algorithms. Furthermore, by comparing the results of Tables 5 and 6, it was found that the stacking hybrid method with the meta-Gaussian Processes algorithm is better than the basic and individual algorithms presented in Table 5. According to Table 5, the accuracy prediction value using the KNN algorithm is 78.7%, while that of KNN meta-algorithm shown in Table 6 is equal to 88.11%.

Basic Algorithms	Meta Algorithm	Accuracy(%)
LR, NN, SVM	KNN	88.11
LR, SVM,KNN	NN	91.56
LR, SVM, KNN, NN	Gaussian Processes	97.75

Table 6: Comparison of the accuracy with different meta algorithms in Stacking

Additionally, from Table 5, the accuracy prediction of the NN algorithm is 89.67%, while that of the combined method with meta-Gaussian Processes prediction is 97.75%. Therefore, these results disclose that the proposed framework has higher accuracy in comparison to other methods and can be regarded as a reliable framework. It should be noted that in the literature mostly the accuracy criterion is used as the benchmark for evaluation of classifiers performance, however, using this criterion solely is not suitable especially for the unbalance data due to the significance numerically difference between their number of positive and negative labels in the real world. Therefore, the f-score criterion, which is derived from the combination of recall and precision criteria, was used to evaluate the efficiency of classifiers. Ideally, its value is 1 and it is zero in the worst case. Another important criterion for assessing the efficiency of classifiers is the Area under Curve (AUC) criterion. This criterion represents the area below the Receiver Operating Characteristic (ROC) chart. The ROC curve is a two-dimensional curve whose X-axis is FPR and then the Y-axis is TPR. The more accurate the model, the AUC is closer to 1, and this number is closer to zero if the classifier performance is weaker. Table 7 shows the evaluation results of the F-score and AUC criteria for the proposed framework on the ISSDA dataset.

Dataset	Accuracy%	Recall%	Precision%	F-score%	AUC%
ISSDA	97.75	97.82	98.22	98.02	98.14

Table 7: The Accuracy, Recall, Precision, F-score, and AUC, using the proposed framework

The data in Table 7 shows that both the F-score and AUC criteria yielded a high percentage of desirability in the proposed framework. In another experiment, the results of the proposed algorithm were compared with the experimental results reported by (Jokar et al., 2016) on the ISSDA dataset, as shown in Table 9. In one of the experiments, only normal samples and in another experiment only the f2(yt) attack (see Table 1) were used for data training. Table 9 shows the results of these experiments.

Experiment	DR(%)	FPR(%)
Using Normal Samples for Training(Jokar et al., 2016)	76	29
Only h3(xt) Attack was Used for Training(Jokar et al., 2016)[a]	86	16
Using Normal Samples for Training in Proposed Algorithm	87	21
Only f2(yt) Attack was Used for Training in Proposed Algorithm	92	11
a h3(xt)=γtxt, γt=random (0.1, 0.8), x={x1,...,x24}, t=1,...,24		

Table 9: Comparison of the results of the proposed algorithm with (Jokar et al., 2016)

According to the results of Table 9, in the case of normal samples for training, the DR and FPR values in the proposed algorithm are 87% and 21%, respectively, however, those reported by Jokar were 76% and 29%, respectively. Moreover, it can be evident that the DR and FPR values are 86% and 16%, respectively, for the case that only h3(xt) was used for training by Jokar, while those in the proposed algorithm were 92% and 11%, respectively, indicating the improvement of these values in the proposed algorithm.

In another experiment, the AUC of the proposed framework was compared with research (Peng et al., 2021). According to the results of Table 10, the AUC of the proposed framework is 98.14%.

Method	**AUC(%)**
Research (Peng et al., 2021)	81.50
Proposed Framework	98.14

Table 10: Comparison of the AUC of the proposed algorithm with research (Peng et al., 2021)

In the last experiment, the accuracy of the proposed framework was compared with the results of literature articles Research(Khan et al., 2020), (Nabil et al., 2019) and (Ibrahem et al., 2019) on the ISSDA dataset. In this experiment, (Jokar et al., 2016) research attacks (6 attacks) were used. According to Table 11, it can be seen the Accuracy of the proposed method is higher than two.

Method	***Accuracy*(%)**
ETDFE(Ibrahem et al., 2019)	93.36
Model1(Nabil et al., 2019)	91.8
Model2(Nabil et al., 2019)	90.2
Research(Khan et al., 2020)	95
Proposed Framework	97.75

Table 11: Comparison of the results of the proposed algorithm with other algorithms

The results of Table 11 indicate that the value of the Accuracy of the proposed algorithm is higher than others works. Therefore, according to the proposed framework, the percentage of accurate prediction of customers who manipulate their metrics and do not send their actual consumption data to the center has improved.

6. Conclusion

In this research, due to concerns related to electricity theft by illegal and dishonest customers, a four-stage framework was proposed for the discovery of abnormal. In the first phase, normalization and pre-processing of data were performed. Then, in the second phase, because of the significance of key feature selection, effective features were selected using the RRO algorithm. Due to the fact that there is no reference dataset covering both normal and abnormal samples of customer consumption, for the ISSDA dataset, abnormal samples were created using artificial attacks before the second phase. In the third phase, inspired by the Raven algorithm, each of the normal and abnormal samples was divided into three clusters and the cluster number was labeled as the data class. In the last phase, data modeling was performed using the Stacking hybrid method, which is a two-step algorithm. In the first step, simple algorithms such as LR, SVM, KNN, and NN algorithms were used and in the second step, the meat-Gaussian Processes algorithm was used for data modeling. The results of each phase revealed that the proposed algorithms had high performance. To evaluate the efficiency of the proposed algorithm, the Accuracy, F-measure, and AUC criteria were used. The results of the proposed algorithm were compared with the literature research and it was found that the results of the proposed algorithm are better. Since robust theft detection is important, it is recommended that the peak periods of consumption in different seasons of the year are involved in the detection process as future work.

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22. Segmentation of App Users in Non-University Education Segmentación de Usuarios de Apps en Educación no Universitaria

F. Javier Rondan-Cataluña
University of Seville (Spain)
rondan@us.es

Jorge Arenas-Gaitan
University of Seville (Spain)
jarenas@us.es

Patricio Ramírez-Correa
Catholic University of the North (Chile)
Patricio.ramirez@ucn.cl

Abstract

Education is one of the most important public services, especially from a budgetary point of view. The objective of this study is to make a segmentation of the users of the Apps to manage the relationships 212of families with educational centers. This segmentation is done through the internet lifestyle scale (e-lifestyle). By discovering the profiles of these users, taking into account their way of acting and using the Internet, educational administrations can take measures to improve the use and satisfaction of users and that this can be reversed in an improvement in the sustainability and results of the educational system. Our results show 3 segments: Internet addicts, neutral users and anti-Internet users, the latter being the smallest group in our study, although it represents 20% of the parents interviewed.

Keywords: electronic tutoring, segmentation, non-university education.

1. Introducción

La pandemia del COVID-19 ha venido a afianzar algunas tendencias que ya existían en nuestra sociedad. Quizás una de las más visibles es la transformación de la sociedad hacia una mayor digitalización. A lo largo de los duros meses de confinamiento, como sociedad, hemos seguido trabajando, relacionándonos, o disfrutando….pero conectados. La digitalización ha ganado peso en todos los aspectos de nuestra vida, también frente a las Administraciones Públicas. Uno de los pilares del actual Estado de Bienestar es la Educación. Desde el punto de vista del Sistema Educativo, un ejemplo puede estar en la relación entre los padres de hijos escolarizados con los profesores, directores, administradores y demás personal del Sistema Educativo. La adecuada gestión de esta relación supone un refuerzo de la Comunidad Educativa en su conjunto (profesores, alumnos, padres, etc.). La comunicación fluida entre los padres y los centros educativos favorece el proceso de aprendizaje de los alumnos mediante un mejor seguimiento, independientemente del nivel de digitalización del aprendizaje (presencial, semipresencial, on-line). En este sentido, las aplicaciones online, como iPasen en el Sistema Andaluz de Educación (Andalucía es la región más poblada de España con 8.5 millones de habitantes), han sido de una ayuda fundamental en estos tiempos.

Hoy, y más en los próximos años, resulta fundamental la digitalización de las administraciones públicas. Datos de la propia Unión Europea señalan que la puesta en práctica del Mercado Único Digital supondría un incremento de unos 415000 millones de euros a la economía europea, y que la digitalización de la relación entre administraciones y ciudadanos supondrá un ahorro de unos 5000 millones de euros anuales para la UE y por supuesto para los distintos países y regiones que la integran. Con estas cifras, la importancia del tema está más que justificada. Si anteriormente se han digitalizado con éxito servicios como la banca o el turismo, ahora ha llegado el momento de la digitalización de las administraciones públicas.

El objetivo de este estudio es hacer una segmentación de los usuarios de las Apps para gestionar las relaciones de las familias con los centros educativos. Esta segmentación se hace a través de la escala de estilos de vida de internet (e-lifestyle) de Yu Son (Son, 2011). Descubriendo los perfiles de dichos usuarios, teniendo en cuenta su forma de actuar y usar Internet, las administraciones educativas pueden tomar medidas que permitan mejorar el uso y satisfacción de los usuarios y que esto pueda revertirse en una mejora en la sostenibilidad y resultados del Sistema educativo. La segmentación de la población nos permite comprobar qué grupos de ciudadanos requieren más ayuda e impulso para la adopción de TICs, y reducir la brecha digital entre los andaluces. Con este fin, se usarán herramientas de segmentación (análisis cluster). Los segmentos que resulten con una mayor brecha digital se podrán abordar con políticas más concretas y específicas para este grupo de ciudadanos con carencias de conocimiento digital.

2. Revisión de la literatura

En este apartado nos vamos a centrar en analizar la importancia del e-government y las Apps educativas en la educación, ya sea pública o privada. En el siguiente apartado analizamos el estilo de vida de Internet como forma de segmentación con respecto a las TIC.

2.1 Importancia del e-government en la educación no universitaria

Desde un punto de vista académico, llamamos “engagement” a un proceso interactivo y bidireccional que genera en los usuarios cambios en su estado cognitivo y en la aceptación de una plataforma digital. Nuestra propuesta tiene como objetivo atender la aceleración de la transformación digital que se está produciendo en la relación entre el ciudadano y las Administraciones Públicas, especialmente en el área de Educación. Potenciado el engagement de los ciudadanos con la administración electrónica (e-Goverment).

Durante todo el periodo de confinamiento debido a la pandemia del Covid-19 que ha tenido lugar en España, y en buena parte del mundo, la digitalización ha servido para mantener puestos de trabajo (teletrabajo), información (medios de comunicación), relaciones (redes sociales), abastecimiento (e-commerce). Sin embargo, sí se ha puesto de manifiesto la necesidad de profundizar en la digitalización de la Administración Pública (e-Goverment). No todos los países comparten la misma situación respecto al uso de la digitalización de la relación entre las administraciones y sus ciudadanos. Por ejemplo, combinando indicadores que miden el porcentaje de ciudadanos con acceso y uso de e-Government y e-Salud, Seddon y Currie identifican tres agrupaciones de países de la Unión Europea (UE): Frontrunners, Seguidores y Rezagados (Seddon & Currie, 2017). Los países líderes muestran perfiles claros que combinan infraestructuras adecuadas de TIC y eSalud, lo que sí se pone de manifiesto en este estudio es la gran brecha digital entre países e incluso entre regiones dentro de un mismo país, como en el caso de España.

Nuestro trabajo se dirige a abordar algunas de las necesidades anteriormente mencionadas usando como herramienta las tendencias que están presentes en nuestra sociedad. Es decir, mediante la digitalización de las Administraciones Públicas (e-Goverment), y de las relaciones con los ciudadanos, pretendemos afrontar la necesidad social de disponer de un Sistema educativo sostenible. La sostenibilidad del Sistema educativo implica entre otras cosas: una mayor igualdad entre los ciudadanos, mejor acceso a los servicios, la reducción de costes y la aparición de nuevas oportunidades económicas. Por otra parte, el proceso de administración electrónica no se puede realizar sin un cambio en el pensamiento, organización del trabajo y en la gestión de procesos, permitiendo mejorar y acercar los servicios públicos a los ciudadanos, las empresas y la sociedad (KLIEROVA & KUTIK, 2017).

En este sentido, existe una apuesta decidida de las administraciones públicas por explotar las tecnologías digitales, cambiando la forma de interactuar con los ciudadanos y ofreciendo nuevos servicios interactivos. Dentro de estas aplicaciones destacan las vinculadas a los dispositivos móviles debido a la amplia extensión de su uso. De esta manera, las aplicaciones smartphone emergen no solo como un nuevo canal de comunicación para trasladar información, sino como un nuevo tipo de tecnología e innovación que permita disfrutar de mayor comodidad y conveniencia en el uso de los servicios públicos, hacia una administración pública más cercana y eficiente (Eom & Kim, 2014).

En el ámbito de la Educación, la digitalización ha llegado desde varios aspectos: desde la aplicación de esta tecnología a la docencia, con diferentes niveles de integración (docencia presencial, blend-learning y e-learning), hasta los libros y las pizarras electrónicas. En nuestro trabajo nos enfocamos en analizar la relación entre los ciudadanos y la Administración, por ello nos resulta especialmente interesante la aplicación (app) iPASEN desarrollada por la Consejería de Educación de la Junta de Andalucía. Esta aplicación actúa de canal de comunicación y ofrece a todos los agentes de la Comunidad Educativa la posibilidad de mantener un diálogo fluido y cotidiano, aún para aquellos que, por diversos motivos, ya sean personales, laborales o de cualquier otro origen, no puedan llevarlo a cabo del modo tradicional haciendo efectiva el concepto de la tutoría electrónica. En este sentido, entre las muchas funciones podemos destacar la consulta, justificación y comunicación de ausencias, comunicaciones de las calificaciones, consulta de actividades evaluables, tareas, controles, etc., creados en los cuadernos de clase del profesorado, las observaciones que se hayan introducido por parte del profesorado sobre la marcha de los alumnos.

Sin embargo, la mayoría de los esfuerzos para entender y atender el e-Goverment se ha hecho desde la perspectiva de las propias Administraciones Públicas (Twizeyimana et al., 2019). Para entender el uso de una aplicación desde el punto de vista del consumidor se vienen empleado con éxito los modelos de aceptación de tecnologías (Rondan-Cataluña et al., 2015). Es importante comprender las motivaciones, pero también las barreras, que los ciudadanos encuentran para acceder a estos tipos de servicios electrónicos. En este sentido, aparecen un elevado número de variables a considerar, desde cuestiones demográficas como el género (J. Arenas-Gaitán et al., 2013), la edad (P. Ramírez-Correa et al., 2019), a cuestiones relacionadas con la formación, o con elementos psicográficos (Peral-Peral et al., 2015; P. E. Ramírez-Correa et al., 2018). Frecuentemente, más que una única explicación, existe un conjunto de variables que interaccionan entre ellas y que influyen en el comportamiento de los individuos (Jorge Arenas-Gaitán et al., 2019).

2.2 Segmentación a través de estilos de vida por Internet

Los estilos de vida se vienen usando en marketing especialmente para la segmentación de consumidores desde hace décadas (Lazer, 1963; Plummer, 1974). Si bien en un principio, con el objetivo de segmentar se usaron variables de carácter demográfico, como la edad o el sexo, con el desarrollo de la sociedad de consumo estos criterios fueron cada vez menos explicativos. Por ello, se empezaron a usar otras variables con un marcado carácter psicográfico. Estas variables psicográficas mostraban una mayor capacidad explicativa del comportamiento de los consumidores (Peral-Peral et al., 2015). En este contexto, es en el que se desarrollan los estilos de vida como una base para crear grupos de consumidores con comportamientos homogéneos, y heterogéneos entre grupos.

Al hablar de estilo de vida, en el ámbito del comportamiento del consumidor, implica a un conjunto de conductas que manifiestan los individuos motivadas por su entorno físico y psíquico. Se utiliza como un concepto que agrupa valores, actitudes, creencias y patrones de comportamiento de los consumidores (Koshksaray et al., 2015). Nos referimos a la idea de cómo los consumidores viven su vida y gastan su tiempo y dinero. Es decir, son patrones de conducta que diferencian a las personas y que nos ayudan a entender las razones por las que cada una actúa de una determinada manera (Hassan et al., 2015). Los estilos de vida son consistentes a lo largo del tiempo y son un buen predictor del comportamiento de los consumidores ante determinados productos o servicios.

En el caso de los estilos de vida relacionados con Internet, tiene especial sentido dado que los individuos adoptan un doble papel: en primer lugar, como usuarios de una tecnología -Internet- desarrollada a través de computadoras, y en segundo lugar, como consumidores de productos que eligen este canal para satisfacer sus necesidades en alguna de las diferentes fases del proceso de compra (Pandey & Chawla, 2018). Por tanto, el estilo de vida en Internet puede diferir significativamente del estilo de vida “general” presentado por un individuo (García-Fernández et al., 2020).

Han existido varias propuestas de escalas de estilos de vida relacionados con Internet. Por ejemplo, una primera aproximación es el trabajo de Lee, Lim, Jolly, & Lee (2009). Ellos realizaron un estudio analizando la relación entre el estilo de vida y la selección de productos tecnológicos. Identificaron cuatro estilos de vida en esta área: conciencia de la moda, orientación al ocio, participación en Internet y preferencias de compras electrónicas. Sus resultados muestran que estos cuatro estilos de vida son antecedentes directos, o indirectos, de la tendencia a adoptar productos de alta tecnología. Sin embargo, la investigación más completa y rigurosa para crear una herramienta para medir el estilo de vida relacionado con Internet es el de Yu (2011).

Yu (2011) desarrolló un estudio, mediante análisis factoriales exploratorio y confirmatorio, para crear una escala de estilos de vida relacionados con Internet, o eLifestyle. Dicha escala adapta las actividades, intereses y opiniones de AIO (Wells & Tigert, 1971) y los valores de VALS (Mitchell, 1983; Richie, 1989) al contexto de Internet. Los 39 items de la escala se agrupan en siete factores, relativos a las necesidades, intereses, entretenimiento, sociabilidad, importancia percibida, desinterés o preocupación y novedad.

La escala de eLifestyle desarrollada por Yu (2011) ha sido empleada frecuentemente en estudios anteriores. Por ejemplo, Koshksaray et al., (2015) encuentran relación entre las dimensiones del eLifestyle y evitar la publicidad en Internet por parte de los individuos. El propio Yu (2015) aplicó su escala de eLifestyle en el campo de la banca por móvil. En otro trabajo, Hassan et al. (2015) analizan el eLifestyle desarrollado por los individuos de la generación Y. Yin, Li, Zhang, & Liu, (2019) encontraron tres segmentos de eLifestyle a los que llamaron: entusiastas de la tecnología digital, rezagados con la tecnología digital y neutrales a la tecnología digital. Recientemente, Hassan, Zhen, Mahmud, & Omar (2020) se centraron en los jóvenes musulmanes, para quienes Internet es una parte importante de sus vidas.

3. Metodología

A través de un muestreo no aleatorio hecho en un panel de usuarios de Internet obtuvimos 600 entrevistas online de personas que tienen hijos en edad escolar que viven en Andalucía (región al sur de España) y usan alguna App de comunicación entre escuelas y familias. Al final se seleccionan 589 encuestas ya que se eliminan las que se han contestado en menos de 3 minutos. La más usada se denomina iPasen, que se usa en todos los centros de educación primaria y secundaria públicos. El esquema de la metodología aplicada se muestra en la figura 1.

Figura 1: Esquema metodológico

A partir del análisis factorial aplicado a los 39 ítems de la escala de Yu (2011) se obtienen las puntuaciones factoriales para cada una de las dimensiones de esta escala. En el trabajo original de este autor son 7 dimensiones las que conforman esta escala que son: necesidades, interés, entretenimiento, sociabilidad, importancia percibida, barreras y novedad. En nuestro trabajo se confirman las 6 últimas. Sin embargo, se encontraron dos factores diferenciados de necesidades: necesidades laborales y otras necesidades (leer noticias, compras online, gestiones bancarias).

Una vez obtenidas las puntuaciones factoriales de las 8 dimensiones, hacemos un cluster k medias con estas variables para identificar grupos homogéneos dentro de sí y heterogéneos entre sí. Tras aplicar el método del codo (Bholowalia & Kumar, 2014), se seleccionan 3 clústeres. Por último, se realizan Anovas y medidas de asociación para analizar las diferencias de dichos clústeres con las distintas variables sociodemográficas obtenidas de la encuesta. Todos los análisis llevados a cabo se realizaron con IBMSPSS versión 26.

4. Resultados

En este apartado se presentan los principales resultados obtenidos con los distintos análisis efectuados.

Como se ha comentado anteriormente, la primera fase de la metodología aplicada fue aplicar un análisis factorial confirmatorio a los 39 ítems de la escala de estilos de vida en Internet de Yu (2011). Todas las dimensiones de la escala original se mantienen excepto las necesidades que en este trabajo se dividen en dos dimensiones (ver tabla 1).

	Componente	
	1	2
Habitualmente empleo para mi trabajo Internet y aplicaciones online	,848	,180
Internet y las aplicaciones online me facilitan el día a día	,493	,631
Internet y aplicaciones online mejoran la eficiencia de mi trabajo	,778	,344
Suelo usar Internet y aplicaciones online para leer noticias y obtener datos	,245	,795
Habitualmente compro por Internet y aplicaciones online	,180	,806
Suelo visitar mi banco a través de Internet o aplicaciones online	,238	,736
Mi entorno laboral se ha visto influido por Internet y las aplicaciones online, y yo me he beneficiado de su impacto	,815	,234
Mi entorno general se ha visto influido por Internet y las aplicaciones online, y yo me he beneficiado de su impacto	,647	,367
A medida que paso más tiempo en Internet y en aplicaciones online, creo que obtengo muchas ventajas.	,432	,619

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.[a]

a. Rotation converged in 3 iterations.

Tabla 1: Matriz de componentes rotados de Necesidades

A partir de los valores obtenidos podemos observar que el componente 1 se centra en los ítems que recogen aspectos laborales (necesidades laborales), y el componente 2 se centra en otras necesidades (obtener información, compras online, operaciones bancarias).

Siguiendo el método del codo para seleccionar el número de clústeres en el método K-medias (Bholowalia & Kumar, 2014) vemos en la figura 2 que el punto cambio de tendencia (codo) se da con 3 segmentos. La opción de tres segmentos ofrecía una división con tamaños de segmentos del suficiente tamaño.

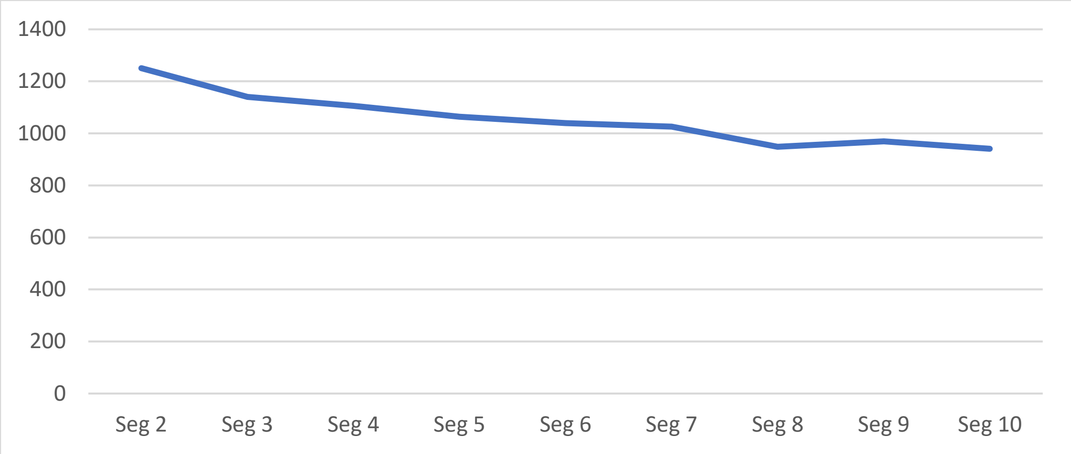

Figura 2: Selección del número de clústeres

Se han usado los valores factoriales de las 8 dimensiones de la escala e-lifestyle para hacer el clúster K-medias. Podemos ver que el clúster 2 es el más grande, seguido del 1, siendo más pequeño el 3 con sólo 118 personas (tabla 2). Por tanto, podemos identificar 3 grupos de usuarios a partir de dicha escala sobre estilos de vida en Internet.

Cluster	1	205
	2	266
	3	118
Valid		589
Missing		,000

Tabla 2: Número de casos en cada clúster

En la tabla 3, vemos cómo se caracteriza cada clúster a partir de las dimensiones de la escala de Yu (2011). Podemos ver que las personas del clúster 1 tienden a tener altos valores positivos en todas las dimensiones excepto en las barreras al uso de Internet donde puntúan de forma negativa. Esto quiere decir que para este grupo Internet es muy importante para cubrir sus necesidades, intereses, entretenimiento, aspectos sociales, lo perciben como importante y novedoso. Podemos decir que son los *adictos a Internet*.

Los individuos del segmento 2 tienden a tener valores cercanos a 0 en casi todas las dimensiones y lo ven como algo malo respecto a la vida social, y ven también altas barreras para su uso, podemos llamarlos *usuarios neutros.*

Los individuos del grupo 3 puntúan negativamente y con valores altos en todas las dimensiones, excepto en las barreras, es decir ellos están más bien en contra del uso de internet en todas sus facetas podemos considerarlos los *anti-Internet*.

	1	2	3
Necesidad Laboral	,51041	-,09155	-,68036
Necesidad No Laboral	,61896	,00858	-1,09466
Intereses	,90462	-,08414	-1,38193
Entretenimiento	,87385	-,08328	-1,33039
Social	,85799	-,20334	-1,03220
Importancia Percibida	,90832	-,14804	-1,24428
Barreras	-,35315	,20508	,15122
Novedad	,89397	-,12899	-1,26231

Tabla 3: Centros de los clústeres

En el apéndice 1 se muestra el análisis descriptivo para edad, número de personas en el hogar, número de menores de 18 años en el hogar, número de personas de 70 años o más o personas dependientes en el hogar y renta media en cada uno de los 3 clústeres obtenidos para intentar definir mejor los 3 grupos de usuarios detectados. Después se hizo un ANOVA para detectar diferencias significativas en estas variables para cada grupo, sólo se detectan diferencias significativas para la variable renta media que está medida en una escala Lickert donde el 1 es una renta muy inferior a la renta media y el 5 una renta muy superior a dicha renta. En el apéndice 1 podemos apreciar que el grupo de adictos a Internet tiene un valor percibido de renta superior a los otros 2 grupos. También en las comparaciones múltiples, usando el test de Bonferroni y de Tamhane se observan que las diferencias se dan entre el segmento 1 con el resto (ver tabla 4). Se puede decir que el grupo de adictos a Internet tienen una significativamente mayor renta que los neutros y anti-Internet.

		Sum of Squares	df	Mean Square	F	Sig.
En comparación con la sociedad andaluza en general (la renta media andaluza es de 2160€ brutos mensuales por hogar)	Between Groups	14,235	2	7,118	5,934	,003
	Within Groups	702,855	586	1,199		
	Total	717,090	588			

Multiple Comparisons

Dependent Variable		(I) Cluster 3 K Medias	(J) Cluster 3 K Medias	Mean Difference (I-J)	Std. Error	Sig.
En comparación con la sociedad andaluza en general (la renta media andaluza es	Bonferroni	1	2	,27161*	,10178	,023
			3	,39905*	,12655	,005
		2	1	-,27161*	,10178	,023

de 2160€ brutos mensuales por hogar),			3	,12744	,12113	,880
		3	1	-,39905*	,12655	,005
			2	-,12744	,12113	,880
	Tamhane	1	2	,27161*	,10187	,024
			3	,39905*	,12853	,006
		2	1	-,27161*	,10187	,024
			3	,12744	,12169	,651
		3	1	-,39905*	,12853	,006
			2	-,12744	,12169	,651

*. The mean difference is significant at the 0.05 level.

Tabla 4: Anova y comparaciones múltiples para renta media por clúster.

En el apéndice 2, se presenta el análisis descriptivo para intención de uso de tutoría electrónica, uso de iPasen, uso de otras plataformas de tutoría electrónica, uso de móvil, tabletas y ordenadores para acceder a la tutoría electrónica, percepción de mejora del rendimiento académico de los hijos, percepción de mejora de relaciones con los profesores, facilitar comunicación con el centro educativo, control de tareas, control de asistencia, frecuencia de uso de Whatsapp de padres y utilidad de Whatsapp de padres para cada uno de los segmentos.

El ANOVA nos presenta diferencias significativas entre los 3 grupos identificados para todas las variables relacionadas con la tutoría electrónica, excepto para el uso de iPasen, ya que esta herramienta es obligatoria para todos los centros educativos no universitarios públicos de la región de Andalucía en España (apéndice 3).

En el apéndice 4 se muestran los tests de Bonferroni y Tamahane para ver las comparaciones múltiples de las diferencias significativas para cada una de las variables relacionadas con la tutoría electrónica. En general, el grupo de adictos a Internet tiene mayor uso en todas las variables analizadas.

También se ha analizado la relación entre el nivel educativo de los encuestados y si tiene hijos en edad de educación primaria y vemos relaciones significativas para estas variables y los 3 clústeres analizados. Resulta que los adictos a Internet tienen un nivel educativo universitario en mayor proporción que los otros dos segmentos. También los que tienen hijos en educación primaria tienen un mayor peso entre los miembros del segmento de adictos a Internet. Esta información se puede ver en el Apéndice1.

5. Conclusiones

El objetivo de este estudio es hacer una segmentación de los usuarios de las Apps para gestionar las relaciones de las familias con los centros educativos. Esta segmentación se hace a través de la escala de estilos de vida de internet (e-lifestyle). Han surgido 3 segmentos: los adictos a Internet, los usuarios neutros y los anti-Internet, siendo éste último el grupo más reducido en nuestro estudio, aunque representa un 20% de los padres entrevistados. También vamos a analizar la importancia de la segmentación para identificar perfiles de usuarios que permitan a los gestores educativos tomar las medidas y programas más adecuados para que estos usuarios puedan hacer un mayor, mejor y más eficiente uso de estas Apps.

Aparece una brecha digital entre los usuarios de Internet con referencia a la renta media disponible, ya que los que disponen de mayor renta tienden a ser más adictos a Internet en nuestra muestra, también ocurre lo mismo si hablamos de nivel de estudios, a mayor nivel de estudios más tendencia a pertenecer al segmento de adictos. Los padres encuestados que están en este grupo que además tienen mayor proporción de hijos en edad escolar tienden a usar más las tutorías electrónicas y las Apps correspondientes a centros educativos privados/concertados, también tienen una mayor utilización de estas Apps tanto a través de smartphones, tablets y ordenadores. Tienen una mejor percepción de estas herramientas porque creen en mayor medida en comparación a los otros dos grupos con respecto a que el uso de estas Apps les ayuda a: mejorar el rendimiento académico de sus hijos, facilitar las relaciones con los profesores, facilitar la comunicación con el centro educativo, controlar mejor las tareas académicas de sus hijos, usan más y les dan mayor utilidad a los grupos de WhatsApp de padres. Los resultados de este trabajo ponen de manifiesto una brecha digital especialmente en el grupo de padres anti-Internet, ya que están en contra de su uso, encuentran más barreras, tienen una renta media más baja, menor intención de uso de las tutorías electrónicas y puede ser que esta falta de interés y quizás medios o formación digital adecuados pueda afectar al rendimiento de sus hijos en las escuelas y también a la percepción que tengan éstos de las nuevas tecnologías. De nuevo este estudio muestra que la brecha digital hoy día no está en el género sino más bien en una mezcla formada por nivel social, económico y educativo. Las autoridades académicas tienen que hacer un esfuerzo para conseguir llegar a estos padres quizás a través de medios más tradicionales o formarles adecuadamente para que puedan usar las nuevas herramientas a su disposición con respecto a las tutorías electrónicas.

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Apéndice 1

Análisis descriptivo para edad, número de personas en el hogar, número de menores de 18 años, número de personas de 70 años o más o personas dependientes en el hogar y renta media para cada uno de los segmentos.

		N	Mean	Std. Deviation	Minimum	Maximum
EDAD_Edad	1	205	38,1951	9,35891	18,00	59,00
	2	266	39,6015	10,36754	18,00	74,00
	3	118	37,6780	11,24922	19,00	64,00
	Total	589	38,7267	10,23109	18,00	74,00
Nhogar_personas	1	205	3,8634	1,01018	2,00	10,00
	2	266	3,8759	,85761	2,00	7,00
	3	118	3,9492	1,01145	2,00	8,00
	Total	589	3,8862	,94345	2,00	10,00
Nmas18_menores	1	205	1,5854	,86816	,00	6,00
	2	266	1,5489	,77670	,00	5,00
	3	118	1,4068	,77611	,00	4,00
	Total	589	1,5331	,81086	,00	6,00
Número de mayores de 70 años, o personas dependientes, en el hogar	1	205	,1610	,39412	,00	2,00
	2	266	,1880	,50132	,00	3,00
	3	118	,2203	,50865	,00	2,00
	Total	589	,1851	,46808	,00	3,00
En comparación con la sociedad andaluza en general (la renta media andaluza es de 2160€ brutos mensuales por hogar),	1	205	3,1024	1,11331	1,00	5,00
	2	266	2,8308	1,07350	1,00	5,00

	3	118	2,7034	1,11178	1,00	5,00
	Total	589	2,8998	1,10433	1,00	5,00

Apéndice 2

Análisis descriptivo para intención de uso de tutoría electrónica, uso de IPASEN, de otras plataformas de tutoría electrónica, de móvil, tabletas y ordenadores para acceder a la tutoría electrónica, percepción de mejora del rendimiento académico de los hijos, y de mejora de relaciones con los profesores, facilitar comunicación con el centro educativo, control de tareas, de asistencia, frecuencia de uso y utilidad de Whatsapp de padres.

		N	Mean	Std. Deviation	Minimum	Maximum
Intención uso Tutoria Electrónica	1	205	,4623350	,96559052	-2,57203	1,57551
	2	266	-,0772119	,87340015	-3,38576	1,57551
	3	118	-,6291552	,94069517	-3,38576	1,57551
	Total	589	,0000000	1,00000000	-3,38576	1,57551
iPasen	1	205	3,4585	1,82426	1,00	6,00
	2	266	3,4699	1,63021	1,00	6,00
	3	118	3,6780	1,45521	1,00	6,00
	Total	589	3,5076	1,66763	1,00	6,00
Plataformas propias del colegio (Educamos, Alexia, Esemtia, Escuela360, etc…)	1	205	3,9366	1,63925	1,00	6,00
	2	266	3,2895	1,61912	1,00	6,00
	3	118	3,0085	1,46466	1,00	6,00
	Total	589	3,4584	1,63519	1,00	6,00
Móvil	1	205	4,8098	1,32765	1,00	6,00
	2	266	4,5827	1,23576	1,00	6,00
	3	118	4,3644	1,37540	1,00	6,00
	Total	589	4,6180	1,30479	1,00	6,00
Tablets	1	205	3,2195	1,81918	1,00	6,00
	2	266	2,7444	1,63062	1,00	6,00
	3	118	2,6441	1,65134	1,00	6,00

	Total	589	2,8896	1,71717	1,00	6,00
Mediante ordenador, portatil o de sobremesa, o videoconsola	1	205	3,8878	1,67803	1,00	6,00
	2	266	3,4511	1,68441	1,00	6,00
	3	118	3,1271	1,60420	1,00	6,00
	Total	589	3,5382	1,68748	1,00	6,00
Mejorar el rendimiento académico de mis hijos.	1	205	4,3268	,82576	1,00	5,00
	2	266	3,8647	,72977	1,00	5,00
	3	118	3,5424	,84372	1,00	5,00
	Total	589	3,9610	,83920	1,00	5,00
Facilitar las relaciones con los profesores	1	205	4,5805	,69283	1,00	5,00
	2	266	4,1015	,75301	1,00	5,00
	3	118	3,6356	,88352	2,00	5,00
	Total	589	4,1749	,83400	1,00	5,00
Facilitar la comunicación con el centro educativo	1	205	4,6439	,64552	1,00	5,00
	2	266	4,2180	,66546	2,00	5,00
	3	118	3,6102	,90614	1,00	5,00
	Total	589	4,2445	,80263	1,00	5,00
Controlar las tareas académicas	1	205	4,5951	,71193	1,00	5,00
	2	266	4,0902	,78628	1,00	5,00
	3	118	3,7034	,87030	1,00	5,00
	Total	589	4,1885	,84524	1,00	5,00
Controlar la asistencia	1	205	4,6146	,71591	1,00	5,00
	2	266	4,2594	,72970	1,00	5,00
	3	118	3,7797	,93494	1,00	5,00
	Total	589	4,2869	,82531	1,00	5,00
Frecuencia de uso de Grupo de WhatsApp de padres	1	205	4,6878	1,39330	1,00	6,00
	2	266	4,0075	1,52214	1,00	6,00

	3	118	3,6780	1,61659	1,00	6,00
	Total	589	4,1783	1,54649	1,00	6,00
Considero útil el de uso de Grupo de WhatsApp de padres	1	205	4,1268	1,08172	1,00	5,00
	2	266	3,6241	1,07879	1,00	5,00
	3	118	3,3051	1,00858	1,00	5,00
	Total	589	3,7351	1,10863	1,00	5,00

Los apéndices 3 a 5 no se pueden mostrar por falta de espacio, se podrán ver en la presentación de la comunicación.

23. Stakeholder Readiness for Adopting a Big Data Governance Framework in a South African Metropolitan Municipality

Lesiba Jerry Seko
University of Cape Town
skxles002@myuct.ac.za

Malcolm Garbutt
University of the Western Cape
mgarbutt@uwc.ac.za

Pitso Tsibolane
University of Cape Town
pitso.tsibolane@uct.ac.za

Abstract

Digital transformation in the public sector can lead to innovative ways of working with stakeholders, improved service delivery frameworks, and data-driven societal benefits. However, not all public sector organizations, particularly local governments, are ready to adopt digital technologies such as big data. Governance frameworks are critical for technology management, and key stakeholders must be prepared before technology adoption. Recognizing that top management support is crucial for digital transformation projects, this study looked at the state of readiness of metropolitan municipalities in South Africa to adopt a big data governance framework (BGDF). The study had two objectives: first, to assess the readiness for a big data governance framework, and second, to identify what the respondents considered essential in such a framework. Framed by the technology readiness index (TRI), the study found that the stakeholders were not only ready but also had a good idea of what should be included in the framework. Both of the findings resonate with extant literature. The study concluded that the technology readiness index was suitable for investigating digital transformation readiness and that the proposed big data governance framework is a viable initial option.

Keywords: Digital Transformation, Big Data Governance Framework, Technology Readiness, Metropolitan Municipality, Local Government.

1. Introduction

Digital transformation has become inevitable and irrevocable in local government (Ahn & Chen, 2022). Digital transformation is the process whereby organizations use digital technologies to respond to environmental changes (Zhu, Ge & Wang, 2021). Thus, digital transformation is more concerned with strategy than technology (Zhu et al., 2021). For long-term growth, absorption and adoption of digital technologies with organizational transformation and renewal are necessary (Miceli et al., 2021). Miceli et al. (2021) refer to this growth as thriving beyond surviving. Digital transformation uses technology to enhance experiences and satisfy customer needs, from improving automation to rebuilding business models (Mergel et al., 2019). The benefits of digital transformation fall within what Zhu et al. (2021) refer to as the thriving stage of digital transformation. The thriving stage is the third of three stages after the embryonic and development stages and deals with implementations, dynamic capabilities, social factors, maturity frameworks, and digital transformation drivers (Zhu et al., 2021). Whereas strategy is fundamental to the development stage, governance is essential to the embryonic stage (Zhu et al., 2021). Mergel et al. (2019) support Zhu et al.'s view of the environmental drivers of digital transformation in their findings which showed that 83% of the change in public administration came from the external environment. However, 17% of transformational pressure is from internal sources. Like Zhu et al. (2021), Mergel et al. (2019) considered technology less important than organizational change. This was particularly noticeable for the internal factors, where business processes and models were the primary foci of transformation. Similarly, Myeong et al. (2021) suggest that expensive infrastructure and technology are less critical than social factors, with the caveat of the requirement of solid leadership.

Public organizations have adopted the term digital transformation from the private sector to refer to the competitive use of technology (Mergel et al., 2019). Likewise, the public sector has adopted technologies such as big data from the private sector (Vydra & Klievink, 2019). A recent addition to big data research is big data governance, which is still in its infancy in the public sector (De Souza & Jacob, 2017). Safitri (2021) observed that big data holds four primary opportunities for local government; evidence-based policy setting, improved service delivery, better citizen engagement, and easier city management. Safitri (2021) provides several key factors required to reap the benefits of big data. Foremost are top management support, organizational change, privacy and security, data availability, cost, skillset and knowledge, and technological infrastructure. The need for technology policy is the primary concern of the embryonic stage of digital transformation, according to Zhu et al. (2021). Included in the list is big data policy-setting. A big data governance framework (BDGF) for the public sector is vital as uncertainties and doubts regarding skills, software, and hardware equipment hinder the fast-tracking of big data adoption (Klievink et al., 2017). On the other hand, digital transformation in local government has been observed to be limited due to a lack of readiness by top management (Srinavin et al., 2021). The readiness of key stakeholders is crucial as they use their organizational status, power, and motivation, to affect technology adoption and drive the success of the technology implementation (Mori, 2010).

This study explored the readiness of key stakeholders at a principal metropolitan municipality to accept BDGF as a precursor to adopting big data for digital transformation. The base logic for the research was based on digital transformation's need for policy setting at the embryonic stage (Zhu et al., 2021) and top management's readiness to adopt technology as a critical success factor (Safitri, 2021). A subsidiary aim was to identify what features should be incorporated in a BDGF in the sample metropolitan municipality. Using the setting of the South African City of Tshwane Metropolitan Municipality (CoT), the following research questions guided this study:

- What is the readiness of the key stakeholders in a metropolitan municipality to adopt a big data governance framework?
- What should big data governance frameworks include for a local government environment?

The report proceeds as follows. Section 2 provides a background to the study. Section 3 describes the research approach and the compliance with ethics. Section 4 describes the study's findings, and section 5 concludes the study.

2 Theoretical Background

Big data is central to BDGF. The definition of big data provides the means to differentiate it from conventional data and consequently dictates how to manage it uniquely (Plotkin, 2020; Shlomo & Goldstein, 2015). Nevertheless, big data is more straightforward to describe than define (De Mauro, Greco & Grimaldi, 2016).

2.1 Big Data

The fourth industrial revolution (4IR) era ushered in advancing technologies in data collection, storage, mining, synthesis, and analysis, making it possible to use large volumes of data to inform real-time decision-making (Rubinfeld & Gal, 2017). With its impact on pre-existing economic, social practices, business, and ways of life, big data has been likened to oil in the 3rd Industrial Revolution (Hirsch, 2013; Markowitz, 2019). The most basic definition of big data uses the 3Vs, volume, velocity, and variety (Emmanuel & Stanier, 2016). The 3Vs shown in Table 1 describe high-volume, high-velocity, and high-variety information assets that require new forms of processing to enable enhanced decision-making, insight discovery, and process optimization. (Jony et al., 2016). Big data includes raw and processed data, data storage, managing data, processing, and analytics required to derive value from it (Merino et al., 2016). Consequently, people with appropriate knowledge, competencies, and analysis skills are critical for the end-to-end management of big data (Abdulla et al., 2015).

Volume	Big data accumulation is now measured in zettabytes and requires new methods and technologies to manage the big data lifecycle and derive value (Chavan & Phursule, 2014). These volumes render big data challenging to capture, store, manage and analyze using traditional data management and storage tools (Zerhari, Lahcen, and Mouline, 2015).
Velocity	Big data velocity measures data creation, streaming, and aggregation (Jony et al., 2016). Velocity includes the dynamics of data assimilation as well as the need to disseminate real-time analysis (Casado & Younas, 2015).
Variety	Variety refers to the heterogeneous nature of big data, which includes traditional structured data, semi-structured and unstructured data in the form of audio files, images or photos, XML files, and videos (Della Valle, Dell'Aglio, & Margara, 2016). Semi- and unstructured data make it almost impossible for traditional data storage to manipulate big data (Wang et al., 2010).

Table 1. The 3V's of Big Data

2.1.1 Drivers of Big Data

With the private sector leveraging big data for increased profit margins (Joseph & Johnson, 2013), government and open data initiatives are the drivers for big data in the public sector (Munné, 2016). Big data opportunities include improving government service delivery and changing modern cities into smart cities (Giest, 2017). Accordingly, in 2019, the South African Presidential Commission on the Fourth Industrial Revolution was appointed to render advisory services to enable the government to take advantage of the opportunities presented by the digital industrial revolution (South African Government, 2019). Big data has many aspects, including cyber security and risk management (Jang & Lee, 2019), implementation (Kim & Cho, 2018), smart grids and energy distribution (Munshi & Yasser, 2017), customer relationship management, and citizen-centric analytics (Ju, Liu & Feng, 2018), government e-services (Rajagopalan & Vellaipandiyan, 2013) and governance maturity (Soares, 2012). Another aspect is innovation in response to the organization's environment, internal structure, and processes (Lewis, Ricard & Klijn, 2018; Wang et al., 2019). However, following the three stages of digital transformation, a governance framework is required before implementing big data (Zhu et al., 2021).

2.1.2 Big Data Governance Framework

Big data governance is an enterprise model of managing the data lifecycle from creation to archiving or retirement of the data. Governance enshrines the data policies, standards, and procedures to monitor compliance, create value and manage risk exposure (Abram, Schneider & vom Brocke 2019). Thus, a BDGF is the collective of best practices required to exercise authority and control over enterprise data assets and incorporate people, processes, and technology to manage and protect data as an enterprise asset (Ladley, 2019).

2.2 A Proposed Big Data Governance Framework

Recognizing that no single BDGF applies to all circumstances, Al-Badi, Tarhini, and Khan (2018) synthesized several data governance frameworks to propose an inclusive framework, which they assessed against the ISO 8000 data governance framework. The Al-Badi et al. (2018) framework includes eight processes shown in Figure 1 and Table 2.

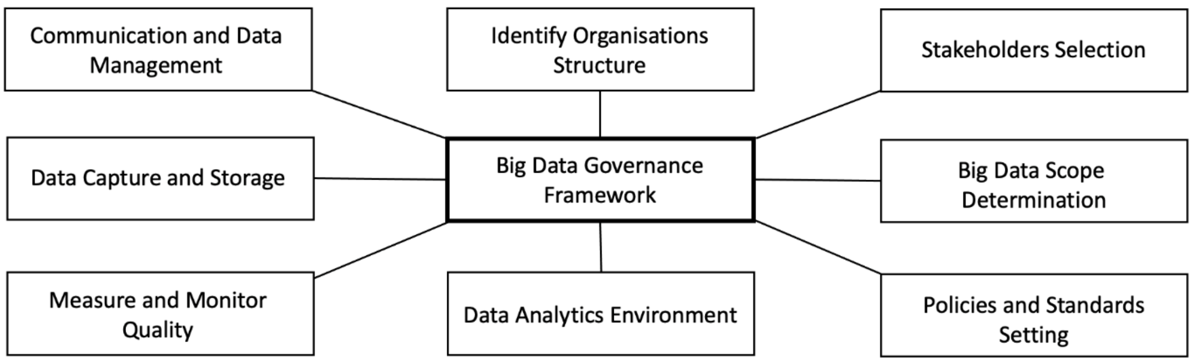

Figure 1. Proposed Big Data Governance Framework (adapted from Al-Badi, Tarhini & Khan, 2018)

2.3. Stakeholders

Stakeholders are individuals, groups, or entities with a legitimate interest in an enterprise's affairs (Brugha & Varvasovszky, 2000). Stakeholders can be internal or external to the organization, directly or indirectly influencing the adoption and eventual use of technologies (Berardi, 2013). Ultimately, internal stakeholders' behavior determines the fate of a project (Beringer, Jonas & Lock, 2013). This is no different in governmental projects (Al-Rashidi, 2013), where the stakeholders' roles and responsibilities are critical for successful adoption. Alharthi, Krotov, and Bowman (2017) identified humans as one of the barriers to big data adoption.

McGrath and Whitty (2017) classified stakeholders into four classes: invested, contributing, observer, and tertiary, while Günther et al. (2017) emphasized that value-creation through big data occurs when organizations realign work practices, organizational models, and stakeholders' interests to reap the benefits of their use. However, Rezazade, Mehrizi, and Lashkarbolouki (2016) warn that a realignment can mean a radical departure from the existing ways of doing business and from the logic, values, and beliefs that drive work practices and behaviors in an organization.

2.4 Metropolitan Municipalities

The government in the Republic of South Africa is federated into national, provincial, and local governments. Local government is further differentiated into Category A: Metropolitan municipalities, Category B: Local Municipalities, and Category C: District Municipalities (South African Government, 1998). Compared to non-metropolitan municipalities, metropolitan municipalities are more likely to need a BDGF in response to big data accelerators (Montin, 2016) as they embark on technology initiatives and investments to meet and exceed customer and citizen expectations (Berst, 2015).

2.5 Technology Readiness

Technology readiness may refer to either the technical maturity of the technology (Gavankar, Suh, and Keller, 2015) or the socio-technology readiness of users, consumers, and enterprises (Ahmed, Qin, and Aduamoah, 2018). Technology readiness is people's propensity to embrace and use new technologies to accomplish goals (Parasuraman & Colby, 2015).

Potential technology implementations can be initially assessed through stakeholders' and organizations' readiness for the technology.

Process	Description
Communication	Inherent in the data governance of providing the right sets of data to the right people at the right time is the dependency on communication for data collection and dissemination.
Organizational Structure	The organizational structure influences big data governance, which should be aligned with the objectives and vision of the organization.
Stakeholder Selection	A key element is the identification of relevant stakeholders such as data scientists, analysts, business stewards, data stewards, and steering committees.
Big Data Scope	It is imperative to define the scope of big data and ensure it applies to the organization. The scope frames the technology selection, stewardship, information governance, data definition and usage standards, master data management, metadata management, data lifecycle management, risk, cost containment, and communication.
Policies and Standards	The BDGF is essential for framing policies, processes, and standards for effectively managing and ensuring big data availability, usability, integrity, consistency, auditability, and security.
Data Capture and Storage	The BDGF must provide guidelines and measures for secure data assimilation, storage, and dissemination tempered with accessibility.
Data Quality	The quality of the disseminated data depends on the assimilated data's accuracy and quality. The BDGF must provide guidelines for managing, monitoring, and measuring data throughout the data lifecycle.
Data Analytics Environment	The BDGF must provide guidelines for setting an environment that assimilates and disseminates accurate data. For the quality of decisions, guidance for extracting, transforming, loading, and extracting big data is crucial. Alignment of the data with business strategy must be considered in this process.

Table 2. Big Data Governance Framework Processes

From an organizational context, readiness can be deduced by considering the socio-technical factors to determine the preparedness of people, processes, and technology (Nair, Chellsamy, and Singh, 2019). Scholars and social scientists have developed frameworks and models to measure the multi-faceted human disposition towards technology and its usage (Nilsen, 2020). While most theories center around behavior, the interest in this study is pre-behavioral. At the organizational level, assessment can be done through the technology, organizational and environmental (TOE) framework, which has proven reliable in assessing technology readiness (Nair, Chellsamy, and Singh, 2019). At the individual level, the technology readiness index (TRI) proposes that individuals' interactions with new technologies can be categorized into four psychographic factors views (beliefs, perceptions, feelings, and motivations) (Parasuraman, 2000). TRI proposes that optimism and innovativeness have a positive influence on the readiness of stakeholders for new technology. Conversely, discomfort and insecurity are inhibitors of readiness (Parasuaman, 2000). According to Chiu and Cho (2020), optimism is a positive belief that technology increases efficiency, control, and flexibility in people's daily lives. Innovativeness reflects a tendency to be a thought leader or pioneer in testing innovative technology-based services or products (Chiu & Cho, 2020). Discomfort reflects individuals' perceptions of lacking control and confidence (Chiu & Cho, 2020). Insecurity refers to distrust of technology, stemming from skepticism about its ability to work appropriately and concerns about its potentially harmful consequences (Chiu & Cho, 2020).

Cohn (2015) identifies strong executive leadership as one of the critical elements for successful governance. With the potential for sizeable digital technology investments to be underutilized, it is imperative to understand stakeholder perceptions upfront so that appropriate change management interventions are initiated (Hayes, 2018). Consequently, the technology readiness index (Parasuraman, 2000) guided the stakeholder interviews.

3 Research Approach

The research approach for this study followed an interpretive philosophy in acknowledging that people and their feelings, attitude, and beliefs are active actors in defining new knowledge and understanding of the phenomenon at a particular place, time, and circumstance (Guha Thakurta & Chetty, 2015). A deductive-inductive research approach was adopted to make logical conclusions from a set of premises for theory-testing research (Bhattacherjee, 2012) of the TRI constructs and to identify new patterns in the empirical data. Empirical data was collected using semi-structured interviews at a single metropolitan municipality in South Africa with a cross-sectional time horizon. The City of Tshwane consented to interviews with selected stakeholders based on their areas of expertise, influence, and appointment designation. Ethics clearance for the study was obtained from the Commerce Faculty of the University of Cape Town before the data collection. All participants consented to an interview and the recording of the interview. Due to the COVID-19 pandemic, the participants were interviewed through Microsoft Teams.

The study used purposive sampling to identify knowledge-rich and well-informed participants (Etikan, Musa & Akassim, 2016) who held influence and functional and technical expertise in data trusteeship, stewardship, ownership, and custodianship. A pilot test (Zikmund, Carr & Griffin, 2013) of the semi-structured interview was undertaken with two participants and adjusted accordingly after each interview. Where necessary, further minor adjustments to the interview schedule occurred ad hoc to clarify the respondents' responses. The interview data were analyzed using thematic analysis, where words are not taken for their semantic face value but analyzed for deeper interpretation to reach the assumptions underlying the data and elucidate probable themes (Braun & Clarke, 2006; Vaismoradi, Jones, Turunen, & Snelgrove, 2016). Table 3 summarizes the steps followed for the data analysis based on Braun and Clarke (2006).

Step	Process
Familiarization	This stage involved transcribing the audio and video data, reading through the text and taking initial notes, and generally becoming familiar with the data (Braun & Clarke, 2006; Vaismoradi, Jones, Turunen, & Snelgrove, 2016).
Coding	In this stage, phrases and sentences were marked with codes to describe their content and highlight the main points and common meanings (Braun & Clarke, 2006; Vaismoradi, Jones, Turunen, & Snelgrove, 2016).
Generating themes	This stage combined related codes across the data to form a theme (Braun & Clarke, 2006; Vaismoradi, Jones, Turunen, & Snelgrove, 2016). Ambiguous codes were discarded or combined. The study used a deductive-inductive thematic approach. The deductive approach was derived from the themes advocated by the TRI theory (Parasuraman, 2000). The inductive approach incorporated new findings from the collected data (Azungah, 2018) into a proposed model.
Review of themes	This step ascertained the usefulness and appropriateness of the crafted themes against the data. Themes deemed vague are reworded, combined, split, or discarded until the final set is congruent to the data that provided the base for them (Braun & Clarke, 2006).
Defining and naming themes	This stage provided a succinct and easily understandable name for each theme. Defining the themes would ensure consistency in line with understanding the data (Braun & Clarke, 2006) and link themes to show how they complement each other (Vaismoradi, Jones, Turunen, & Snelgrove, 2016).

Table 3: Thematic Analysis Process (based on Braun and Clarke (2006))

4. Findings

The City of Tshwane (CoT) is regarded as the capital city of South Africa and the largest municipality by land mass. CoT was established in December 2000 through the amalgamation of the City Council of Pretoria, Akasia, and Centurion Town Councils. In 2008, the Metsweding District Municipality, Dinokeng, and Kungwini Municipalities were incorporated (Tshwane, 2019). The mergers brought together disparate legacy systems that resulted in duplications, lack of integration, and high license and application maintenance costs, making a data governance framework imperative.

4.1 Big Data Governance Framework Readiness

Fourteen participants were interviewed for this study with designations ranging from Deputy Director to Departmental Head. The respondent set provided a mix of managers who manage service delivery's operational and tactical aspects and senior managers who sit at executive meetings.

Although it was recognized as necessary, CoT does not have a documented BDGF: *"... we currently do not have a form of big data governance approach or framework." (DH1)*. The ramifications were alluded to by DH2: *"I do not think we capture the data appropriately and … I would even argue that we are not even truly aware of the type of data we generate" (DH2).*

4.1.1 Optimism

The respondents were optimistic about the value-add of BDGF despite the organization's lack of a framework. *"… all organizations [need a BDGF] because data is about the reality on the ground that informs you on what is happening. It's very important for you to know, because … [accurate] data becomes very important in that regard" (DH3). "[It is] imperative to have [a BDGF] … because you need big data governance to be able to manage and monitor the data as it is with regard to access, authorization, usage and storage of the particular data." (DD5).*

4.1.2 Innovativeness

The perceived value of big data governance was observed to stimulate innovativeness among stakeholders. One respondent shared a mental picture of the future role of a BDGF*: "OK, my role is to ensure that a #1 we know where data is, #2 we know how that data is protected and what needs to be done in terms of protection. I need to ensure that people who are accessing that data are authorized to access this data, and then we do data classification to know where our critical data lies within different departments within the organization" (DD5).*

Similarly, another respondent showed a willingness to champion the course to derive maximum benefits from a framework: *"... in an era where there is no responsibility and accountability, someone needs to step in. So I think the role is going to be (1) to coordinate the formulation of the framework. (2) to coordinate the gathering of their resources for the strategy and the framework and to also, possibly (3) run the community, whether it's in the form of a committee or a forum that then looks at the ongoing monitoring of the implementation of the framework" (DH0).*

4.1.3 Discomfort

The respondents expressed their discomfort with approaches to data handling and usage. *"I am not at ease at all … You can even go now inside each department. If you go to [a department] and ask them about something that happened in [their] space, you get two different things" (ADH3).* Follow-up questions discovered that such negative factors do not necessarily discard the thought of adopting BDGF. *"[We should] try to coordinate some of the things around big data. Let us look at what already exists from a system perspective and say how you coordinate the big data so that people can use it for decision making and planning" (ADH3).*

DD4 advocated more communication to overcome discomfort, *"I think if we were communicating these more aggressively … a concerted effort at institutional level to make sure that there is a lot of awareness being made, not only through publication of leaflets or notifications, but holding workshops." (DD4),* DH1 was more uncomfortable with lack of compliance than communication: *"I do not think it is a question of communicating. It is a question of whether we need to comply with this law. As with any other regulation or law, if you do not comply, fines or penalties can be leveled against the city. So, we need to move with haste so that we can ensure that we comply with the law." (DH1).*

4.1.4 Insecurity

DIR1 acknowledged insecurity but also recommended mitigations to counter the potential negative impacts. *"I think I am in for [cloud computing], you know, but the problem is that we should put proper systems and mechanisms in place so that we don't find ourselves thinking we are putting data somewhere in the cloud, only to find that no, one day when we need that data, it is not accessible" (DIR1).* Likewise, DD6 acknowledged the potential insecurity and recommended a measure to help contain the risk. *"I think in terms of working with the service provider we must make sure that they transfer their skills and they make sure that they provide us with the data that they have been generating for months with us. We must make sure that we have all the data …" (DD6).*

Some respondents were relatively secure about the data. *"We have actually made quite a significant investment into this area, and so I am quite content that we do have the tools in place, but of course, this is always a moving target" (DH1).* Others felt less secure: *"I think in terms of recovery capability, the city would not recover outright until we centralize that, so that we have data back-up, data recovery, etc. from data management and protection point of view" (DD5).*

4.1.5 Readiness Summary

The findings support the proposition that optimism and innovativeness positively influence the readiness for a BDGF. While the respondents acknowledged discomfort and insecurity, visionary stakeholders may counter this with innovativeness and be prepared to adopt BGDF. The implication is that the organization must leverage the enthusiasm and willingness presented by the respondents.

4.2 Big Data Governance Framework for a Local Government Environment

The interviews provided insights into what the respondents expect from an ideal framework from the perspective of a local government environment. In the absence of a BDGF, the data analysis was primarily grounded. Nevertheless, the data resonated with Al-Badi et al. (2018).

4.2.1 Communication

The respondents observed the need for communication both internally and externally. *"Let us look at what already exists from a system perspective and say how you coordinate the big data so that people can use it for decision making and planning, but also make use of it for our own vision so that we must improve customer experience" (ADH3). "I think if we were communicating these more aggressively … a concerted effort at institutional level to make sure that there is a lot of awareness being made, not only through publication of leaflets or notifications, but holding workshops." (DD4).*

4.2.2 Organizational Structure

The organizational structure influences were observed in the respondents' answers.*"If you go to [department g] and ask them about something that happened in the [departmental] space, you get two different things" (ADH3).* "*It is about maybe convincing decision makers to say data is important and as such, let us start taking care of it because in fact data is big business" (DH3).*

4.2.3 Stakeholder Selection

Stakeholder selection was integral to the organizational context. *"It is about maybe convincing decision makers to say data is important" (DH3). "... someone needs to step in … whether it's in the form of a committee or a forum that then looks at the ongoing monitoring of the implementation of the framework" (DH0).*

4.2.4 Big Data Scope

Respondents showed appreciation for the need to define the scope of big data. *"Our definition, perhaps we need an institutional definition of what we call data and of what we call information. So there has to be a clear institutional position or definition of these two and the significance of it" (DD4).*

4.2.5 Policies and Standards

Multiple respondents referred to policies and standards. *"If we have a centralized one (recovery plan) that deals with that, the disaster recovery plan must be end-to-end to talk to any system or any device that carries data within the organization" (DD5). "I think in terms of working with the service provider we must make sure that they transfer their skills and they make sure that they provide us with the data that they have been generating for months with us. We must make sure that we have all the data" (DD6). "It is a question of whether we need to comply with this law … we need to move with haste so that we can ensure that we comply with the law" (DH1).*

4.2.6 Data Capture and Storage

Data capture, storage, and dissemination were areas of concern for some respondents. *"I do not think we capture the data appropriately and then in some cases I would even argue that we are not even really aware of the type of data we generate" (DH2*). *"… you need big data governance to be able to manage and monitor the data as it is with regard to access, authorization, usage and storage of the particular data." (DD5).*

4.2.7 Data Quality and Data Analytics Environment

The respondents often combined data quality and data analytics. Concern regarding the data quality was observed as accurate and adequate data is integral to data analytics for helpful information. *"[We should] try to coordinate some of the things around big data. Let us look at what already exists from a system perspective and say how you coordinate the big data so that people can use it for decision making and planning" (ADH3). "…data is about the reality on the ground that is informing you on what is happening. It's very important for you to know, because … [accurate] data becomes very important in that regard" (DH3).*

5. Discussion and Conclusion

This study set out to assess the readiness of key stakeholders to adopt a BDGF within a metropolitan municipality, with a secondary aim to determine what should be included in such a framework. The respondents were capable and experienced stakeholders who were observed to be optimistic about adopting BDGF and provided innovative ideas to enhance the adoption and facilitate the usage of big data technologies. This finding was in accordance with the drivers of the technology readiness index (Parasuraman, 2000). Likewise, inhibitors of discomfort and insecurity were identified. However, it was observed that the inhibitors could be offset through innovativeness. Hence, the municipality would do well to leverage the enthusiasm and willingness presented by the respondents.

The secondary objective was to identify the components of a BDGF. As the respondents were not directly asked for their opinion in this regard, the findings were grounded in analyzing the respondents' answers to the TRI questions. The grounded findings aligned with the proposed framework of Al-Badi et al. (2018): communication, organizational structure, stakeholder selection, big data scope, policies and standards, data capture and storage, data quality, and data analytics environment. Overall, the respondents were ready for the initial phases of developing a BDGF for which the Al-Badi framework may be a good fit in a metropolitan, municipal setting.

As with all research, several limitations were encountered in the study. The most significant limitation is the approach of the initial TRI model. Using the later TRI 2.0 (Parasuraman & Colby, 2015) may provide more detail for determining a prospective BDGF specific to the research setting of a metropolitan municipality. The study's cross-sectional nature was not a limitation for readiness but will require a more extended period for accurately defining a suitable BGDF. A lesser limitation was the use of online interviews due to Covid-19 precautions. Face-to-face interviews may have provided richer data.

Several potential research areas were indicated during this study, including what local governments can do to improve BGDF readiness and if the framework may translate to other public sector organizations. These recommendations will require identifying mutual and unique contexts to guide the applicability or adaptions needed to the proposed BGDF to apply to other public sectors and industries.

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24. The Indigenous digital divide:

COVID-19 and its impacts on educational delivery to First Nation university students

Arthur M. Wilson III
Curtin University
arthur.wilson1@curtin.edu.au

Mandy Downing
Curtin University
mandy.downing@curtin.edu.au

Amma Buckley
Curtin University
amma.buckley@curtin.edu.au

Julie Owen
Library for all
julie.owen@libraryforall.org

Max Jackson
Curtin University
max.jackson@curtin.edu.au

Abstract

The global COVID 19 pandemic highlighted that the delivery of online education inadvertently disadvantaged Indigenous Australian university students. This situation was particularly critical for Indigenous students from rural and remote locations. Australian universities increased the use of digital technologies to engage, support and teach due to students' inability to access campuses. This presented universities with challenges in supporting Indigenous students living in and returning to non-urban settings. Often not recognised is the need for better strategies and plans for Indigenous students returning to their rural or remote community to continue their studies due to COVID. These communities often lack suitable infrastructure that would allow access to pedagogical and learning support opportunities. This paper explores how the business decision made by Australian universities to increase reliance on teaching online during COVID impacted the education of Indigenous students. This paper will then canvas ways this ongoing dilemma can be addressed by considering risks, measuring and monitoring performance to guide transformation, including universities' more inclusive and respectful use of digital technologies involving First Nations people and cultures.

Keywords: Aboriginal and Torres Strait Islanders, Indigenous students, online university education, digital divide, transformation, COVID-19.

Acknowledgement of Country

I respectfully acknowledge the First Nations people of Australia for being custodians of the land keepers of the spirit and their enduring resilience. I acknowledge and respect the Elders of Aboriginal and Torres Strait Islander people past, present and future.

1. Introduction

The Acknowledgement of Country aims to assist with establishing the context of this paper. The acknowledgement is a sign of respect and a recognition of the resilience of Aboriginal and Torres Strait

Islander (Indigenous[3]) people despite the trauma endured through colonisation. Colonisation created a situation that continues to effect university students of Indigenous heritage. The persistence of the effects of colonisation is reflected in the unequal treatment of Indigenous students during the COVID-19 pandemic. The focus of this paper is not to revisit the catalyst of the trauma, but to develop an understanding of the challenge facing Indigenous students, particularly those in rural and remote areas so that a solution can be critically considered. Without this understanding, the risk of underestimating the change required increases.

This presents a deceptively simple research question:

> How can Australian universities maintain engagement with Indigenous Australian students during situations, such as the COVID-19 pandemic?

To address this research question, a literature review was conducted, themes created, and opportunities investigated to reduce the digital divide and its negative impact on Indigenous students in rural and remote communities. This study is exploratory and of a qualitative nature.

2. Literature review

2.1. Context

Indigenous Australians are relatively new to attending universities due to being marginalised and oppressed through colonial practices, policies supported by Australia Federal, State and Territory legislation.

The first Australian university, the University of Sydney, was founded in 1850 (CatEight, 2021). While the first Aboriginal person to graduate from university was the late Charles Perkins in 1965 (Williams, 2005). Once the doors of universities were eventually opened to Indigenous students, in addition to their studies of western ways, they had to overcome the stigma of being treated as flora and fauna for generations. Conversely, Australian universities with Indigenous students, seeking to grow the base of Indigenous students had to consider the creation of a culturally safe learning environment for these students.

Australian universities are still learning how to create safe and secure learning environment for Indigenous students. This transformation is a result of the lessons incrementally learned over time. Like the incremental changes to create a safe and secure environment by universities, the trauma faced by Indigenous students is receding in increments. Changing this situation involves universities recognising that a positive lived experience of university life is still unknown to many Indigenous families. This can affect the support Indigenous students receive at home and their community. Technology and university education is intertwined with many Indigenous Australians, and Indigenous people seeing technology as a pathway to a better future (Rennie, Thomas, and Wilson, 2019). However, not all Indigenous people can access and use this technology.

2.2. Digital divide

Access to the Internet contributes to the welfare of people and is now considered widely as an essential service comparable to other basic utilities (Rennie et al., 2019; Wilson, 2021). On university campuses,

[3] Use of capital “I” for Indigenous is common practice in Australia and a sign of respect and courtesy for Australian First Nations people. The capital “I” in Indigenous is not intended disrespectful conference proceedings in any way.

Indigenous students from rural and remote Australian communities have technology that can assist them remain connected to their family and community.

However, not all rural and remote areas have sufficient technological infrastructure to support maintaining family connections, or enabling online education (Wyatt, 2019). This condition is known as a digital divide. Before the pandemic, the term digital divide was used to describe the gap between people with access to digital technologies and reliable and stable Internet and those without (Bennett, Uink, and Cross, 2020). Although there have been improvements in access to technology, the digital divide remains for students at the lower end of the socioeconomic spectrum (Bennett et al., 2020; Brown, Te Riele, Shelley, and Woodroffe, 2020).

In addition to potential lack of infrastructure, the affordability of the technology and the Internet, and the capacity and capability of the users influence the adoption and use of the Internet (Rennie et al., 2019) and how Indigenous students engage with universities online.

2.3. The Pandemic

In 2019, the COVID-19 pandemic disrupted communities and industries across the globe, including the higher education sector. COVID-19 magnified digital divide issues that equity practitioners and policy-makers have been seeking to address for decades (O'Shea, Koshy, and Drane, 2021). COVID caused significant changes in the way university students, lecturers, and administrators interacted not only in Australia, but also in countries, including New Zealand (Akuhata-Huntington et al., 2020) and Canada (Galloway, Bowra, Butsang, and Mashford-Pringle, 2020). Although universities delivered courses online, the scale of change from the current blend of online and face-to-face to fully online teaching and learning were significant. Universities reallocated human and financial resources from blended learning to fully online delivery (Heckenberg et al., 2020). In March 2020, efforts to protect Australian people from COVID-19 included the closure of Australian universities with learning on campus rescheduled or cancelled (Dodd, Dadaczynski, Okan, McCaffery, and Pickles, 2021). Within the Australian higher education sector COVID-19 presented multiple challenges (Dodd et al., 2021).

While students in metropolitan and regional centres had access to suitable space and technology to continue their university studies, students in rural and remote Australia may not have had the same opportunity. In particular, the differences between Indigenous students and their non-Indigenous classmates remain, as Wyatt (2019) and many others have identified, the situation needs to be addressed.

2.4. Effect of COVID on Indigenous Australian Students

Many Indigenous students are either the first or second generation that have had the opportunity to study at an Australian university. In Australia data from 2017 shows that the undergraduate attrition rate was estimated to be 16%. For Indigenous students, the attrition rate was almost 29% (O'Shea et al., 2021). Although over the past decade there have been improvements, admission and completion rates of Indigenous people in Australia are the lowest in terms of proportional representation at universities (Bennett et al., 2020). With the emergence of COVID-19 many Indigenous students that were studying face-to-face, were forced to shift to online learning. This transition presented multiple challenges that forced numerous Aboriginal students to withdraw from university, including mental health difficulties (Dodd et al., 2021). Many Indigenous students did not have access to home computers or the internet, or if they had access there were circumstances where they only had one home computer that was shared with siblings also learning from home (Holt and Worrell, 2021).

Many Indigenous students in rural and remote communities were not able to come to campus. Few Indigenous students from regional and remote Australia have a preference for online learning because of the cost, lack of stable internet access, or restricted access to devices (Brown et al., 2020). Cultural factors are also a consideration as money is often shared within Indigenous families and influences the allocation of funds for technology and internet access (Rennie et al., 2019).

2.5. Effect of COVID on Lecturers teaching Indigenous Australian Students

As COVID-19 emerged, lecturers primarily focused on face-to-face delivery and had the challenge of learning to teach and interact with students online (Daumiller et al., 2021). However, many lecturing staff did not have the knowledge and skills to develop and deliver engaging material suitable for an online environment. According to Daumiller et al. (2021, p. 2) this had the potential to cause one of "three types of attitudes: perceived threat (e.g., being concerned about problems that could arise from the shift from face-to-face to online teaching), perceived usefulness for competence development (e.g., finding the shift helpful to learn and increase professional competences), and perceived positive challenge (e.g., experiencing feelings of confidence and capability concerning meeting the demands tied to the shift)".

Another dimension of the complexity of teaching online as a result of COVID-19 was the thought and effort needed to support and to keep Indigenous students engaged. With the number of risks being considered, the consequences for Indigenous students may not have been understood, or adequately considered or sufficiently prioritised by university leadership. This could be reflected the trend in Indigenous students commencing their studies in 209, 22.8% not returning in 2020, which was below the 2016 rate (Productivity Commission, 2022).

2.6. Priorities of Administrators and effect of COVID on Indigenous Australian Students

In June 2021, the Federal Minister for Education and Youth, The Hon. Alan Tudge presented the priorities for higher education as: research commercialisation, international education, the domestic student experience, and freedom of speech (Tudge, 2021). When considering domestic student experience, the Minister's focus was on the return to face-to-face learning where possible and to enhance the classroom and learning experience of Australian students.

An important matter that may have been included in the discussion about the domestic student experience but was not at the forefront, were matters associated with Indigenous student engagement and the challenges of the digital divide.

However, two of the four priorities set by the Minister for university administration appears to be financial related, commercialisation and international students. It appeared that more concern was raised at least from a media perspective, about the loss of revenue especially from overseas students and a balance sheet of Australian universities, rather than engaging and maintaining Indigenous students.

3. Discussion

Education is a human right (Shultz, 2015; United Nations General Assembly, 2007) and COVID-19 presented unique sociotechnical dilemmas that involved a transformation process in which universities commenced journeys from a current state of teaching and engaging with students face-to-face, to a desired state of online teaching and engagement. This change in delivering education affects student lives and their well-being as individuals, families and communities (Anderson and Ostrom, 2015). This change may need to consider a stronger focus on cultural matters for Indigenous students in rural and remote locations.

Similar to other large, complex sociotechnical initiatives, a number of risks need to be considered and resolved. According to Obondi (2022), many studies have concentrated on risk identification, assessment, and analysis while neglecting activities related to controlling, monitoring and mitigating risk. These risks consider both human and non-human multidisciplinary actors involving leaders and managers driving strategy, marketing to influence culture change, changes to processes such as supply chains and technology to support these activities (Verhoef et al., 2021). These issues may contribute to the high rate of failure of sociotechnical initiatives (Obondi, 2022).

Adopting a multidisciplinary approach to consider and monitor the risks of human and non-human factors may help reduce the high failure rate. However, the number of actors and associated risks linked to the actors can prove significant and complex. Existing models and frameworks may not be suitable for managing the complex processes of transforming how universities engage and teach Indigenous students in rural and remote communities (Khazieva, Tomé, and Caganova, 2018).

The sociotechnical risk in this study can be reflected in as strategic or operational networks that enrol actors, form new networks, obtain and relinquish power as they interact with one another to contribute and influence sociotechnical initiatives. The actors and networks also interact with one another to identify and mitigate risk associated with the initiative (Wilson, 2021). To help manage the complexity, the actors and networks are categorised into four domains: leadership and management (a strategic domain), culture (a strategic domain), process (an operational domain) and technology (an operational domain).

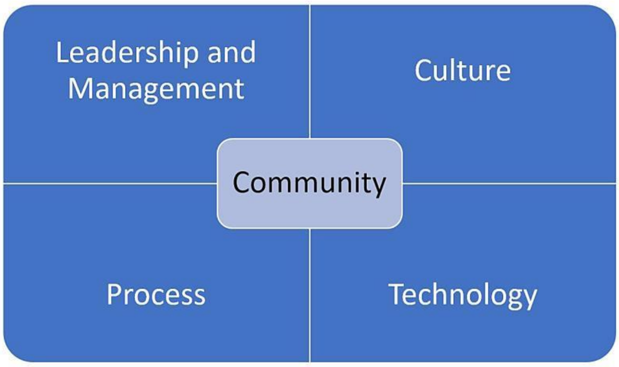

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Figure 1: Relationship between strategic and operational actors, networks and four risk domains.

3.1. Leadership Management

Actors and networks in the leadership and management domain focus on activities that include governance, strategy, policy, allocation of human and financial resources and alignment with federal, state, and local government requirements. Leadership and management also involve being accountable for risks and risk management for the initiative, to ensure Indigenous students are engaged. The support of leaders and managers must be visible and sustained or the effort to support Indigenous students may fail. If recognising the importance maintaining and enhancing opportunities to engage and teach Indigenous students is not sufficient and sustained by university leadership and management, their effort can be seen as an unsatisfactory and morally insufficient. A failure to take strong action can be viewed as a token gesture by many in the Indigenous community and may be considered unjust by reinforcing unjust inequities. According to Grant (2017), tokenism is the practice of appease or act to pacify a demand to undertake a particular course of action.

Examples of risk and mitigating actions that university leadership and management can consider related to Indigenous students in rural and remote Australia include:

Leadership risk 1: University leaders and managers may not have the knowledge, experience or have the trust or relationships with Indigenous people to understand the situation in rural and remote communities.

Leadership mitigation 1: Ensuring there is an appropriate and authentic Indigenous voice guiding the university's executive team regarding engaging, supporting and teaching students in rural and remote communities.

Leadership risk 2: Insufficient human and financial resources allocated to engage, support and teach Indigenous students in rural and remote communities.

Leadership mitigation 2: Leaders and managers develop plans, strategies and policies to ensure human and financial resources are allocated to meet requirements laid out in strategies plans and procedures. Leaders and managers will also work with organisations external to the university to ensure solutions can be developed and funded to create the infrastructure, including telecommunications and spaces for Indigenous students to study.

3.2. Culture

To transform from a current to a desired state where Indigenous students can be engaged, have sufficient support and access to learning from universities may face resistance. This resistance may be from a lack of understanding of the plight facing Indigenous students, or opposition to the allocation of human and, or financial resources needed for transformation, or the importance of building trust with Indigenous communities and students. A challenge managing sociotechnical initiatives is the need to develop and communicate to multiple stakeholders from multiple disciplines the purpose, status, and issues associated with the transform (Bygstad, Nielsen, and Munkvold, 2010; Jarulaitis, 2015). This is a reason that steps to influence culture is considered important for this transformation initiative. The change in culture. These perspectives and related risks, include understanding the culture of multiple networks within and external to the university and the activities needed to influence this culture. These networks may include Indigenous and non-Indigenous community residents, Indigenous students, organisations (e.g., telecommunication providers) as well as other stakeholder networks (Wilson, 2021).

From an Indigenous perspective, the cultural safety and security of Indigenous students can be considered paramount (Coffin, 2007). It is important to note that Indigenous students require different support structures when compared to non-Indigenous people (Kickett-Tucker, 2021; Wright, Culbong, Crisp, Biedermann, and Lin, 2019). A thorough culture change process can assist alter attitudes to gain support for change in a respectful manner.

The culture of an organisation is influenced by its leadership. If leadership and managers demonstrate dedication to achieving a vision and allocate appropriate human and non-human resources, it can contribute to supporting and sustaining transformation. These resources should encompass and acknowledge the challenges of colonialism and the negative impact on Indigenous people. This includes a better understanding how colonisation created an environment in which Indigenous people are often disadvantaged when it comes to justice, education, housing and healthcare. With this understanding more thoughtful and considerate decisions can be made.

Examples of risk and mitigating actions that university leadership and management can consider related to cultural matters include:

Culture risk 1: Thorough, Indigenous led cultural awareness initiatives are not developed for non-Indigenous stakeholders.

Culture mitigation 1: Cultural awareness training developed for stakeholders to assist them to understand the challenges facing Indigenous students, people, and community self-determination.

Culture risk 2: Lack of understanding of the need to support Indigenous students.

Culture mitigation 2: Engage with Indigenous Elders, students, families, and communities to build trust, understand the needs and work together on how to support attaining the need.

3.3. Process

Universities may need to create new or enhance existing processes to effectively engage, support, and teach Indigenous students from rural and remote communities. A key process involves the creation and management of knowledge for continuous improvement in supporting Indigenous students. This involves the creating or acquiring knowledge to store and accumulate; pool, assemble, transfer and assess knowledge; and the application or utilisation of knowledge (Evans, Dalkir, and Bidian, 2015). Knowledge gained from this process may assist the effort of universities to gain and sustain support for the initiative that supports Indigenous students in rural and remote communities.

Fundamental to the solution proposed in this paper are processes to support risk planning, assessment, risk handling and monitoring. Each domain of leadership and management, culture, process and technology include multiple risks that influence how Indigenous students in rural and remote areas are engaged, supported and taught, need to be identified, managed and mitigated.

Examples of risk and mitigating actions that university related to process include:

Process risk 1: Some dwellings housing Indigenous students in rural and remote communities may lack space for the students to learn.

Process mitigation 1: In collaboration with Indigenous communities, create a process to identify culturally safe and secure spaces for Indigenous students to study and learn online in regional and remote areas. For example, a classroom at the school after hours or a room in the council building.

Process risk 2: Current university processes to engage, provide support and teach Indigenous students online may not satisfy target student audiences.

Process mitigation 2: Review and refine or create processes to ensure Indigenous students can engage, be supported, and learn. This can be done during initial interviews, online surveys, and personal contact with the cohort.

3.4. Technology

The final domain briefly described in this paper is the technology domain. The vision for the desired state encompasses the use of technology to engage, support and provide students the opportunity to learn online. However, according to Cresswell and Sheikh (2013) technology based initiatives are complex and have a high failure rate. To reduce this risk, technology will need to be considered in a sociotechnical context of the integration of human and non-human actors that include strategies, people and management processes (Coltman, Tallon, Sharma, and Queiroz, 2015) as well as legal, ethical and social perspectives (Fisher et al., 2015).

The technology domain interacts with these sociotechnical activities to help present a broad multidisciplinary view of the initiative and influence how the university engages with Indigenous students in rural or remote communities.

Technology risk 1: Indigenous students do not have access to adequate technology for online engagement, support and learning.

Technology mitigation 1: The university can provide Indigenous students with access to adequate technology through multiple channels. This may include loan of technology or provide access to locations, such as community centres where the technology and space is available for use by the Indigenous students.

Technology risk 2: Indigenous students do not have access to the Internet, or access is insufficient in rural or remote communities.

Technology mitigation 2: Universities in collaboration with other stakeholders, such as telecommunication providers will create solutions to ensure sufficient Internet access is available to Indigenous students in rural and remote communities. This could be a partnership with local schools or clinics to provide internet access.

3.5. Transformation cycle

The domains of leadership and management, culture, process and technology interact to transform the existing situation to a desired one. This is summarised in figure 1.2.

Figure 2: A simplified transformation cycle informed by Karp (2006)

Using figure 2 as a guide, the transformation cycle as discussed.

Existing situation: The existing situation is that Indigenous students in rural and remote communities are disengaging from university studies because of the lack of online support due to the lack of infrastructure.

Vision: The vision of the desired state includes universities have the capacity and capability to engage and support Indigenous students online in rural and remote locations.

Transform: With a vision, visibly and tangibly supported by the university, the process to transform the current state into the desired situation commences. This transformation involves identification of multidisciplinary human and non-human actors aligned in a way to achieve the desired situation.

Desired situation: The transformation process encompasses the change from a previous state to the desired. During this stage, the desired situation is achieved.

Knowledge gained: During the knowledge gained stage, the transition from the previous state to the desired state is achieved. The desired becomes the new current state. The new current state is considered. The ability of Indigenous students in rural and remote communities to access online support and learning are assessed against the vision for the desired state. If the solution can be developed to strengthen how Indigenous students in rural and remote communities engage and learn, the journey to transform may continue if there is sufficient support from leaders, managers and community stakeholders.

Several steps can be undertaken to reduce the risk of further disengagement of Indigenous students because of situations such as COVID-19. As previous stated, sociotechnical initiatives are complex and to be effective and sustainable, the transformation cycle will need to be iterative, and the cycle repeated multiple times until the desired stated is attained. With each iteration, knowledge is gained to assist with the next iteration.

4. Conclusion

COVID-19 shed light on the challenges faced by Indigenous students located in rural and remote communities to engage and be supported to learn. This digital divide is a sociotechnical situation in which Indigenous students in rural and remote areas are at a disadvantage when compared to other students in urban and regional centre settings. To plan and progress with an imitative to successfully address this challenge would require a multidisciplinary approach. However, according to academic literature, the failure rates of such initiatives are high.

Of potential concern in efforts to resolve the challenges related to supporting Indigenous students in rural and remote communities it the lack of human and non-human actors to support efforts to service university Indigenous students during the height of the COVID-19 pandemic. To address this sociotechnical issue, it is recognised that a sustained solution is complex.

To assist address the matter of complexity, in this paper, risk is categorised into the domains of leadership and management, culture, process, and technology. Using these domains, the risks may be better identified, managed, monitored and mitigated.

The model presented in this paper focuses on Indigenous students from a broad perspective that includes social, economic and cultural dimensions along with human rights for Indigenous people. This aims to ensuring that Indigenous students from rural and remote locations have the space and technology to have culturally safe and sustained pathways to learning and engagement while in their communities.

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25. The Nature of Business Process Redesign in Small and Medium-Sized Enterprises in a Developing Country Context

David Sanka Laar
Department of Information Systems
University of Cape Town,
South Africa
LRXDAV013@myuct.ac.za

Lisa F. Seymour
Department of Information Systems
University of Cape Town
South Africa
lisa.seymour@uct.ac.za

Abstract

As important drivers of the economy, Small and medium-sized enterprises (SMEs)in developing countries need to adopt innovative business practices to deal with their volatile economic environment. Business process (BP) redesign provides transformational capabilities that can improve the performance of SMEs. However, research in BP redesign has concentrated on large organisations, mostly in developed economies, resulting in methods that are not suitable for SMEs in developing countries. This has resulted in limited adoption of BP redesign among these enterprises. SMEs have unique challenges such as resource poverty, lack of business skills, and different business goals and practices. Thus, they require BP redesign methods tailored to their needs. To contribute to addressing this gap, this paper explored the issues raised by SMEs in BP redesign initiatives in a developing country context. Through exploratory interviews with managers of SMEs, the findings show that the SMEs are characterised by severe limitations in resources, and uncertain business environment. Thus, they engage in agile, iterative, systemic, and context-sensitive process change practices. As part of a larger design science research (DSR) project, these findings serve as a foundation for designing and developing a BP redesign method suitable for SMEs in developing country contexts.

Keywords: Business process management, Business process redesign, SMEs, Developing countries.

1. Introduction

Small and medium-sized enterprises in developing countries contribute significantly to national income, employment, exports, and entrepreneurship development (Agboh, 2015). However, they face many challenges including resource poverty, and volatile and business environment which inhibit their growth and sustainability (Amoah & Amoah, 2018). Thus, they need to adopt innovative practices such as advanced management strategies, new technologies and organisational forms (Terziovski, 2010). Business Process (BP) Management (BPM) provides the capabilities to innovate and continuously transform businesses and entire cross-organizational value chains (Buh, Kovacic, & Indihar Štemberger, 2015). It leads to substantial improvements in performance such as greater flexibility, increased accuracy, reduced cost, increased productivity and customer satisfaction (Hammer, 2010).

Although there is a positive correlation between BPM and organisational performance among SMEs, the extent of BPM adoption is very low in SMEs in developing countries (Radosavljevic, 2014). On the other hand, research in BPM has dwelled heavily on larger, organizations, mostly in developed economies (Dallas & Wynn, 2014). This has resulted in generic and mechanistic BPM methods (Bucher, Raber, & Winter, 2015) that are not appropriate for SMEs since the conditions in SMEs are different from that of large organisations (Fogarty & Armstrong, 2009). Meanwhile, studies on BPM in SMEs in developing countries have concentrated on identifying the conditions that should prevail in

SMEs to ensure the success of BPM initiatives without considering the suitability of existing BPM methods (Bazhenova, Taratukhin, & Becker, 2010). As Rosemann and vom Brocke (2015) caution, it is important to consider the diverse contexts of process change initiatives when employing methods since any one-size-fits-all solution is unlikely to succeed.

We focus on BP redesign as it has been considered the backbone and a critical stage in BPM adoption, and the most value-adding activity in the BPM lifecycle (Dumas, La Rosa, Mendling, Reijers, & others, 2018). It has also received the least methodical support (Vanwersch et al., 2016). Thus, it is important to provide SMEs in developing country contexts with an effective BP redesign method to help them develop the needed capabilities for effective innovation. This requires prior knowledge of how their process change looks like. Thus, the research question is *What does business process redesign look like in SMEs in a developing country context?* The objectives are to: (1) explore the characteristics, challenges, and practices of SMEs with regards to BP redesign, and (2) to determine the implications of the redesign characteristics for BP redesign methods. Section 1 provided the research background, question, and objectives. Section 2 provides a brief literature review and a conceptual framework for the research. Section 3 deals with the research methodology, outlining the research process as well as the techniques and tools used for data collection and analysis. In section 4, the results are presented and discussed while section 5 provides the concluding remarks.

2. Conceptual Framework

Studies on BP redesign in SMEs have focused on identifying the critical success factors (CSFs) such as communication, continuous improvement, cross-functional mindset amongst senior executives, top management support, clarity on a strategic level, and information technology (Lückmann & Feldmann, 2017). However, little work has been done to uncover the features of BP redesign methods for SMEs. Although some of the studies such as Smart et al. (2004) adopted a methodological approach on BP redesign, they have not taken the impact of the organisational context into consideration. Kirchmer (2017) has considered the influence of the SMEs context but focused exclusively on developed contexts.

2.1 Business process redesign methods and SMEs

BP redesign is considered broadly as the articulation of a BP in terms of its interdependent tasks, resources and other factors that have an influence on the success of the process (Limam Mansar & Reijers, 2007). It can be based on the philosophy of BP improvement (BPI) where it is concerned with relatively minor specific changes to existing BPs, or BP reengineering (BPR) where it involves major efforts undertaken to significantly improve existing processes or to create new ones (Zellner, 2011). It has been used for structuring and improving enterprise systems and processes in SME's value chain (Feldbacher et al., 2011).

Researchers have suggested that BP redesign should be approached as an 'art' rather than a science in order not to stifle innovation and creativity (Davenport, 1993). However, a methodology provides guidance for practitioners to avoid mistakes, help focus on important issues and raise important questions during a redesign effort (Vakola & Rezgui, 2000). A BP redesign method can be defined as a consistent set of techniques, guidelines and tools which enables the BP redesigner to reorganize business activities and processes in an organization (vom Brocke et al., 2021). Various researchers have proposed frameworks for BP redesign (Vanwersch et al., 2016). A set of elements synthesised from these frameworks include the *aim*, *actors*, *input*, *output*, *procedure model*, *technique*, *and tool.* However, vom Brocke, Zelt, & Schmiedel (2016) have criticized the existing frameworks as lacking a contextual dimension, arguing that context is critical for success. Thus, we conceptualise a context-sensitive methodological framework for BP redesign as comprising the elements of a BP redesign method embedded in the context of the organisation as illustrated in Figure 1.

The **aim** specifies the objectives and intended outcome that result from the application of a redesign method (Smart, Maull, & Childe, 1997). The **procedure model** indicates the order of activities to be fulfilled when redesigning BPs (Zellner, 2011). Palma-Mendoza et al. (2014) provide one of the most detailed procedure models for BP redesign. **Techniques** and **tools** help to generate the required output for each activity of redesign (Grant, 2016; Kettinger, Teng, & Guha, 1997). **Inputs** include information such as redesign requirements, redesign limitations, and as-is process specifications that are to be analysed and redesigned. **Outputs** or deliverables refer to artifacts such as documents, to-be assessments, and to-be or final redesigned process models that are produced by the activities of redesign (Vanwersch et al., 2016). **Actors** refer to the intended participants, who are responsible for carrying out the tasks of redesign (Smart et al., 1997).

However, BP redesign is shaped by the context of organisations in which it is applied including SMEs (vom Brocke et al., 2016). Although it is difficult to classify SMEs as a whole, recent developments points to the need for more investigations into their functional characteristics linked to specific areas of management methods (Kozlowski & Matejun, 2016). Varied definitions of SMEs have been devised. In this work, a SME is defined as any enterprise with 5 - 99 employees (Kayanula & Peter, 2000). Ghobadian and Gallear (1997) provide a comprehensive treatment of SMEs. Cocca and Alberti (2010) broadly categorise SME characteristics into **internal** and **external** contexts. SMEs are characterised by personalized management, severe limitations in human and financial resources, limited number of customers and access to markets; informal, dynamic strategies; a reactive, fire-fighting attitude; high innovative potential, and flat and flexible organisational structure. Most of these characteristics can be assumed to shape the practice of BP redesign in SMEs.

Previous studies have identified the most outstanding challenges of BP redesign in SMEs as including lack of financial resources, time pressure, cost pressure, limited human resource capacity, multiple roles of employees, low skill level, lack of support from senior executives, and poor knowledge of process-oriented approaches (Chong, 2007; Kirchmer, 2017). In developing countries, these constraints are compounded by adverse environmental factors such as the poor state of IT infrastructure, IT security issues, frequent power outages, lack of training opportunities and low IT skills (Asare, Gopolang, & Mogotlhwane, 2012). These result in high initial investments, and significant obstacles for undertaking BPM projects (Becker, Pfeiffer, Räckers, Falk, & Czerwonka, 2015). However, some characteristics of SMEs facilitate the adoption of BPM in SMEs (Kirchmer, 2017). Thus, a BP redesign approach for SMEs need to exploit the facilitating factors while addressing the inhibiting ones to ensure successful redesign.

3.0 Research methodology

The work reported in this article is part of a larger research project based on the Design Science Research (DSR) paradigm (Hevner, March, Park, & Ram, 2004) which is aimed at designing and developing a business process redesign method, an artifact of DSR (Gregor & Hevner, 2013). The project follows the DSR methodology (DSRM) by Peffers, Tuunanen, Rothenberger, & Chatterjee (2007), consisting of six steps: (1) Problem identification and motivation, (2) definition of the objectives for a solution, (3) Design and development, (4) Demonstration, (5) Evaluation, and (6) communication. It draws heavily from pragmatic lines of inquiry where theories are judged not by their claims to truth, but by their ability to accomplish work processes (Dewey, 1938; Goldkuhl, 2011). This view recognises that research occurs in social, historical, political, and other contexts, thus opening the door to different worldviews and assumptions (Cherryholmes, 1992), and varied research approaches (Tashakkori & Teddlie, 1998).

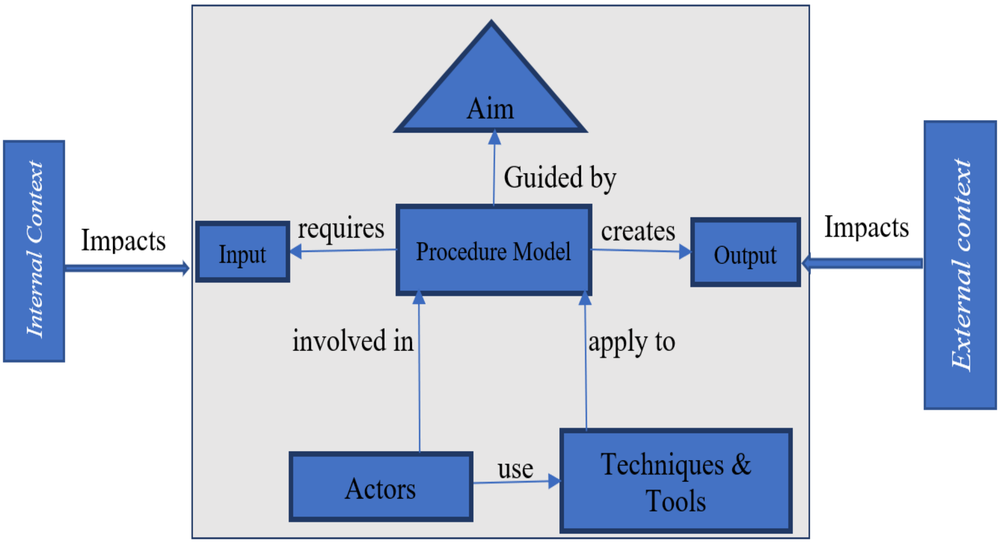

Figure 12: A Context-Sensitive method meta-model for Business process redesign

This paper is concerned with the first and second steps of the DSRM, aimed at understanding the nature of BP redesign in SMEs. Thus, an exploratory review of literature was conducted to identify the research problem and understand the concept of BP redesign (Levy & Ellis, 2006). This was followed by a qualitative study to help uncover the issues faced by SMEs and their BP redesign practices and provide a problem analysis on which to ground the design of a BP redesign method in subsequent research. The study involved three SMEs in Ghana, a developing country, which had recently undertaken some form of BP change. SMEs in Ghana form a core element that fosters employment, economic growth, and poverty alleviation (Amoah & Amoah, 2018). However, they face major challenges, most notably access to Finance, which affect their growth.

The instrument used for data collection was semi-structured interviews (Myers, 2013) and participants included SME managers, project team members, and process owners and executers. The interviews lasted for 40-60 minutes, and were audio recorded, transcribed, and loaded into NVivo 12 Plus, a Computer-Assisted Qualitative Data Analysis Software, for coding and analysis. The data was analysed using the thematic analysis method (Braun & Clarke, 2006). Ethics clearance was obtained from the Ethics Committee of the University of Cape Town and further permissions received from the management of the participating SMEs. The participants also completed a consent form before interviews proceeded. To ensure anonymity, the SMEs are labelled as Enterprise A, B, and C as shown in Table1 together with the study participants.

4. Findings and Discussion

Themes were inductively generated from the data and categorised according to the conceptual framework in section 2. The findings are grouped into internal and external characteristics of SMEs, and their BP redesign practices. The implications of these for BP redesign approaches and methods are subsequently discussed.

4.1. Characteristics of SMEs that may shape business process redesign

In the internal context, several issues were raised by the participants as shaping their business operations. The participants talked about ***goals*** their enterprises had, including gaining competitive edge, offering high quality products, expanding business operations, refocusing services, and satisfying customers. The CEO of Enterprise B stated, "high quality products first of all within the three northern regions and beyond." For the Director of enterprise C, "… one of the objectives is to be the leading agro-chemical distributor in the north and also to be the best seed processing company in the north." In terms of BPs, majority of the participants revealed that the SMEs were characterised by *undocumented and informal business processes***.** "Yes, we have processes, but it is not well formalised, we have a way of doing that, which includes either the open market or selling to customers at the government subsidized price." (C-CEO); "No. we just use the traditional way of doing things, that is the oral communication between me and the customer. We do not have any formal way of operation. They are in our heads" (A-CEO).

Another issue was *weak human resource capacity* occasioned by *few workers* who are *overstretched, inadequate training, and poor attitude towards work***.** "Yeah, getting the employee, someone to work with was a problem. Those that can use the machine, getting such people became a problem. The working hours also becomes too much sometimes." (B-Accounts officer). "I was the one operating the system, I just trained myself to do that." (B- Training manger). "Workers' behavior towards work, sometimes, a worker will not come to work and will not give any excuses." (C-Assistant director). The participants also exhibited *limited knowledge of BPM***.** "I heard of it during my school days but don't know more about it." (A- CEO). "I have heard of it but don't know much about it." (A-Storekeeper). "No for business process redesign and BPR, yes for BPM but no idea what it is." (B-Training manager). "No idea." (B-Accounts officer). "Yes, in general terms." (B-CEO). The enterprises were also found to be characterised by *Limited financial resources, difficulty collecting debts, and limited physical space.* "The challenges … are in terms of financing to grow." (B-CEO). "Collecting money from debtors, one of the problems faced is on our debtors. Sometimes we run short of stock, but we can't refill because we don't have money. We find it difficult collecting the debts." (A-Storekeeper); "We do give them on credit to use and come and pay. There are people you will chase and chase for long time before they will come and pay." (C-Accountant). "The place is too small and for that matter affecting the growth. We want to bring in more goods buts it isn't possible because of either capital or the location of the shop, etc." (A-CEO).

In the external context of SMEs, the issues included *high cost of energy, financial obligations to state agencies, and Customer pouching.* "I think it's the cost of power. We pay more to […] than any single staff at…takes home. …That is the most difficult challenge, that can affect a lot of things." (B- CEO). "Sometimes […] will come and say you have not paid your taxes or […] will say you have not paid your workers' contribution for some time." (C-Operations manager). "Some people come for our invoices for the purpose of using it to take money for payment from customers. These people go to inflate our prices in order to convince the customer to buy from them." (A-Salesperson). Other external issues included *policy restrictions and Limited literacy of customers***.** "Like my previous workplace, you know it's a financial institution, but later they wanted to move into transport … but the certificate they acquired didn't make it possible for them." (C-Accountant). "The illiteracy level of our farmers. We are dealing with lives (in terms of chemicals), and sometimes we find it very difficult explaining issues to the farmers. Most of the products come with labels and directions as to how to use the product, but because majority of my people are illiterates, we find it difficult selling this information to them." (C-CEO).

4.2. Business process change practices of SMEs

Various ***aims*** were cited by the participants for redesigning BPs and introducing new systems. Some the reasons include to *retain and grow clients and revenue* "There are some customers, they have genuine concerns." (C-Director). "We think we could find a way to bond closer to our customers." (B-CEO); "We wanted to improve our services or our sales and attract more customers." (B-Accounts officer). Some of the enterprises aimed at *improving operations, reducing cost and waste, and improving output.* For example, at enterprise A, the aim was "to improve the way, we work." (A-Salesperson). The accounts officer at Enterprise B explained that they benefited so much from implementing a new software application: "The thing is just there all you need to do is change. That's when there is a change on price or the dollar exchange rate in the international market... It reduces the cost of stationary that are often used in the processes."

Another motivation was to *improve order processing and product distribution.* "We benefited a lot from the change… our distribution has really improved. Formerly, when we import goods, it will be on the warehouse for long and we will not know how to distribute. Not that they don't request, but as I said, we don't know how to distribute to them because of where they stay. As a result of that, we introduced the distribution in badges. It is helpful." (C-Assistant director); "… but now the accountant is involved in the fifth process. He will complete the fifth process then the cashier receives the cash before the customer goes to the warehouse to take the goods, … At first, the cashier will always issue what we call an invoice, and that invoice is given to the warehouse, and they will also deliver that. But now everything has been computerized." (C-Accountant). Some of the enterprises undertook process redesign to *adopt new technology.* A manager pointed out that his enterprise redesigned its BPs to enable it to adopt a new technology. *"*Yeah, just recently we did some changes, we were doing normal like I told you, but we just introduced some software for accounting purpose, … initially we use to give the waybills, sometimes where you buy, we give you receipt or invoices." The computer generates the invoice and prints it for you." (C-warehouse manager).

***Actors in process redesign*:** Participants reported that most *process change projects are initiated by the CEO*. For example, "Those times we were finding difficulty in our work, so he [CEO] just came to inform us about it and…. said he will introduce a system so that we will not find it difficult in our work." (A-Storekeeper). "From the starting, he [Director] brought the idea…The CEO is leading because he brings out all the information and other issues." (C-Assistant director). "Our boss is the main person involved. He comes to collect our suggestions so he can now guide us on how to do it (B-Training manger). The participants reported *inclusive form of stakeholder involvement*. "My boss - the CEO and some of my seniors (A-Storekeeper); "Board Chairman, Consultant of the company, legal team, the Operations Manager and the Deputy CEO of the company, and the accountant". (C-Director). "Some of us were part; some from other branches were part." (B- Accounts officer).

Procedures and tools for business process redesign:

The enterprises engaged *occasionally in major process redesign projects* while doing *process improvement frequently*. "We make major changes once or twice every year because the thing is that we have a meeting every month … every manager comes out to talk about his or her unit, the challenges they face and then the rest of the house will suggest how to improve it…but major changes, once or twice a year." (B-CEO). The steps involved in BP redesign were *informal, iterative, and collaborative*. While some of the participants described the steps they followed, others said there were no steps involved. "There was nothing like steps or any technique, it just came by itself." (A-CEO); "We divided the work and gave it out to individuals, after which we came together to discuss the results and conclusions … after discussion, we are to visit our previous stage, … We were designing, ... There is a time you come back to revisit other things listed but not achieved." (B-Accounts officer).

It was pointed out that the redesign of BPs is a complicated process and that it required the *right guidance tools and digital technologies***.** However, the participants were unable to mention specific methods, techniques or tools used in their redesign projects. "If there was a structured method to follow in implementing the change it would have been better." (A-Storekeeper). "I would prefer a guide/ tool to help guide me do things better than I use to do." (A-CEO. "What I am saying is that the approach may be good but the implementation. If you didn't take the right tool, you'll finally have some challenges." (C-Accounts officer). "We always wait until we all come together then we pinpoint some of the things we need to do, but I suggest that we should have a platform or email then we can discuss this and share the ideas with each other online before we now come together…" (B-Training manager).

Priorities in process redesign:

The participants expressed the need for *effective planning and consideration of key factors* to help mitigate challenges in redesign. "We need to strictly consider other factors and plan before we decide what we want to do. We do it but we don't do it thoroughly." (B-Training manager). It was also considered critical to engage in *monitoring and evaluation, and to adopt new technologies* that will aid in efficiently rendering services "We have someone who normally does the assessment, a daily analysis of how work is done." (C-Accountant). "It should be a system with bar code like Melcom, I think it will be fine." (A-Salesperson). It was also emphasized that *an inclusive working space should be provided* "Also, commercial areas like this [upstairs] the place should be disable-friendly." (B-Training manager).

Staff retention, training and development were considered a priority in redesign. "The other thing that was considered was staffing. I had this that no matter the kind of change, all staff should be maintained. Their roles may change but they shouldn't leave." (B-CEO). *Training staff* on newly introduced systems was considered critical to enable employees operate effectively. "Even if they are not there and one of you is around, you should be able to adjust... So, everyone is trained to know almost all the services rendered so if someone is not around, others can work for him." (B-Accountant). "After the installation of the software, they were taken through using their computers as to how to come out with an electronic invoice, how they can change prices as and when the need arises." (C-Operations manager). The participants revealed that the need to consider the *implications of finances*. "It was well checked because people's role will eventually lead to a change in their salaries." (B-CEO). "And moreover, all will be done with finance, money, if there is much money, we should have been able to separate some of these things and position them in a very nice place than mixing it with other services." (B-Training manager).

Customer centricity was considered critical in redesign. "From the middle to the end of 2016 we started realizing that our clients were not happy as they used to be. And then… we kept looking for the solutions and we realized that customer care was very necessary. No customer should walk in and spend more than 15 seconds without being attended to" (B-CEO). Similarly, enterprise C prioritised making its BPs more customer focused. "The approach we used was the farmer-based method. What happens is that we had the farmer groups already, some … grow rice, others… grow soya beans, etc. So, you will meet the farmer group and talk to them" (C-Accountant). "May be, talking about welcoming the person, even if what the person is looking for isn't there, you can go to the near-by shops to look for it for the person." (A-Salesperson).

4.3. Summary of findings

The findings of study are summarised in Figure 2. The model shows the nature of BP redesign as practiced by the studied SMEs and shaped by their external and internal features. The SMEs are characterised by limited resources, informal practices, empathy for workers, limited literacy, and high level of competition. This portrayed a highly uncertain environment requiring attention in process redesign. In line with previous studies which have noted that SMEs are uncomfortable with formal change approaches (Ghobadian & Gallear, 1997), none of the participants mentioned a specific method followed in their redesign initiatives. However, they expressed the desire for a structured approach and guidance tools. Existing literature does not provide guidance on how to evaluate, select or develop redesign methods for SMEs.

The uncertain environment, organic structure and fluid culture of SMEs make them rely on business agility and innovation as a competitive advantage (Marjanovic, 2009). This featured prominently in the organisational goals of SME as the desire for change and business model innovation is high and frequent. Consequently, they require less bureaucratic redesign methods to allow them to learn about their environment and develop solutions in line with their peculiar characteristics and needs.

As the SMEs have little control over most of their constraints, notably limited financial resources, they need to focus on important initiatives and their key capabilities, and aim to make process change occur quickly and effectively (Kirchmer, 2017). Their redesign approaches must incorporate risk- or cost-benefit analysis to enable them to evaluate a proposed change against their resource capacity and environmental characteristics to ensure alignment. This calls for a context sensitive and systemic approach to redesign to enable SMEs to effectively incorporate their peculiar needs in a redesign project. The SMEs need to employ cost effective redesign methods, techniques, tools and strategies such as beginning on a small scale, flexible approach, and continuous improvement in order to deal with their limited financial capacity, managerial time, skills, and technical skills (Thiemich & Puhlmann, 2013).

The procedure model shared by the SMEs is not too different from those in mainstream literature on BP redesign (Palma-Mendoza et al., 2014). However, the difference lies in the order of activities, tools, and priorities in the redesign exercise. For the case SMEs, the procedure needs to be iterative and flexible in nature. As indicated by existing literature (vom Brocke et al., 2016; Yusof & Aspinwall, 2000), the nature of BPs and activities require them to use process change methods that are systematic, be easily understood, be simple in structure, have clear links between elements which are presented, be general enough to suit different contexts as SMEs are not a homogenous group. It should also represent a road map and a planning tool for redesigning and implementing BPs as SMEs are concerned with operational issues and immediate results. It must also incorporate digital and social technologies to facilitate collaboration among redesigners while easing the cognitive burden of redesign. It is important to note that though most of the empirical SME characteristics resemble that of large enterprises, these are on a higher side for the studied SMEs. The highlighted characteristics are specifically associated with SMEs in developing countries and should be given special attention in redesign methods and projects. The findings are not meant to be generalised, but to shade light on the features and redesign practices of the studied SMEs for projecting to similar contexts in developing countries.

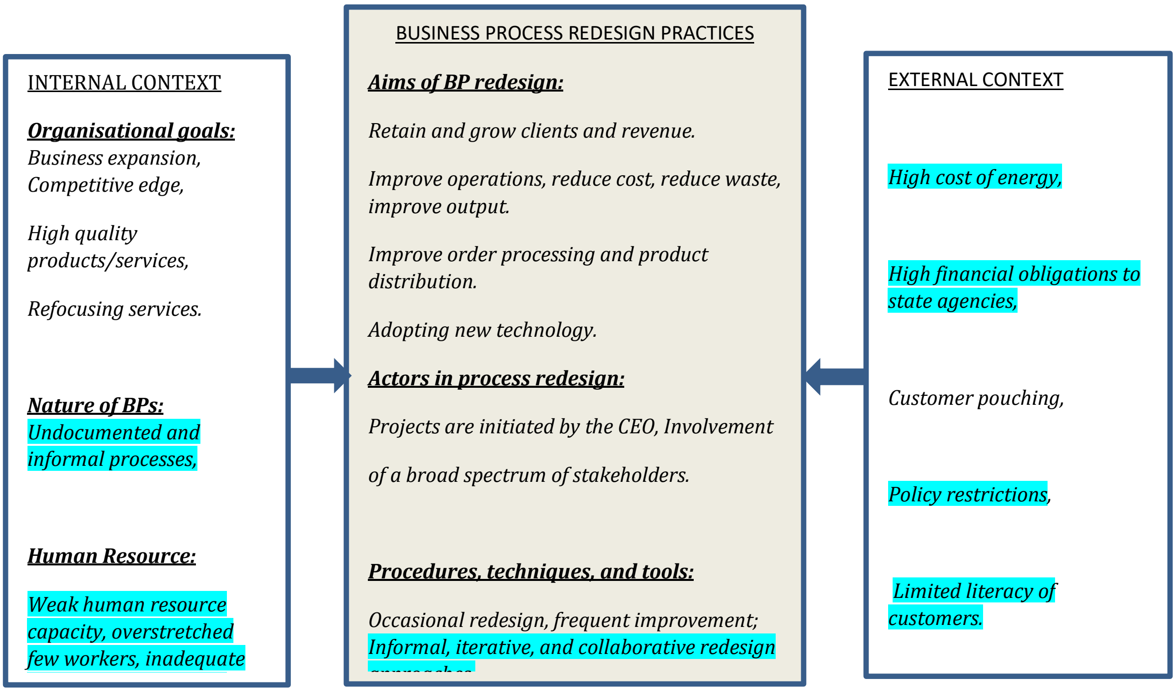

Figure 2: A Model of Business Process redesign in SMEs

5. Conclusion

We sought to address the problem of lack of suitable BP redesign methods for SMEs in developing country contexts. First, we inductively derived a conceptual framework of BP redesign methods from the mainstream BP redesign literature which helped to frame the research endeavor. The framework is an original contribution as existing literature does not provide a context-sensitive perspective for investigating BP redesign practices. The constructs of a BP redesign method have been well defined. However, they do not incorporate the peculiarities of SMEs, especially those in developing country contexts. This makes it difficult for these entities to effectively engage in BP redesign initiatives. Therefore, there is the need to design and develop business process redesign methods specifically tailored to the needs of SMEs in developing country contexts. We contributed towards addressing this problem by revealing the challenges and process change practices of SMEs in a developing country context. The studied SMEs exhibited peculiar characteristics such as severe limitations in human and financial resources, and uncertain business environment. These in turn occasioned special approaches and priorities such as agile, cost effective, and systemic redesign approaches which have implications for the design of BP redesign methods for SMEs. The empirically generated model adds to the BP redesign literature by providing an understanding for practitioners and researchers to design BPs and develop methods for SMEs respectively.

The main limitation of this study is the small sample size involved, which makes the results difficult to generalise. However, amid limited prior work and the emerging nature of BP redesign in the study area, the qualitative study on the small sample provided the opportunity to unearth the challenges and needs of SMEs. Future studies can use mixed methods to validate these findings with large sample sizes while qualitatively looking for additional emerging issues. Future work can also build on these findings to derive more formalised design requirements for designing a BP redesign method that fits the needs of SMEs in developing countries.

Acknowledgements: David Sanka Laar acknowledges support from the Hasso Plattner Institute (HPI) Research School at University of Cape Town.

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26. The Performativity of IS implementation outcomes: the case of an Enterprise System Implementation at Ìwádí University

Adedolapo Akin-Adetoro
Department of Information Systems
University of Cape Town
adedolapo.adetoro@gmail.com

Lisa Seymour
Department of Information Systems
University of Cape Town
lisa.seymour@uct.ac.za

Abstract

IS implementation failure is high, yet uptake of these systems is still on the rise. This inconsistency might be because of the rational and narrative approach which characterizes how IS implementation success and failure are currently assessed and defined in research. This study challenges these dominant approaches (rational and narrative) which views outcomes as static and fixed by adopting a performative view. Hence the question: How are the realities of IS Implementation outcomes performed? This study adopted a case study methodology and used Actor Network Theory (ANT) in reconstructing the implementation story and producing knowledge claims. Findings indicate that the realities of IS implementation outcomes are performed by and within the groups in which the IS implementation is assessed. In this study, the IS implementation was assessed in two different groups and performed concurrent competing realities of IS implementation outcomes. This study elicits how factors such as expectation management, organizational politics, market recognition and the conditions of possibility played a key role in the intra-actions that enacted the realities of IS implementation outcomes. These factors were not pre-given rather they were locally produced within the IS implementation actor network.

Keywords: IS implementation success and failure, Actor Network Theory (ANT)

1. Introduction

The extant landscape of research on the outcomes of information systems development and implementation suggests that this domain has been extensively researched (Doherty et al., 2012). Results indicate high information systems (IS) implementation failure, yet uptake of these systems is still on the rise (Mahmud et al., 2017). In response to the alarming failure rates, researchers and practitioners have extensively researched the concept of IS success and failure prescribing and promoting a cumulative list of critical success factors which they believe should improve the success (Jewer & Compeau, 2021). This effort, however, has not yielded much improvement considering the vast amount of research in this domain (Baghizadeh et al., 2020). This inconsistency might be as a result of the rational and narrative approach which characterizes how IS implementation success and failure are currently assessed, defined and framed in research (Mpazanje et al., 2013).

The dominant rational approach (scientific realism) presents IS implementation success and failure as static, discrete, determinate, and time resistant despite the uncertainty and unpredictability involved (Cecez-Kecmanovic et al., 2014). It has been criticized for being simplistic in its representation of success, and by implication failure, in IS implementation (Cecez-Kecmanovic et al., 2014). The narrative approach presents IS implementation success and failure as being created through subjective interpretation, narratives and social construction (Bartis & Mitev, 2008; Walsham, 1999). Given the multifaceted nature of IS, this approach argues that the success and failure of an IS implementation cannot be objectively determined as different social groups attribute different understanding and meaning to the concepts of IS implementation success and failure (Bartis & Mitev, 2008). Both the rational and narrative approach have taken a representational view where certain key elements are used to represent the important aspects and characteristics of IS implementation outcomes. It is assumed that surrogates related to measures and perceptions can be used to operationalize success and failure.

This representational view which characterizes much of research in IS (Grover & Lyytinen, 2015) means success is either represented by objective measures or by subjective perceptions of social actors. The problem with this representational view is that: (1) IS success and failure is reified as given, fixed and time resistant, (2) it encourages the importation of incomprehensive models as readymade products that can be used out of the box to determine success or failure (Sadoughi et al., 2013) (3) The information technology (IT) system in focus is often black-boxed and downplayed. With the IT system being exogenous to theorizing in IS research, there is a scarcity of innovative theorizing, hence, an increase in the number of incommensurate mid-level models or frameworks that produce confounding results (Grover & Lyytinen, 2015).

We, therefore, challenge the dominant representational view of IS assessment which views outcomes as static and fixed by adopting a performative view in which the outcomes of an IS implementation is fundamentally indeterminate, which then becomes temporally determinate by observing related actors and their dynamic intra-acting within emerging actor networks from which properties, boundaries and concepts emerge and makes sense (Cecez-Kecmanovic et al., 2014). Reality is enacted; hence, it is not static and singular, instead, dynamic and plural. This outlook does not imply multiple views to one true reality, rather multiple realities in which truth is no longer the only criteria for validating and disproving reality (Law, 2004). Thus, the possibility exists of multiple concurrent realities of success and failure as outcomes of an IS implementation. Yet, it is not clear how the realities of implementation outcomes are performed. By providing understanding of this phenomenon, this study contributes to the ongoing theorizing of IS implementation outcomes. In addition, organisations can understand what actions/activities to adopt or avoid in relation to the performativity of implementation outcomes. Based on this background, this study, sets out to answer the research question: How are the realities of IS implementation outcomes performed? In this introduction we have reviewed literature on IS implementation outcomes which we find limited. The rest of the paper contains related literature on Actor Network Theory (ANT) concepts, the research method, the IS implementation case study, ANT analysis, discussion, and conclusion.

2. ANT- Overview of Important Concepts

An anti-representational account of reality is performative (Barad, 2003). Performativity posits that the relation and boundaries between the social and material are enacted in practice rather than given (Jones, 2014). This study adopts ANT as its theoretical lens because like the performative perspective, ANT views all actors alike (humans and non-humans), zooms out on them and zooms in on their relationships which produce actions and events from which realities of success and failures are enacted (Jrad & Sundaram, 2016). This turn towards performativity has odd consequences, in that, things referred to as singular, in theory, exist as multiples in practices. Each practice enacts a different reality which rarely momentarily collapses into a single reality. Although it seems counter-intuitive, a completed translation does not create a single consistent configured network or reality, rather a multiplicity of realities emerge (Mol, 2002). In this section, we now explain the relevant ANT vocabulary and analytical concepts.

2.1 Actor/Network

An actor is not the sole performer of action; instead, it is the target of a substantial collection of entities grouping towards it (Latour, 2005). An actor is the outcome of a relational configuration. It does not exist outside the relation or network that defines it. A network in ANT sense should not be confused with a telephone or subway network. Far from it, the network in question is an expression, a notion and not a thing. It is not what is being described but, a tool that assists in describing things (Latour, 2005). It ensures the analysis of different patterns of connections.

2.2 Translation

Translation is a process of aligning, shifting and making equivalent (Law, 2009). The process of translation consists of the following steps labelled as problematization, interessement and enrolment which can overlap in reality (Callon, 1986).The first moment during translation is problematization, during which one or more key, primary or focal actors "determine a set of actors and define their identities in such a way as to establish themselves as an obligatory passage point in the network of relationships they are building" (Callon, 1986 p.6). Interessement is the second moment of translation. Prior to it, problematization is still hypothetical. Hence, at this moment, the focal actor tries to negotiate, impose and stabilise the identity or roles of actors to that defined at the moment of problematization (Callon, 1986). A successful interessement confirms problematization and leads to enrolment. Enrolment is the third moment of translation during which other actors accept the roles or identities defined for them by the focal actor (Callon, 1986). The translation process creates an actor network from which groups emerge. Groups are meaningless and only understood by studying their formation (Latour, 2005). The starting point for an ANT analysis is not to find which groups make up the social rather; it commences by discovering what group actors belong to by following them via the traces that were left behind by their activity of assembling and dissembling groups (Latour, 2005).

3. Method

This study aims to make sense and provide the understanding on how success or failure comes about in an IS implementation. Given the aim of this study, a case study research method was chosen. The case study method is appropriate for implementation studies because they are characterized by dynamic processes that are best investigated in their natural setting (Venugopal & Rao, 2011). In selecting the single case, the following aspects were considered; the number of cases to be selected, the unit of analysis, longitudinal or retrospective case(s), and the case selection criteria. Two possible cases were reviewed based on their recent implementation endeavor. The first involved the implementation of an enterprise system (ES) research information management system (RIMS) while the second involved the implementation of a customer relationship management system (CRM) both in a large higher education institution (HEI) in South Africa which we will anonymise as Ìwádí. The first case was selected because it was a retrospective case which was accessible by the researcher.

3.1 Data Collection and Analysis

Data was collected through semi-structured interviews, observations, documents, and field notes. A total of 33 interviews were conducted and 27 documents were collected. The interviewees included members of the implementation team, the publication management team, faculty coordinators, departmental administrator, and a research manager from a different HEI. The use of field notes corroborated the observations as it involved taking a continuous commentary on activities, actions, and events in a case study. From December 2018 to June 2019, the researcher spent at least three Fridays every month at Ìwádí and from July 2019 to October 2019 the researcher visited the research site at least two times a month.

The research questions were constructed based on the concepts of translation, materiality, relationality, performativity, and practice. All the main interviews, follow-up interviews and impromptu conversations were conducted in the offices of the research participants, so this gave the researcher an opportunity to observe participants in their natural environment.

In analysing the collected data, this study used an ANT analysis strategy. The ANT analysis began during the data collection process. At this step, the researcher continuously read, annotated, and inductively coded the interview transcripts, observational notes and other secondary data sources, from which anecdotes or textual accounts began to emerge. Then, using ANT's concept of translation, the researcher analysed the collected data and pieced together (enacted) the sequence of events during the pre-implementation, the implementation and post-implementation stages of the RIMS system. The number of events generated were enormous and the researcher had to focus the analysis by identifying and making sense of key events that were relevant to the RIMS implementation outcomes. The researcher then translated the result of the analysis into descriptive textual accounts.

3.2 Ìwádí University and the Publication Count Process

In 2014, Ìwádí declared a new ten-year strategy (2015-2025) to become a research-intensive university, and it acknowledged the need for excellent IT resources and support to achieve its goal. At Ìwádí, there was a plethora of disjointed research systems and processes which created an environment where supporting research was challenging. To resolve this problem, a consultant architect was employed by the research office. The research office was responsible for research affairs. The consultant architect initially focused on the publication count process. The consultant architect identified quick wins for this process because it was a mature process that affected several organisational units within the university's research enterprise. Furthermore, it was an important process because Ìwádí depended significantly on the subsidy received from the Department of Higher Education and Training (DHET) for financing and supporting research.

The publication count process commonly referred to as pubcount in Ìwádí is an annual research support activity conducted in public higher education institutions (HEIs) in South Africa. It involves HEIs submitting research publications affiliated to their institutions to the DHET for research subsidy. The pubcount process included five stages namely: sourcing, verification, validation, auditing and screening, and submission. At the sourcing stage, the researchers submitted their research articles to their departmental administrators who manually captured them into the legacy RIMS called Óparí. Next, departmental administrators verified that the submitted publications met the pubcount criteria specified in the DHET research output policy. They then submitted each publication electronically (metadata) and in full text (hard copy) to their respective faculty coordinators. At the second level of verification, the faculty coordinators verified the submitted hard copies against the electronic metadata of the published articles. They then submitted all the verified publications for validation. Once the publication management team completed validation, they prepared the DHET report which was audited by external auditors before submission to the DHET for subsidy. To improve the pubcount process, the consultant architect designed a research administration digitisation (RAD) program. The RAD program consisted of several projects and implementing a new RIMS for the pubcount process was a key project.

4. ANT Analysis

The translation process consisted of three moments, namely problematization, interessement and enrolment. The researcher followed the focal actors through these moments.

4.1 Problematization

The interest of the research office was to implement a RIMS that could support research administration at Ìwádí. The realisation that Óparí was not going to support the Ìwádí's new strategy made it easy for the consultant architect to engage the research office into the idea of implementing a new RIMS that could support the pubcount process and other research administration processes within the university. The research office appointed the consultant architect as the program manager. The program manager inherited the interest of the research office. With the mantle of this new position, the program manager took on the responsibility of identifying and engaging key actors and thus assumed the role of the focal actor.

The program manager (ex-consultant architect) commenced with engaging a few external consultants to make up the initial members of the RAD implementation team. Next, the program manager made attempts to engage other key actors such as the RIMS vendor, the RIMS, the publication management team, the faculty coordinators, and the departmental administrators. The next step of problematization was to define the obligatory passage point (OPP). The OPP is an event that needed to occur for all actors to realise their interests, as defined by the focal actor (Callon, 1986). The program manager put forward the RAD program as the OPP. This decision meant that the RAD program, more specifically the implementation of the RIMS for the pubcount process was necessary for the interests of the pubcount stakeholders to be satisfied.

4.2 Interessement

At the second moment of translation, the focal actor deployed strategies and devices to convince other actors to accept the definitions of interests defined for them. The following sections describe the negotiation between the focal actor and other key actors involved in the implementation of the RIMS for the pubcount process.

4.2.1 Negotiation with the RIMS Vendor

The RIMS vendor was an international analytics organisation that created and sold various academic research solutions. It was interested in selling its RIMS and assisted organisations with its implementation and support. As part of the RAD program, the focal actor needed a modern RIMS to replace the outdated Ópari system in administering the pubcount process. To achieve this, the focal actor engaged and negotiated with several RIMS vendors. One of the strategies applied by the focal actor was issuing a request for proposal and inviting RIMS vendors for a demo presentation. This strategy created awareness and showed the focal actor's commitment towards engaging a RIMS Vendor. A RAD implementation team member reported: *There were presentations by vendors, and we did a balance kind of scorecard thing where everything was weighed. There was a shortlist of two, and they decided to go with one.* ***(RAD implementation team member 2)***

4.2.2 Negotiation with the RIMS

The RIMS was a configurable and customisable package information system. It was a researcher-centric system that assisted organisations streamline business processes for various administrative functions supporting research. Out of the box, it consisted of several prebuilt sub-systems that are usually configured and customised further by system users to meets the user's requirement. The focal actor needed to engage the RIMS to eliminate administrative burdens by automating the publication administration process. Thus, the focal actor, through the RIMS vendor, negotiated the engagement of the RIMS. For instance, the RIMS required that the focal actor put in place resources such as the servers, operating system (OS), networks, security, and system engineers.

4.2.3 Negotiation with the Project Implementation Committee

The project implementation committee (PIC) was responsible for the overall governance of the RAD implementation program. The PIC represented the university's management in the RAD implementation program. They were primarily concerned with monitoring the progress of the implementation and providing the needed resources. The group consisted of high-level senior management and delegates from different organisational units such as the research office within the university. The PIC had both internal and external interests. Internally, the PIC was interested in ensuring that the implementation was delivered within time, cost, and scope. Externally, the PIC was concerned about how the outcome of the implementation affected the university hence, it was interested in ensuring that the implementation was assessed as a success by other HEIs in South Africa.

4.2.4 Negotiation with the RAD implementation team

The focal actor needed the RAD implementation team to execute implementation tasks such as configuring the RIMS and developing the DHET report for the pubcount process. The focal actor began negotiating with potential members of the RAD implementation team because of their skills, expertise, and experience. To engage these potential members, the focal actor offered temporary employment contracts on the RAD program. The employment contract was an interessement device that provided potential members employment and the possibility for job experience.

4.2.5 Negotiation with the Publication management team

The publication management team administrated and managed the pubcount process using the Ópárí System; hence they were the domain experts. The focal actor needed the publication management team to take ownership in the implementation of RIMS. This involved providing business requirements to the implementation team, testing the RIMS, providing feedback to the implementation team, managing the new pubcount process, and training and supporting the end-users of the RIMS. To engage the publication management team, the focal actor got them excited about new features and functionalities offered by the RIMS.

4.2.6 Negotiation with Faculty coordinators

The faculty coordinators were staff or ad-hoc staff of the university responsible for managing the pubcount process at the faculty level of the university. Through the publication management team, the focal actor engaged with the faculty coordinators. The focal actor required the faculty coordinators to use the RIMS to manage the faculty's pubcount process. The focal actor engaged the faculty coordinators by providing system functionalities and features that addressed issues associated with the Ópárí system.

4.2.7 Negotiation with Departmental administrators

The departmental administrators are staff or ad-hoc staff within academic departments. They are responsible for sourcing and capturing publications affiliated with their departments on the RIMS. The captured publications are sourced directly from the researchers or external databases. Through the faculty coordinators, the focal actor engaged the departmental administrators. The focal actor aimed to replicate the same role from the Ópárí system; hence, the focal actor assigned the departmental coordinator with a publication capturer role on the RIMS. Activities such as publication sourcing and capturing had been defined as part of departmental administrators' job. A RAD implementation team member explained: *And then department admins, faculty coordinators it is just their job, so they have to do it…, I suppose they get deadlines from the research office.* ***(RAD implementation team member 2)***

4.3 Enrolment

Enrolment is the third moment of translation. This is the stage where actors accept the roles defined for them by the focal actor (Callon, 1986). The interessement strategies do not automatically lead to enrolment hence at this stage, we unpack the multiple negotiations, obstacles, and concessions that accompany the interessement and caused them to succeed or fail (Callon, 1986).

4.3.1 Enrolment of RIMS Vendor

For the vendor to be enrolled, it must accept the role of providing and implementing the RIMS at Ìwádí university. In other to accept the role of providing the RIMS, the vendor had to respond to the request for proposal and partake in the RAD program system procurement process. The process involved competing with other vendors and showing that the RIMS could meet the requirement of the RAD program. The RIMS acquisition by Ìwádí university in 2015 confirmed the enrolment of the RIMS vendor. This was explained by the RIMS vendor consultant: *The application was acquired by Ìwádí University in 2015, I got involved in March 2016* ***(RIMS Vendor consultant).***

4.3.2 Enrolment of RIMS

For the RIMS to be enrolled, it must accept the role of being the IT system that supports the publication management process at Ìwádí university. That is, it must be installed, integrated, configured, and customized prior to the 2016 pubcount cycle. For the enrolment to be achieved, the focal actor needed to ensure that the IT department of the institution put in place resources such as the servers, operating system (OS), networks, security, and system engineers needed to support the enrolment of the RIMS. The focal actor was unable to meet the operating system requirement of RIMS because the university's IT department who hosted the RIMS did not have system engineers with the technical ability required to install and support the required OS. Despite this challenge, the RIMS confirmed enrolment by being successfully installed on premise on an unsupported OS (Ubuntu).

4.3.3 Enrolment of Project Implementation Committee

For the PIC to be enrolled, it must accept the role of providing the required resources and support needed by the focal to implement the RIMS. The kickoff of the RAD implementation program, the procurement of the RIMS and the employment of members of RAD implementation members are events that confirmed the enrolment of the PIC. The PIC supported the RAD implementation post the 2016 pubcount cycle. This was confirmed by the two years extension granted to the RAD program manager to complete and extend the scope of RAD implementation. This was highlighted by the RAD implementation team member 5: *I was brought on the project when the project was an extension I believe. The project had already taken place two years prior to me arriving here and it was extended for another two years 2018-2019* ***(RAD implementation team member 5).***

4.3.4 Enrolment of RAD implementation team

Through the secondment and recruitment process, existing employees of Ìwádí University and external job seekers accepted the role of joining the RAD implementation team. The outcome of the 2016 pubcount count cycle highlighted several issues with the implementation delivery of the RAD implementation team. Issues such as the inability of the RIM's reporting engine to automatically underline authors on the DHET report, the harvesting functionality and data quality issues were pointed out by RIMS users. However, these issues were not showstoppers that could have prevented the completion of the 2016 pubcount cycle because of the workarounds that were put in place. In all, the RAD implementation team were able to implement about 85 percent of the RIMS for the pubcount process. This was highlighted by the RAD project manager: *In the first cycle we made 80 to 85 percent of the requirement. The gaps were underlining names, data quality issues (RAD Project manager)*

4.3.5 Enrolment of Publication management team

Taking up the role to assist the RAD implementation team, was a difficult challenge for the publication management team. This was because of their non-inclusion when making decisions and the presence of functionalities that did not work as expected. Despite the challenges which weakened the enrolment efforts of the focal actor and the RAD implementation team, we see that the publication management team was enrolled. They completed the 2016 pubcount cycle using the RIMS. They acknowledged that the system had the basics required to support the 2016 pubcount cycle. However, they considered the 2016 cycle a failure because they had to apply so many workarounds to make it a success. This was explained by Publication management team member 5: *we have had to manipulate and change a lot to call it a success. I think the editing has to be minimized a lot more before we can call it a success. We make it a success because we have to, we go through the records and it ended up being very manual and we make things add up* ***(Publication management team member 5)***

4.3.6 Enrolment of Faculty coordinators

The faculty coordinators faced several challenges in taking up the role defined for them by the focal actor. These included: the amount of effort required to participate in the pubcount process even though it was not part of their core responsibilities; lack of proper training on the RIMS and their non-inclusion in the core focus group that implemented the RIMS. Despite the challenges faced by the faculty coordinators, they accepted the role and were enrolled by the focal actor and the publication management team prior to the 2016 pub count cycle. The faculty coordinators used the RIMS to manage the faculty's pubcount process because it was part of their job responsibilities. They experienced a lot of teething problem while using the RIMS to manage the faculty pubcount process. This was highlighted by Faculty coordinator 2: *It was a nightmare, it was difficult….there are initial teething problems with any new system, and I have dealt with new systems before but this one was different because there was no support. Because even the support did not know* ***(Faculty coordinator 2).***

4.3.7 Enrolment of Departmental administrators

The faculty coordinators assisted the focal actor with the enrollment efforts. In negotiating to accept the role of publication capturer, the departmental administrators faced challenges such as the harvesting functionality not working as expected and negative comments about the RIMS from the publication management team. Nonetheless, the departmental administrators used the RIMS to capture publications for the 2016 pubcount cycle because it was part of their job responsibilities.

5. Discussion – Performativity of the RIMS implementation Outcomes

At the beginning of the 2016 pubcount cycle there was one large RIMS implementation actor network that consisted of enrolled actors. The intra-actions within this actor network created groups. Groups are formed by the identification of anti-groups (Latour, 2005). That is, groups are formed by actors identifying the alternative groups they do not belong to. In this case, the RIMS end user group was formed by members of the publication management team who represented RIMS users. They made comments concerning how they were not involved in the decision-making process during the implementation of the RIMS: "*It was very challenging and not only because with every new system you expect teething problems but because of how decisions seemed to have been changed and we were not informed… I can't even talk to procurement because we were never involved"* ***(Publication management team member 1).*** This comment did not only reflect the absence of RIMS end users' group from the decision-making process, it also highlights the presence of an alternative group (RIMS implementation group) which made the decision concerning the implementation of the RIMS. This was highlighted by a member of the RAD implementation team: *"I think that we should have included the administrators especially the publication management team, we should have included them more in what we were doing but the again we just never had time to do that.* The intra-actions within these groups gave rise to agencies which enacted the RIMS as an object of assessment as well as their assessments of its implementation. These agencies are referred to as agencies of assessment. "An agency of assessment is a specific kind of agency that arises through intra-actions and shows up in the resulting sociomaterial practice that enacts a particular assessment together with the object of assessment" (Cecez-Kecmanovic et al., 2014 p.22)

The RIMS end user group consisted of actors such as the RIMS, the departmental coordinators, the faculty coordinators, the publication management team, and the job responsibility document. These actors belong to the RIMS end user group because they use the RIMS for the pubcount process, and they were not involved in the decision-making process. As soon as the 2016 pubcount cycle started, several challenges emerged within the RIMS end user group. The departmental administrators and the faculty coordinators mentioned that they experienced key problems such as bad HR data and the non-usability of the harvesting feature while sourcing, capturing, and verifying publications on RIMS. The HR data integration and publication harvesting were key feature that was used by the focal actor in getting end users interested in the system. These features were supposed to revolutionize the way end users capture publications, but they did not work as expected and it was a major disappointment. This outcome highlights an opportunity where continued expectation management by the focal actor would have assisted in mitigating the negative consequence. IS implementation outcomes are not really a function of right or wrong but rather good or bad and on this continuum, expectation plays a key role (Neves et al., 2016). The impact of these challenges was felt by the publication management team (the spokesperson of the RIMS end user group) as they had to do a lot of workarounds (manual corrections due to dirty HR data and manual capturing errors) to validate and prepare the pubcount report for the DHET. The RIMS end group had to manipulate and manually change things on the RIMS to ensure that the RIMS implementation was assessed as a success. However, within the RIMS end user group, the RIMS implementation (object of assessment) was enacted as an implementation with too many workarounds (sociomaterial practice) and was considered a failure (assessment outcome) because the features promised by the focal actor did not work as expected (assessment criteria). As a result, there were calls by actors within the RIMS end user group for a return to Óparí. This however was not realized because the job responsibility document mandated that end users use the RIMS for pubcount. In an ANT study, an action is not performed under the full control of consciousness of the actor as there are several other forces not of the making of the actor that are at play when it acts (Latour, 2005). There are agencies (in this case, the agency of the job responsibility document) which actors have no control over that makes them do and not do things. The performativity of the failed implementation outcome at this point (end of the 2016 pubcount cycle) is not the end state of the RIMS implementation outcome within the RIMS end user group. A failed implementation outcome at this stage is typical, particularly because of the inflated expectations focal actors use in interesting end users. Sarker et al. (2006) highlights how a business process change failed because of a failed enrolment. However, we see that even a successful enrolment does not guarantee a successful outcome. Members of the RIMS end user group were enrolled to the implementation actor network, yet they considered the implementation a failure.

The RIMS implementation group consisted of actors such as the RIMS, the publication management team, the RAD Implementation team, the PIC, and the RIMS implementation status report. These actors belong to the RIMS implementation group because they played a major part in making decisions and implementing the RIMS for pubcount. Members of the RIMS implementation group had an implementation status meeting quarterly (sociomaterial practice) through which the agency of assessment arose and the assessment criteria defined. The RIMS implementation group expected a quality RIMS to be delivered on time and within budget (as highlighted in the implementation status meeting minutes and by the program manager). Prior to go-live, the focal actor faced a dilemma due to RIMS implementation issues. This meant postponing go-live for a year to fix the issues or go-live with the system as-is and put in place workarounds. Malaurent and Avison (2015) showed that workarounds can be an effective tool to turn around a failing implementation. The first option (postponing go-live) created the problem of the implementation going overtime and over budget because two systems will run in parallel (RIMS and Óparí). As a result, the focal actor decided to go live as-is without consulting the RIMS end user group. By making this choice, the focal actor tried to ensure the success of the RIMS implementation by favoring the PIC at the cost of disappointing and overworking the RIMS end users with workarounds. The choice to side with the PIC highlights the application of organisations politics by the focal actor. Given the lack of financial resources and time, the alternative (postponing go-live) was politically risky and untenable. That is, financial resources and time were necessary conditions for the selection of the alternative to be possible (conditions of possibility). Organisation politics have been emphasized as a tool that can positively influence implementation outcomes (Neves et al., 2016).

At the end of the 2016 pubcount cycle, the focal actor confirmed that the RAD implementation team had completed 80-85% of the RIMS implementation for the pubcount process. The pubcount process was done by most public HEIs in South Africa, hence they were aware of the of the RIMS implementation at Ìwádí and as such, two HEIs commenced implementing RIMS for their pubcount process. One of the HEIs is the biggest in the country in terms of research output production. The research manager at the other HEI and the vendor consultant confirmed that the RIMS implementation at Ìwádí generated adoption interests of the RIMS among other HEIs in the country. Furthermore, the RIMS implementation status report to the university's Senate and Council highlighted the RIMS implementation group position on the outcome of the RIMS implementation. The RIMS implementation group reported the success (assessment outcome) of the RIMS implementation (object of assessment) as they were able to successfully use the RIMS to prepare and submit the 2016 pubcount report to the DHET based on which research output subsidy was awarded to the university (assessment criteria). They linked the increased adoption of the RIMS at other HEIs in the country to the success of their implementation (assessment criteria). Market recognition is an important determinant of a successful implementation outcome (Neves et al., 2016). They acknowledged that the implementation was not trouble free and that the learnings and experience of the first year are being used to improve the effectiveness and ease-of-use of the RIMS for next cycle. The success of the RIMS implementation at the end 2016 pubcount cycle was confirmed by the PIC's extension of the implementation by two years to increase its scope.

6. Conclusion

In this article, we have asked the question: How are the realities of IS implementation outcomes performed? To answer, we adopted the ANT as a theoretical lens to investigate the concept of IS implementation outcomes from a performative perspective. Our findings indicate that realities of IS implementation outcomes are performed locally. That is, they are performed by and within the groups in which the RIMS implementation was assessed(Cecez-Kecmanovic et al., 2014). In this case, we observed that the RIMS implementation was assessed in two different groups (smaller actor networks) which performed concurrent competing realities of the IS implementation outcomes. This study offers contributions both on the theoretical and on the practical level. Theoretically, it contributes to the ongoing theorizing of the assessment of IS implementation outcomes by challenging the existing representational approaches and using the ANT to provide a performative perspective to this phenomenon. Regarding the practical contributions, it sensitizes scholars and practitioners towards the limitation of existing approaches that put forward a singular reality of IS implementation outcomes as given. Such a position blinds us to the possibilities of multiple implementation outcomes being enacted or we conflate multiple realities of IS implementation outcomes into a single reality even though they do not complement. This mis-framing makes a case against the way we currently assess IS implementation outcomes and sheds light into inconsistencies we see between research and practice. Furthermore, this study elicits how factors such as expectation management, organizational politics, market recognition and the conditions of possibility played a key role in the intra-actions that enacted the realities of IS implementation outcomes. These factors were not pre-given rather they were locally produced within the RIMS implementation actor network. Practitioners need to be sensitive to the time and place where these factors are produced and use them to influence desired outcomes. Finally, this study was conducted within a large organization with a large implementation actor network. This context was a condition of possibility that allowed complex intra-actions that enacted multiple realities of IS implementation outcomes. It is unclear whether same findings will hold within a small organization with a small implementation actor network. Future study we argue should scrutinize this outcome and validate its relevance to a small organization context.

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27. Towards a design of E-Health systems to improving healthcare service delivery

Sheethal Liz Tom
Cape Peninsula University of Technology
toms@cput.ac.za

Tiko Iyamu
Cape Peninsula University of Technology
iyamut@cput.ac.za

Abstract

Patients' medical records are critical to services, it helps to prevent errors in prescriptions and medications. Despite the understanding of these consequential risks to patients, medical errors remain prevalence in South Africa and many parts of the world. Empirically, this study reports medical errors and their consequences to patients. Qualitative and quantitative data relating to healthcare services delivery were used. The interpretation of the data reveals that medical errors manifest wrong medications, misrepresentations in prescriptions and mismanagement by facility. Also, patients' lack of access to medical records and the use of incomplete medical records were other factors identified. This study lays justification and motivation for patients' unique identifier, which contributes to improving the quality of healthcare service delivery.

Keywords: Healthcare, Medical errors, Healthcare service, Health in Africa, Medical records.

1. Introduction

Health passport is an electronic smart device that contains patient's (holder's) biodata and health related information. Primarily, it is used as a tool to bridge communication between patients and physicians including administrators of health facilities (such as hospital and clinics). As a tool, it enhances health service delivery from two main angles: (1) reduce patients' unnecessary visits to health facilities (Heifetz & Lunsky, 2018); and (2) increase access to patients' medical history. The health passport concept is in use in New Zealand by the Health and Disability Commission. In the United Kingdom, the concept is purposely to improve communication with health care providers. In South Africa, it is referred to, as "My health passport". It is a nationwide medical communication tool that identifies a patient and associate his/her with medical record. In South Africa, the practice is not common among the facilities (or medical personnel) that are employed by Discovery Health, which is a private health entity.

Accurate, organised and up-do-date medical records are essential for good patients' care. A medical record or a health record demonstrates the patient's health history, physical examination result, progress and the list of prescribed medications (Bali et al., 2011). By examining these records, a physician can easily continue with the treatment of a patient from where another physician has left off, thereby ensuring effectiveness in providing quality healthcare for patients. The information in the medical records also play a crucial role in determining the truth in circumstances where patients claim negligence against the physicians (Pienaar, 2016). Therefore, maintaining and preserving medical records are vital to the provision and judgement of healthcare services.

The administration of medical records in South African context presents a gloomy picture as at the time of this study. On one hand, the quality of record management in the healthcare facilities in South Africa varies depending on various factors like infrastructure, budget, and staff capacity (Katurura & Cilliers, 2018). From another perspective, some of the healthcare facilities have a proper filing system while others do not. Even if a healthcare facility maintains a proper filing system, their medical records are not accessible among the other healthcare facilities across the country. This becomes problematic because of physicians' obligation to treat a patient without knowing his medical history. The medical history provides useful and important health information of a patient that leads to timely and accurate diagnosis (Muhrer, 2014).

Access to the medical history of a patient proves to be cost effective by eliminating the process of physical examination and testing, to determine health conditions. It is also important for a physician to be aware of the medications a patient has taken in the past or is currently taking. The physician can determine the future treatment based on how the patient has responded to these medications. The physicians fail to provide timeous and quality services as they do not have access to the medical records of their patients (N. Marutha & Ngoepe, 2017). The fact is that there is no effective centralized system in South Africa, to guide the health care facilities to care for their patients. Therefore, it necessitates developing a centralized system relating to electronically preserving patient's medical history.

Currently, the practice of the health passport requires patients to have the passport on visit to health facilities. Consequently, any health practitioner or hospital administrative staff can read the information on the passport, which reduces privacy. Despite the benefits of the health passport, Bailie et al. (2020) identified and explained that there is a need to improve clinician engagement and future transference into a smartphone application. Subsequently, from the literature and practice, we identified the gaps in the current health passport concept, as problematized in the section that follows. In bridging the gaps, the main objective is to examine how medical errors come to being and their consequences. This study reveals challenges and presents implications in practice. The novelty of the e-health system is in its diverse nature and accessibility. For example, the e-health system does not necessarily need a patient to always carry his or her passport with. It requires the passport or national identity number (NIP), to uniquely identify the patient and associated him/her with physicians and visits to health facilities, which also reveal previous medications.

2. Problematisation

Patients consult with various physicians, some of whom are situated in different health facilities and locations across the country. The challenge in many countries including South Africa is that patients' medical histories are not easily accessible or shared between physicians across different health facilities and locations, owing to distinct reasons. This has high consequence to the patients in that the lack of access or limited access to patient's record slowdown response time. The challenge emanates from two main perspectives. Firstly, some patients often do not remember or know the medications in their prescriptions from previous visits to physicians. According to Rashid (2018), the health passport seeks to improve the coordination of healthcare for people with intellectual disabilities, with a particular focus on psychiatric and emergency care. Secondly, some patients, simultaneously, visit physicians without disclosing such information. These problems exist because of lack of system that secure and seamlessly provide patients' data for real-time access purposes.

3. Literature Review

Some of the public health centres still use a manual filing system in many countries (Masana & Muriithi, 2019). However, many health systems are enabled and supported by information technology (IT) or information systems (IS), to collect, use and store patient's medical history (Pearce & Bainbridge, 2014). Many studies have proposed solutions, to address challenges that are hindering healthcare advancements. This includes lack of: centralisation, consolidation (Persaud, 2019), synchronisation, and real-time access to patient's medical record (Masana & Muriithi, 2019). Azarm et al.(2017) proposed a cloud-based portal and a web-service API for accessing and exchanging information across healthcare providers. A medical aid, a health organisation maintains an online portal to store medical records, which only be used by their members (Reid et al., 2020).

One of the main challenges is the heterogeneity of patients and medical practitioners. For example, a patient being treated by several doctors have several medical records and there is no guarantee that these records are synchronised or corroborated into one single and accurate medical history (Dubovitskaya et al., 2018). This brings about the importance of having a centralized system (or database) that provides an integrated view of a patients' medical records. A database can be accessed on real-time, from anywhere and at any time, using a smart device referred as to "health Passport" (Bailie et al., 2020). The "health passport" concept have been introduced in several countries with the aim to provide quality health care services to their citizens.

Many countries such as the Australia, Canada, United Kingdom, and South Africa continue to explore ways of improving the processes and activities of health, for better quality of care and services (Andargoli, 2021). This includes the need to centralise healthcare data for real-time accessing of patients' data, which has been under consideration for many years. In 2013, the National Health Service of United Kingdom launched the 'care.data' (care dot data), a centralised system that integrates patients' records and hospital records (Presser et al., 2015). In New Zealand, shared care records (SCR) takes proper measures to ensure that the privacy of the patients is safeguarded by allowing access to only health practitioners who can access the system (Pagliari et al., 2007).

In some countries, particularly in developing countries, the majority of the population are unaware of their health status because the health records are poorly administered (Rensburg, 2021). Owing to the inconsistency and inaccuracy regarding the manual filing of patient medical data and medical error reports, the concept of e-health record (EHR) systems was introduced in Australia (Xu et al., 2013). This does not seems to have resolved the challenges in the country (Collyer et al., 2019). In Canada, the health professionals can access laboratory test results, medication details, diagnostic results and all relevant health information of the patients in their province (Graham et al., 2018). The downfall of this approach is that, in case of an emergency, a health practitioner will be unable to access the details of a patient who is registered in another province (Persaud, 2019).

Health care services integrated with IT or IS have seen significant progress over the past few years (Wu & Trigo, 2020). Currently, there are expectation of physicians to provide quality healthcare services to the people. In addition, there is obligation for physicians to access and share patients' medical records with the relevant authorities and personnel on a regular basis. At present, there is no system in South Africa that allows the health practitioners to access patient records regardless of their location. Therefore, developing a system that contains digitalised patient's medical records and link them to facilities and physicians is necessary.

4. Methodology

The mixed method is employed in this study. Substantially, the methods enrich data collection (Schoonenboom & Johnson, 2017). Mixed methods research design combines the strengths of both methodologies and reduces the weakness of both approaches (Creswell & Poth, 2017). Questions were formulated based on the objectives of the research and the gaps identified in literature. The questions and guidelines were used to collect both qualitative and quantitative data. It entails an in-depth process. It began with formulating eighteen questions, covering patients and medical personnel (nurses and doctors). Thereafter, the questions were for patients and medical personnel, respectively. Each The questions were constructed in a way that suit the participants, for ease of understanding and interaction.

At the end, nine and nine number of questions for patients and medical personnel, respectively, were finalised for data collection. The questions were improved and finalised through an iterative process of verifying whether each question in the guide was linked to the research objectives. The primary data for this study was collected using questionnaires.

The case study approach is most suitable, primarily because it helps with in-depth investigation (Yin, 2018), required for this study. The AfricanHealth hospital in Cape Town, South Africa was selected, for three reasons: (1) it is one of the oldest, thus, it has gone through test of time; (2) it one of the largest hospitals, it comprises of all spheres of medical units, from specialised to general practitioners'; and (3) among other, the management granted access, to use the hospital as case in the study. The hospital host some of the best specialists in the country. AfricanHealth is a pseudo name assigned to give anonymity to the hospital. This was to comply with the hospital's authority, to avoid identity disclosure owing to the sensitive nature of the healthcare environment. Document, nurses and patients were based on their units, availability and interest, to participate in the study. The objectives of the study were explained to interested persons, based on which each decided to participate. The first set of participants introduced their colleagues to the researchers, which was the mechanism used to garner interest of more participants. Data was collection was stopped at a point where participants began to repeat what have previously gathered others.

This study used two sets of questionnaires, for doctors and nurses, and patients. The aim of the questionnaires was to collect the views and perceptions of doctors, nurses and patients regarding the challenges faced by both medical practitioners and patients due to the lack of a system that secures and seamlessly provides patients' data for real-time accessing of patients' records from any health facilities and locations within South Africa. The questionnaires were mixed questionnaires consisting of both closed and open questions.

The pilot interview approach was used to assess the strength and suitability of the questionnaires. People of the diverse groups, medical personnel and patients participated in the pilot. It was important to conduct a trail-run to establish the validity and reliability of the data collection technique and the questions. The usefulness of piloting has long been tested, it assists the researcher to determine whether the designed research instrument is effective in fulfilling the purpose of the study (Friesen et al., 2017). The pilot provided feedback on the structure and format of the questions. From the feedback, the researchers amended the questions. The questionnaires were distributed through electronic means, using Google Forms. The means was convenient to reach participants who were geographically distant, and it was the safest and cheapest way to gather data during the pandemic. A total of 53 people participated in the study of which 7 were doctors, 20 were nurses and 26 were patients.

The data was analysed using content analysis technique from the perspective of interpretivism and statistical analysis of positivism. For the qualitative data, keywords were identified and organised them into categories. The categories were organised into themes thereby deriving a meaningful insight to the study. For the quantitative data, both numerical and graphical statistical descriptive methods were used. The numerical description of the study was represented by statistics, which focuses on frequencies and percentages. The graphical description was presented in the form of tables and charts. These statistics helped to identify meaningful patterns in the data. The findings were reach from the data analysis using the interpretivist approach, towards achieving the objectives.

5. Findings and Discussion

The analysis is conducted based on the objectives of the study, sections 5.1 and 5.2. To avoid repetitions, abbreviations are used to represent some categories. The patients and doctors (including nurses) that participated in the study are referred to as PPs and DNPs, respectively.

5.1 Detailed information about patient's previous medications and prescriptions

Two fundamental actions and practices, detailed information about patients and histories of medical records can be employed, to significantly reduce patients' risks. Although important, the challenges of omission persist in gathering and storing detailed information about patients. For several reasons, medical histories are significant in preventing errors in medications, prescriptions and other consequent risks to patients. FitzGerald (2009) states that there are many errors that can be associated to lack of medication history, such as omitting drugs erroneously, potentially, cause to harm patient. In the context of this study, medical (medication, prescription and facility) error is unintentional action, failure to complete intended or the use of inappropriate action to achieve an aim. Despite the long-standing of these challenges, long lasting solutions seemed farfetched.

The patient participants (PPs) in the study considered it important to remember their previous medication and prescriptions. The PPs considered these details are important as it helps them to track the side effects of the medication prescribed, to monitor the progress in health conditions, and to keep record of the appropriate medications for their illnesses. The challenges of not able to keep track and memoire of information about history is associated to distinct reasons. Both PPs and DNPs considered three, medication, prescriptions, and facilities, as the main types of errors and challenges they frequently and often encounter.

i.Medication error

Some of the common medication errors are incorrect drugs, strength of dosage, and failure to identify drug interactions or contraindications. Medical practitioner and patient cause these types of errors. Other factors contributing to medication errors include inaccurate medication administration record, poor or lack of communication, and lack of strict adherence to medical code of ethics. Linden-Lahti et al. (2021) empirically reveal that medication errors are one of the most prevalent among patients' care. As shown in Figure 1, 96% of patients strongly agree that they find it extremely difficult to keep track of previous medications and history of prescriptions. Jessurun et al. (2022) explained that prescription and medication processes are prone to errors because of the multistep involved.

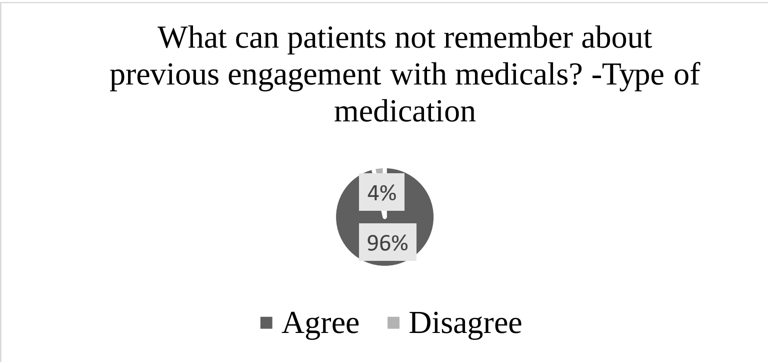

Figure 1: Patients do not remember the type of medication

ii. Prescription error

In the views of some patients, many of the prescribed drugs are difficult to administer, remember and manage, which lead to confusion and errors in the dosage. Frequently, errors occur in the administration of different prescriptions of drugs (Kuitunen et al., 2021). As shown in Figure 2, DNPs attest that 70% of their patients do not always remember their prescriptions. Some of the patients assume that the DNPs should remember on their behalf. In such situations, patients will have to check with the hospital or previous doctors or partners or, consequently, allows the doctors to conduct the investigations and treatments from the beginning.

Prescription errors have caused death or severe harm, and therefore, should be primary target of medication risk management in healthcare facilities (Linden-Lahti et al., 2021). Thus, medical facilities should take more responsibilities and appropriate care.

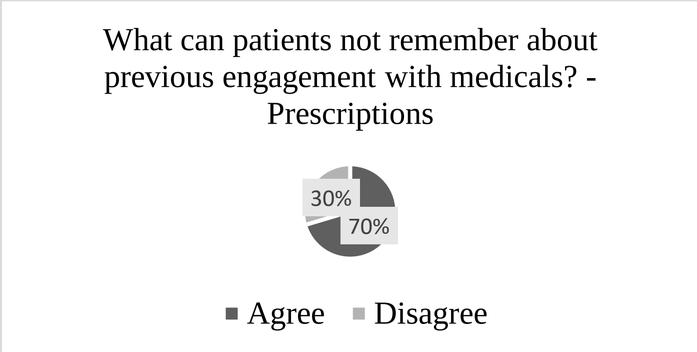

Figure 2: Patients do not remember their prescriptions

iii. Error by Facility

As depicted in Figure 3, 65% of patients often do not remember or accurately, identify either the facility they last visited or the medical personnel that assisted them, or both. Accurate medical history helps to prevent prescription errors, which could have endangered the life of a patient. On the progressive side, nurses, doctors including pharmacists identify errors (Blaine et al., 2022). On the desperate perspective, the same practitioners are associated with diverse types of errors. Thus, it is critical that patients remember the facility and practitioners that provided care to them. According to many of the DNPs, some of the factors that make patients not to remember these critical are memory issues of sick patients, ineffective medication, complicated prescriptions, numerous and rapid changes of doctors and hospitals, and incomplete information provided on visitation.

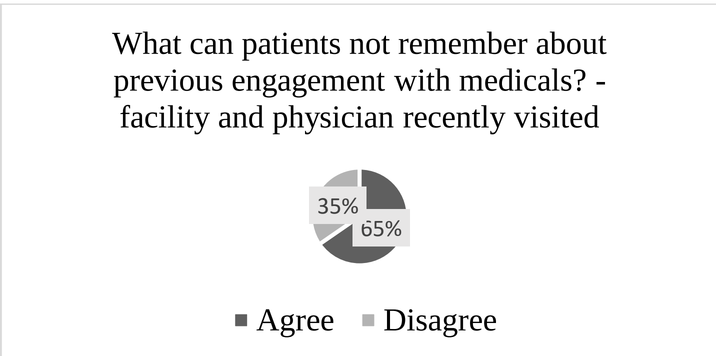

Figure 3: Patients do not remember the facility and physician they visited

Many of the patients consider openness and sharing of medical information with doctors vital, to avoid the risk of prescribing wrong medication and accuracy in diagnosis. FitzGerald (2009) explains how polypharmacy, certain drugs, and clinical specialty can be of severe risk to patients, due to lack of medication records. Incomplete patient medical information can lead to some profound consequences like prolonged consultation time, unnecessary hospital admissions and ICU stays, wrong patient prescriptions, worse health conditions of the patients due to mistreatments and even staff dismissals due to misjudgements from the medical staff. A complete and up-to-date medical record keeping system may assist both the patients and medical staff in such situations. Facility becomes even more important because of the multiplicity of services and people involved, complexity of procedures (Jessurun et al., 2022).

5.2 Synchronization and secure seamless access to patients' medical records

A timely and continuous patient care enriches patients' information and contribute to accurate medical record system. This study elicited information from both patients and medical personnel's perspectives, to ensure balance and corroboration. The balanced views help to develop deeper understanding of how the healthcare environment stimulate from patients' records perspective. From the memoires and views gathered, it is empirically clear that synchronisation of patients' medical information is critical in improving care by South Africa health facilities. By implication, both patients and medical personnel must take responsibility in sharing and management information. Currently, most patients do not have access to their medical information, which exclude them from accountability and responsibility, from one ontological view. From another perspective, lack of access to ones' information renders a patient helpless in times of need. Two factors, (1) Patients' lack of access to medical records, and (2) Incomplete medical records negatively influence synchronisation and secure seamless.

i. Patients' lack of access to medical records

Medical records play a vital role in ensuring quality and continued health care to the patients. Poor record keeping practices may result in incorrect an inefficient delivery of services to the patients. From the experiences of some DNPs, some facilities use digital records and personal electronic medical records to manage patients' real-time medical information, while others employ the manual approach in many facilities. Consequently, the information is not always correct or complete, which contribute to errors, inefficiency and ineffectiveness. Empirically, Masana and Muriithi (2019)confirm that some health centres in South Africa rural areas still make use of manual filing system and this has led to serious consequences such as missing patient file, and incorrect patient details. Lack of complete medical information of patients can delay the patient's treatment, which can be of serious consequences (Marutha, 2016).

As depicted in Figure 4, 77% of the PPs indicated that the medical personnel do not allow them to have access to their medical records. However, a total of 23% of the participants indicated that they do have access to their medical records. The access is often on request, granted on strict conditions, and assisted by third party, such as the medical insurance firms (medical aid apps) and general practitioner (GP). Patients' inclusiveness is their health-related matters is essential. Patients' access to own medical records has several positives, such as empowerment, reduces inaccuracies in reports, improves education about health conditions (Giardina et al., 2014). There are evidences that patient access to medical records has also helped to improve patient-doctor communication (D'Costa et al., 2020).

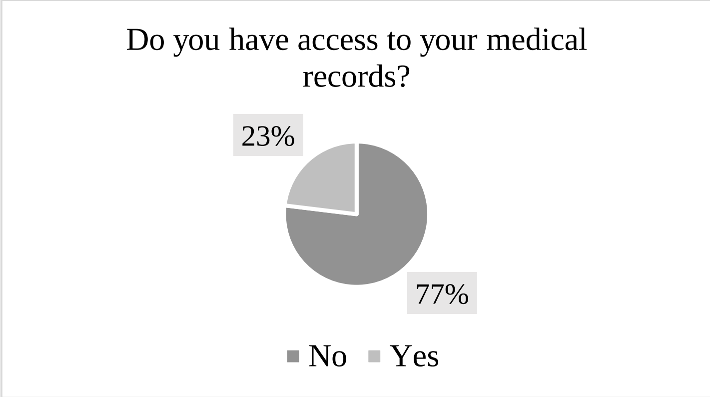

Figure 4: Lack of access to medical records

Despite the current challenges, some PPs considered it important to have access to their medical records. Primarily, it avoids delay in the care that they receive, especially during emergencies, as it can assist future doctors to have a thorough view of previous health conditions. In addition, many PPs feel it is responsible and accountable to be knowledgeable about individual's health condition. Another factor revealed by many of the DNPs is that healthcare professionals in a facility do not have access to patients' record in another facility, in South Africa. According to the 27% of the DNPs, access to patients' records is granted to practitioners from another facilities, on special request. Accuracy and completeness of medical records can be maintained if facilities share patient's medical records (Sayles & Gordon, 2013).

ii.Source of Incomplete medical records

In some cases, some doctors perform tests, investigations and assessments on patients without access to previous medical records. This leads to increased cost to the system and undertreating or overtreating the patient. Also, such circumstance delays treatment, thereby putting the patient's life at risk. From another perspective, incomplete medical records become more problematic in an emergency. In attempt to manage such desperate situation, the doctor may treat the patient based on his/her training and previous experiences or on the symptoms at the time of emergency. Studies reveal that one of the reasons why medical practitioners sometimes prolong patient's hospitalisation is due to fear of prescribing wrong treatments, which often suffice from insufficient medical information (Marutha & Ngoepe, 2017).

In complicated situations, some doctors approach other hospitals and specialists for guidance. According to Sajan, Haeusler and Parrish (2020), physicians usually request for medical information of patients from previous doctors before treating a patient, to avoid further complications. Unfortunately, medical records will be incomplete because of the manual (personal note) approach employed by some practitioners and facilities. Incomplete records can have serious negative impacts on the delivery of healthcare services (Marutha, 2016). This is discouraging because real-time access to medical record system can increase response time, assist doctors with diagnoses of patients, in more correct and accurate manner. This helps doctors to better understand patients' health conditions, assure better service to the patients, eliminate unnecessary tests, and reduce long term hospitalisation. Additionally, real-time systems can assist in monitoring patients' health and providing them with continuous care thereby reducing in-hospital death rate.

6.Implication of Practice

There are four main implications: (1) design and development of a system; (2) transfer of data; (3) training of medical practitioners; and (4) review of policy.

6.1 Design and development of a system

There is a need for a digital system, which captures and stores and update medical information of patients, for completeness and real-time purposes. There seems to be no system that stores real-time, up-to-date patients' records in many South African health facilities. In practice, a digitalised system can assist in conducting and managing more accurate diagnoses and treatments of patients. The DNPs view the contribution of a computerised system from the perspectives of real-time access of patients' medical information. This is purposely to increase response time, and improved accurate view of patients' health conditions, by both patients and medical personnel. This is not new, countries like New Zealand, Australia and United Kingdom have systems that stores real-time medical information of patients, which has assisted in improving the quality of their health care system (Andargoli, 2021).

6.2 Transfer of data

Furthermore, the DNPs stated that there is a lot of effort involved in transferring the data to an electronic system which is an additional burden for them. In practice, two factors are critical importance, technology enablement and validity of the data. Technology solutions enable and support the transfer of patients' data from manual to digital system. The implications include cost of the IT solutions, architecture redesign of the environment, and human efforts. This increases the capacity of health practitioners and improve quality of care to patients, because it increases timeous access patients' information, which increase response time. The validity ensures protection, classification, and certification of the data (Hallinan et al., 2021).

6.3 Training of medical practitioners

Many health practitioners, particularly the older general, find it difficult to learn or use digital systems. Many of the practitioners continue to employ the manual approach. This implication is critical in that the use of new (or emerging) IT solutions to enable and support healthcare services increases access to patients' information, to enhance response time and improve care. The training increases automaticity of the health practitioners. Through training, staff turnover, complete and up-to-date record management system will be improved, which in-turn, assist in providing quality health care services in the country.

6.4 Review of Policy

This implication leads to review of healthcare policy in the country. Fundamentally, policy contributes to improved governance of healthcare services. This is to promote best practices, by ensuring specifics, priorities and timeliness of responses to patients' care in the facilities. Ralston et al. (2021) emphasised on the significant of policy, on divergence and implications for health governance. In practice, the policy helps to define (or redefine) and managing sharing of patients' health information by health practitioners including patients' relations. This aspect of policy should align with the South African Protection of Personal Information Act of 2021. It sets the standard, to evaluate and quantify the efficiency and effectiveness of the services provided by health facilities in the country.

8.Conclusion

This paper highlights the challenges encounter by many health facilities in South Africa, due to lack of access and synchronisation of patients' real-time medical records. As revealed in the study, these challenges manifest into three critical types of errors: medication, prescriptions, and facilities. Some of these errors result to deaths severe medical injury. In practice, this paper contributing by making medical personnel gain deeper understanding of the implications of patients consulting with various physicians, situated in different health facilities and locations across the country, when there is no centralised system that records and provides access to patients' data for real-time access purposes. Another contribution is that the study demonstrates theoretical usefulness of unique identification of patients.

Based on the empirical evidence from the study, a unique identification (UI) of patients can be design and developed. In addition, the findings from the study can be used to guide the development of policy, for protect errors in patients' information. The UI system and policy will be of use and benefit to different stakeholders, which includes patients, medical personnel and government. The usefulness comes when the UI system or policy prevent medical personnel from treating patients without access to real-time medical information, which provides accuracy, for improved quality of care to the patients.

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28. Validating a questionnaire on physical environment factors associated with remote work

Ji Xu
Carleton University
jixu@cmail.carleton.ca

Gerald Grant
Carleton University
Gerald.Grant@carleton.ca

Abstract

Digital technologies, especially information communication technologies (ICTs), make remote work a fashionable method. Remote workers can work from their homes, satellite offices, neighbourhood work centers, and even on the road. People are subjected to various physical environments when working from different places, impacting their work satisfaction, performance, and productivity. In this paper, we conducted an exploratory factor analysis to find factors in a physical environment questionnaire item pool created in a previous study. We also adjusted the factor model and tested its validity and reliability. This questionnaire will be used in research on workplace location, physical environment, and work performance.

Keywords: Exploratory factor analysis, EFA, Physical environment, Remote work, Questionnaire design.

1. Introduction

The development of digital technology has led to several new ways to work (NWW). A typical example is teleworking. Teleworking allows people to work outside conventional workplaces, i.e., employer premises, and communicate with co-workers and clients through telecommunications or computer-based technology (Bailey & Kurland, 2002). Remote workers work from home and anywhere else, such as in satellite offices, neighbourhood work centers, and even on the road (Barsness et al., 2005). Surveys show that more people will likely choose to work remotely in the post-pandemic era (Barrero et al., 2021; Gold, 2021). In other words, remote work will get much more popular. This eventuality opens the opportunity for scholars to research topics about people's work environments in the case of remote work.

It is already known that the physical environment impacts employee's work (e.g., Al-Omari & Okasheh, 2017; Davis, 1984). So, it is reasonable to infer that the remote workplace environment can impact remote workers. Scholars studying the relationship between the physical environment and work performance have used questionnaires to gather data for assessing the relationship. The previous questionnaires include items on temperature, lighting, use of machines, and many other factors. Some questionnaires have items about people's control over workplaces. However, previous questionnaires are not explicitly designed for the case of remote work. It is also unknown what factors in the remote work environment impact people and how these elements impact people. This research is important because we found these factors and created a questionnaire based on them. For example, most previous questionnaires do not include items related to technology such as Internet connection or factors related to workers' affective feelings such as enjoyment. We first conducted a qualitative study to discover what remote workers thought of their work environment and how it impacted their work performance. In that study, we interviewed five remote workers and asked how their work environment impacted them. The interviews, plus existing literature, allowed us to generate an item pool containing 65 items. In the present study, we applied an exploratory factor analysis (EFA) to find factors impacting people's remote work and identify the items associated with each factor. Then, we tested the validity and reliability of the proposed factor model with confirmatory factor analysis (CFA).

The remainder of this paper is organized as follows: In Section 2, the impacts of the physical environment, the differences between employer premises and remote work workplaces, as well as some questionnaires related to the physical environment are reviewed. In Section 3, we introduce our methods and present our results. We also briefly introduce how we created the item pool in this section. The extracted factors are renamed in Section 4, where we also introduce the improvement of our questionnaire. In Section 5, we present the limitations of our research and future studies.

2. The physical work environment

The physical environmental conditions such as sound, temperature, and space can impact people as *stressors*. Such stressors could produce physiologically and psychologically strains (Sander et al., 2019). Examples of physiological strains include increased heart rate and blood pressure (Kristiansen et al., 2009). The psychological strains include fear, tension, anxiety, and other responses (Ganster & Rosen, 2013). A recent study shows that remote workers' satisfaction with environmental conditions, including air quality, ventilation, temperature, and other elements, is positively related to their mental health (Bergefurt et al., 2022). Further, environmental stress could negatively impact people's work performance (Lamb & Kwok, 2016).

Scholars also study the impact of the work environment in *job design* research. Physical environmental elements could moderate the relationship between job characteristics and work outcomes (Oldham & Fried, 2016). In the questionnaire developed and validated by Morgeson and Humphrey (2006), the work context dimension measures the physical environment. Humphrey et al. (2007) expanded the job characteristics model proposed by Hackman and Oldham (1976) with work context characteristics. Humphrey et al. (2007) hypothesized that among work context characteristics, work conditions and ergonomics are positively related to positive behaviour and attitudinal outcomes and are negatively associated with negative behavioural outcomes. Their results show limited support for the impacts on positive attitudinal outcomes.

A good workplace should meet workers' needs. *Person-environment fit theory* indicates that a good match between workers' needs and supplies in the environment leads to increased productivity and well-being (Edwards et al., 1998). However, some remote workers experience misfit issues (Bergefurt et al., 2022). Generally, the fit is high in employer premises because such locations are specifically designed for working. They typically have sufficient equipment and devices while the temperature and lighting are satisfactory. However, employees may perceive a lower fit when working remotely because they are in an environment designed for living or relaxation and may not have sufficient devices and supplies (Microsoft, 2021).

The physical environment is included in some questionnaires. Campion and Thayer (1985) proposed a Measure of Job Design Questionnaire (MJDQ), while Campion (1988) revised it into a self-report questionnaire. Items such as noise, climate, lighting, displays, and workplace layout in this questionnaire are related to the physical environment. Further, Edwards et al. (1999) conducted a factor analysis and revised it into a four-factor questionnaire, where the biological and perceptual-motor factors measure the physical environment. Similarly, in the Work Design Questionnaire developed by Morgeson and Humphrey (2006), the dimension of work context measures the physical environment. The questionnaire used in a study by Lee and Brand (2005) measured satisfaction with and control over the workplace and distraction in the workplace. However, these questionnaires are not specifically designed for the case of remote work. In this study, we validate a more comprehensive questionnaire designed for the case of remote work.

3. Methods

3.1 The item pool

In March and April 2021, we interviewed five remote workers. These workers were in different industries, including information technology, finance, medicine, education, and government. When participating, they had been working from home for almost one year since the start of the COVID pandemic, while two of them occasionally worked remotely before the pandemic. During the interviews, we asked the participants to describe and evaluate their work environment and asked them questions about what they liked and disliked in the environment, how their work environment impacted them, and some other questions. We also asked the participants to compare their remote workplace and their offices. These questions covered the adequacy, arrangement, symbolic features, and sense of control of the workplace environment, as Carnevale and Rios (1995) suggested.

After analyzing the interviews, we proposed some new items that were not included in previous works, such as items about supplies of food and drink and items about the Internet connection. Such new items, plus those in previous works, contributed to the item pool of this study. The items in the item pool cover the four dimensions in Carnevale and Rios's (1995) theoretical model. Items in the Adequacy (AD) dimension are related to devices, climate, Internet connection, ergonomics, and supplies. In the Arrangement (AR) dimension, items are related to decoration, distraction, and relaxation. Besides, the dimension of Sense of Control (SC) includes questions about control over their workplaces. Lastly, Symbolic Features (SF) include the sense of belonging, sense of working, sense of achievement, relaxation, and motivation. The original item pool is presented in the Appendix.

3.2 Procedure

To collect data for the EFA, we published the questionnaire on Qualtrics and distributed it through Amazon Mechanical Turk (Mturk). Each respondent received US$0.5 as compensation after submitting responses. From October 15 to Nov 7, 2021, 770 responses were collected. We firstly deleted incomplete responses. Answers from respondents indicating that they were non-remote workers were deleted because they could not provide valid answers. We also deleted the responses submitted within 5 minutes since such respondents answered questions so fast that they may not carefully read each one. Besides, there are plenty of responses with missing values. There are no patterns among these missing data, and these values are missing at random. Therefore, we deleted these responses with missing values. Overall, 416 responses were valid, above the threshold of 325 (Gorsuch, 1988; Hair et al., 2010). The response rate was 54.03%.

3.3 Data analysis

We employed IBM SPSS 28.0 for EFA in this study. Generally, EFA is used to "discover the number of factors influencing variables and to analyze which variables 'go together' " (Yong & Pearce, 2013, p. 80). We applied Principal Axis Factoring (PAF) as the extraction method with Varimax rotation. Before data analysis, some items were eliminated.

3.3.1 Descriptive analysis

In this study, all respondents were adults and knowledge workers. They had been working remotely for more than three months when participating in this research. More than half were males (62.98%), while about one-third were females (37.02%). Most of them were between 21 to 40 years old (79.15%), but some people were aged below 20 (0.85%) or above 60 (2.13%). More than half of them had worked for more than one year (53.19%). For the frequency, 43.40% of the respondents worked remotely two or three days a week, while 37.45% worked remotely more frequently. Most of them worked from their home (75.74%), but some people worked from shared workplaces (19.15%), libraries (3.83%), or cafes (0.85%). Last, most of the respondents were from the industry of IT (48.94%), financial (15.74%), and education (8.94%).

3.3.2 Item elimination

There were no items deleted due to low correlations. Although five items had low correlations with most other items, they had relatively high correlations with each other, indicating some patterned relationships. Besides, the pair of items that have bivariate correlations above 0.9 should be removed. In our data set, the largest bivariate correlation is 0.729, below the threshold of 0.9 (Yong & Pearce, 2013). Items with communalities below 0.3 should also be removed (Field, 2009). In our dataset, all communalities are above this threshold. Two items (AR9 and AR10) were deleted due to low loadings. Three items (AD18, AD20, and SF5) were deleted since they had high loadings on two subfactors in the process of subfactor extraction. Two items (AD24 and SF2) were deleted since they were not conceptually related to the subfactors they loaded on. Overall, seven items were eliminated, and 58 items were included in the EFA.

3.3.3 Factor analysis

We set the number of factors extracted as four in factor analysis. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) was 0.965, above the threshold of 0.7. Bartlett's Test of Sphericity was significant at the 0.001 level. Besides, the eigenvalue was 1.917, above the threshold of 1, and the cumulative percentage of variance was 56.584%, above 50%. Therefore, the data was suitable for factor analysis.

The threshold of loading in this step was 0.4. As is shown in Table 1, while the majority of items coded as AD had loadings above 0.4 at Factor 1, three items coded as AR (AR1, AR3, and AR4) had loadings above 0.4 on both Factor 1 and Factor 2. They were included in Factor 1 since their loadings on this factor were higher. There are AR items and SF items in Factor 2. Items in Factor 3 are SC items. Last, there were five items in Factor 4, which were coded as AR or SF. The results differed from Carnevale and Rios's (1995) theoretical model. Regarding the reliability, the value of Cronbach's alpha of the whole questionnaire was 0.974, while the values of Cronbach's alpha of the four factors were, respectively, 0.969, 0.945, 0.895, and 0.766. The values were above the threshold of 0.7. The results illustrated the acceptable reliability of the four factors and the whole questionnaire. Since there were too many items on Factors 1 and 2, we attempted to extract subfactors. The factor rotation matrixes are shown in Table 2 and Table 3, respectively.

Subfactors of Factor 1. All items coded as AD and AR1, AR2, AR3, and AR4 were in the subfactor extraction of Factor 1. After trial-and-error, we found that the best number of factors extracted was three. The result of KMO was 0.967, above the threshold of 0.7, while Bartlett's Test was significant at a 0.001 level. The eigenvalue was 1.136, which was above the threshold of 1. Besides, the cumulative percentage was 62.815%, above the threshold of 50%. Therefore, the data was good for factor analysis. The result showed that there were 14 items in Subfactor 1-1, 11 in Subfactor 1-2, and four in Subfactor 1-3.

Subfactors Factor 2. The method used to extract subfactors of Factor 2 was similar. The result of KMO was 0.953, above the threshold of 0.7, while Bartlett's test was significant at a 0.001 level. The eigenvalue was 1.329, above the threshold of 1. The cumulative percentage of variance was 59.273%, above the threshold of 50%. Therefore, the data was suitable for factor analysis. The result showed that four items had loadings above 0.4 on both subfactors, but we included them on Subfactor 2-1 since their loadings were higher on this subfactor. In the end, there were 13 items in Subfactor 2-1 and five in Subfactor 2-2.

	1	2	3	4
AD7	**0.713**	0.198	0.112	0.237
AD6	**0.711**	0.268	0.222	-0.076
AD3	**0.71**	0.273	0.139	0.097
AD5	**0.707**	0.322	0.143	0.123
AD13	**0.703**	0.183	0.189	0.226
AD2	**0.703**	0.215	0.213	0.026
AD14	**0.696**	0.25	0.203	-0.142
AD28	**0.691**	0.271	0.235	-0.03
AD9	**0.691**	0.246	0.153	0.216
AD16	**0.69**	0.303	0.168	-0.088
AD17	**0.684**	0.312	0.156	0.044
AD1	**0.679**	0.306	0.14	0.139
AD21	**0.678**	0.274	0.093	0.176
AD19	**0.676**	0.209	0.132	0.169
AD27	**0.655**	0.269	0.194	0.034
AD23	**0.652**	0.291	0.194	0.22
AD8	**0.644**	0.271	0.21	0.098
AD12	**0.635**	0.206	0.156	0.189
AD10	**0.634**	0.255	0.209	0.083
AD26	**0.627**	0.255	0.319	-0.019
AD4	**0.618**	0.36	0.213	0.051
AD15	**0.575**	0.348	0.075	0.121
AD25	**0.556**	0.24	0.308	0.075
AD11	**0.548**	0.255	0.102	0.14
AD22	**0.524**	0.179	0.267	0.205
AR4	**0.504**	0.45	0.219	0.079
AR1	**0.476**	0.423	0.208	0.233
AR3	**0.471**	0.461	0.11	0.253
AR2	**0.41**	0.382	0.2	0.164
SF14	0.378	**0.647**	0.14	0.061
SF18	0.379	**0.646**	0.193	0.054
SF17	0.307	**0.645**	0.146	0.194
SF16	0.372	**0.598**	0.057	0.072
SF8	0.384	**0.58**	0.315	0.008
SF1	0.151	**0.576**	0.233	0.398
SF15	0.377	**0.574**	0.059	0.19
SF4	0.391	**0.556**	0.292	0.021
SF3	0.359	**0.552**	0.243	0.208
SF12	0.419	**0.52**	0.263	-0.124
SF19	0.448	**0.514**	0.265	0.015
AR8	0.185	**0.513**	0.154	0.374
AR7	0.32	**0.512**	0.253	0.362
SF6	0.401	**0.503**	0.342	0.021
AR6	0.238	**0.474**	0.244	0.334
SF13	0.322	**0.46**	0.421	0.191
SF7	0.344	**0.451**	0.271	0.23
AR5	0.37	**0.442**	0.221	0.351
SC6	0.304	0.244	**0.747**	0.088
SC2	0.23	0.17	**0.66**	0.208
SC5	0.294	0.281	**0.631**	0.241
SC3	0.336	0.269	**0.593**	0.205
SC4	0.364	0.367	**0.585**	0.019
SC1	0.235	0.203	**0.563**	0.373
AR11	0.093	0.065	0.036	**0.709**
AR12	0.012	0.063	0.007	**0.653**
SF9	-0.02	0.037	0.204	**0.526**
SF11	0.161	0.216	0	**0.508**
SF10	0.025	0.073	0.251	**0.427**

Table 1: The Factor Rotation Matrix of the Item Pool

	1-1	1-2	1-3
AD3	**0.637**	0.415	0.229
AD2	**0.629**	0.32	0.331
AD17	**0.626**	0.408	0.23
AD26	**0.624**	0.305	0.288
AD5	**0.616**	0.444	0.271
AD1	**0.608**	0.382	0.306
AD28	**0.606**	0.348	0.351
AD27	**0.594**	0.434	0.166
AD4	**0.588**	0.3	0.384
AD25	**0.556**	0.378	0.151
AD15	**0.552**	0.376	0.174
AD9	0.348	**0.686**	0.281
AD7	0.33	**0.66**	0.337
AD13	0.373	**0.659**	0.269
AD21	0.425	**0.588**	0.251
AD19	0.414	**0.58**	0.236
AD11	0.282	**0.574**	0.207
AD23	0.429	**0.572**	0.3
AD12	0.319	**0.561**	0.347
AD8	0.344	**0.56**	0.394
AD10	0.377	**0.514**	0.359
AD22	0.319	**0.451**	0.326
AR4	0.327	0.267	**0.719**
AR2	0.235	0.23	**0.678**
AR3	0.229	0.382	**0.626**
AR1	0.323	0.323	**0.594**

Table 2: Rotated Factor Matrix of Factor 1

Overall, as a result of factor extraction, we extracted four factors, two of which had subfactors. However, the factor model is different from the theoretical model. Specifically, although items coded as SC were in an individual factor (Factor 3), Factor 1 contained both AD and AR items. Both Factor 2 and 4 had SF and AR items. After testing the validation, we renamed these factors and subfactors.

	2-1	2-2
SF19	**0.72**	0.252
SF12	**0.713**	0.177
SF18	**0.673**	0.378
SF8	**0.672**	0.353
SF14	**0.67**	0.359
SF6	**0.649**	0.304
SF4	**0.641**	0.343
SF15	**0.616**	0.337
SF16	**0.608**	0.32
SF3	**0.583**	0.447
SF17	**0.577**	0.481
SF13	**0.545**	0.429
SF7	**0.484**	0.447
AR6	0.249	**0.718**
AR7	0.37	**0.702**
AR8	0.258	**0.687**
SF1	0.354	**0.672**
AR5	0.329	**0.67**

Table 3: Rotated Factor Matrix of Factor 2.

3.3.4 Validation of the model

As a result of EFA, we divided our questionnaire items into four factors, while two of them had subfactors. In this step, we followed Hair et al.'s (2010) suggestions to perform a CFA to validate our results. From June 25 to June 28, 2022, we collected and prepared data again, using a similar strategy, and performed CFA with the new dataset.

We tested the model containing only first-order factors (Subfactor 1-1, 1-2, 1-3, Subfactor 2-1, 2-2, Factor 3 and 4). The preliminary result showed that the correlation between Subfactor 1-1 and Subfactor 1-2 is as high as 0.894. Therefore, we put the two subfactors together in the revised factor model. Besides, in the revised model, seven items (SF1, SF7, SF9, SF10, SF14, SF15, and SF16) were deleted due to low loadings.

Factor	Item	Std. Loading	Cronbach's Alpha	Composite Reliability
F1_1 and F1_2	AD14	0.804	0.968	0.97
	AD16	0.817		
	AD6	0.818		
	AD3	0.818		
	AD2	0.795		
	AD17	0.769		
	AD26	0.721		
	AD5	0.824		
	AD1	0.766		
	AD28	0.78		
	AD27	0.724		
	AD4	0.766		
	AD25	0.631		
	AD15	0.685		
	AD9	0.709		
	AD7	0.738		
F1_3	AR4	0.861	0.853	0.853
	AR3	0.731		
	AR2	0.745		
	AR1	0.734		
F2_1	SF13	0.604	0.857	0.856
	SF17	0.586		
	SF3	0.679		
	SF4	0.619		
	SF6	0.621		
	SF8	0.673		
	SF18	0.635		
	SF12	0.605		
	SF19	0.666		
F2_2	AR5	0.695	0.826	0.824
	AR8	0.699		
	AR7	0.762		

	AD13	0.765		
	AD21	0.735		
	AD19	0.69		
	AD11	0.668		
	AD23	0.71		
	AD12	0.684		
	AD8	0.76		
	AD10	0.758		
	AD22	0.558		
	AR6	0.79		
F_3	SC6	0.82	0.855	0.856
	SC5	0.746		
	SC4	0.785		
	SC3	0.681		
	SC2	0.616		
	SC1	0.56		
F_4	SF11_R	0.396	0.662	0.611
	AR12_R	0.844		
	AR11_R	0.614		

Table 4: Standardized factor loading, Cronbach's alpha, and composite reliability

	AVE	F1_1and F1_2	F1_3	F2_1	F2_2	F3	F4
F1_1and F1_2	0.551	**0.742**					
F1_3	0.592	0.538	**0.770**				
F2_1	0.400	0.374	0.506	**0.633**			
F2_2	0.544	0.323	0.613	0.585	**0.738**		
F3	0.500	0.349	-0.221	0.624	0.558	**0.707**	
F4	0.415	0.192	0.521	-0.050	-0.323	-0.063	**0.645**

Table 5: AVE and correlations

As is shown in Table 4, in the revised model, the minimal standard loading was 0.394, below but very close to the threshold of 0.4. This item was not reduced since, for each factor, there should be more than three items. The other loadings were above 0.5. All Cronbach's alpha and composite reliability values were above the threshold of 0.6, indicating that the revised model's reliability was acceptable. Regarding the measurement of the model fit, the value of CMIN/DF was 2.157, with a p-value below 0.001. The value of CMIN/DF was below the threshold of 3. The value of the Normed Fit Index (NFI), Tucker-Lewis Index (TLI), and Confirmatory Fit Index (CFI) were 0.738, 0.83, and 839, respectively. Two of these three indicators were above the threshold of 0.8. Root Mean Square Error of Approximation (RMSEA) was 0.065, below 0.08. These indicators illustrated an acceptable convergent validity of the model. Besides, we referred to average variance extracted (AVE) and correlations to test discriminant validity. As was shown in Table 5, AVE values of the combination of Subfactor 1-1 and 1-2, Subfactor 1-3, Subfactor 2-2, and Factor 3 were above 0.5. For Subfactor 2-1 and Subfactor 4, the AVE values were lower but above 0.4. The square roots of AVEs (shown as bold numbers in the diagonal cells) were above the correlations of the corresponding paired items. The result showed an acceptable discriminant validity of the revised model.

4. Discussion

In this study, we did EFA on a questionnaire item pool. We created the items according to five interviews as well as previous literature. We made a factor model from EFA and tested the factor model. We modified the model in the process of CFA and obtained acceptable results. In this section, we name these factors and subfactors and discuss the improvement of our proposed questionnaire.

4.1 Names of the factors and subfactors

Factor 1 contains AD and AR items. While AD items are about the adequacy of the workplace, AR items are related to the size of the space, organization of the space, and overall satisfaction. Because adequacy refers to the quality of the workplace, including space, temperature, furniture, and work support such as equipment, supplies, and office assistance (Carnevale & Rios, 1995), all items in Factor 1, including the four coded as AR, are related to the adequacy of the workplace. Therefore, we name Factor 1 "*Adequacy*."

Factor 1 is divided into three subfactors in the EFA and revised into two subfactors as a result of CFA. The items in Subfactor 1-1 involve i) devices, ii) Internet connection, iii) places for relaxation, and iv) supply of food and drink. In Subfactor 1-2, questionnaire items measure i) lighting, ii) temperature and iii) ergonomics. In effect, these elements are related to people's functional comfort. Functional comfort "refers to the degree to which [the] environment supports users' tasks" (Vischer, 2008, p. 100). While facilities are important, the elements like lighting and ergonomic furniture help ensure functional comforts (Vischer, 2007). Therefore, we name this subfactor (the combination of Subfactor 1-1 and 1-2) "*Functional Adequacy*." In Subfactor 1-3, four items measure the workplace size, organization, and storage, so we name Subfactor 1-3 "*Space adequacy*."

All items in Factor 2, coded as AR or SF, measure people’s feelings in workplaces. Five items (SF1, 7, 14, 15 and 16) were deleted in the process of CFA. This factor is further divided into two subfactors. For Subfactor 2-1, items are related to i) sense of familiarity, ii) sense of achievement, iii) sense of professionalism (*deleted in CFA*), and iv) sense of relaxation. Overall, these items measure people’s joyfulness in remote workplaces. Thus, Subfactor 2-1 is named "*Enjoyment*." Items in Subfactor 2-2 are about the decorations in the workplace. Precisely, these items measure i) how the decoration motivates people, ii) people's comfort regarding the decoration, iii) how the decoration inspires people (*deleted in CFA*), and iv) people’s appreciation of the decoration. Overall, such items measure the extent to which the environment attracts people. Therefore, we name Subfactor 2-2 "*Attractiveness*" and name Factor 2 "*Affects*."

In Factor 3, all items are coded as SC, which means these items are about people’s sense of control over the physical environment. We name this factor "*Control*" since the items measure people’s actual control over the physical environment. Wherever they work, their control over the physical environment is one of their basic needs (Ganster & Fusilier, 1989). Several empirical works have tested the importance of people's control over the environment (e.g., Chandrasekar, 2011; Lee and Brand, 2005).

Factor 4 also includes items AR and SF items. Two factors (SF9 and SF10) were deleted in CFA. The items are about i) visual distractions, ii) the frequency of being distracted by others, iii) the frequency of stopping working and talking to others, and iv) aloneness (*deleted in CFA*). While the first three issues distract people, the sense of aloneness can also distract people (Sekhon & Srivastava, 2019). Therefore, these items measure people's perception of distraction. Accordingly, we name this factor "*Distractions*."

In conclusion, four factors found in this research are i) Adequacy, ii) Control, iii) Affects, and iv) Distractions. Both Adequacy and Affect have subfactors. The Adequacy factor combines i) Functional Adequacy and ii) Space Adequacy. The factor of Affect includes i) Enjoyment and ii) Attractiveness.

4.2 Improvements of the present questionnaire

Relatively, our questionnaire is more specific and comprehensive for the case of remote work. Physical environment, in effect, has been studied in other research and included in other questionnaires. The questionnaire in this research combines the advantages of previous questionnaires as we produced a more comprehensive questionnaire by adding some items associated with remote work. In particular, this questionnaire added items related to information technology facilities. Information technology is an essential element for remote workers. We also include people's affective feelings in this questionnaire. These items are essential because workers are not only subjected to workplace resources but also subjected to their feelings.

5. Conclusion

In this paper, we conducted an EFA to find factors in a questionnaire and conducted a CFA to

validate the factor model. We revised the factor model and achieved a four-factor model with a better model fit. The results of the CFA illustrated acceptable reliability and validity. The four factors are Adequacy, Affects, Control, and Distractions. The Adequacy factor was further divided into two sub-factors, Functional Adequacy and Space Adequacy. The factor of Affects was further divided into Enjoyment and Attractiveness. Control and Distractions factors do not have subfactors.

5.1 Limitations and future studies

This study has some limitations. Firstly, we did not find the dimension of the symbolic feature. According to previous works, symbolic features should be measured since they influence work outcomes. Secondly, as a result of the current study, control is an individual factor, but some scholars think it should be included in physical or psychological comfort (Budie et al., 2018; Vischer, 2007). Thirdly, some items were deleted in the data analysis due to loading issues. Although this step is necessary to guarantee the quality of the questionnaire, some deleted items are meaningful. The richness of the questionnaire items may have been reduced a little. Fourthly, the current research sample differs from the general population. The result of CFA is slightly different from the result of EFA. Both issues show that the generalizability of the conclusion of this research could be limited.

In future studies, we will revise and improve the questionnaire further and apply it to study the impact of the physical environment and geographical location in the remote work scenario. Such a study is critical and relevant given the trend of choosing more remote work by both individuals and companies.

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Appendix. The item pool

Item ID	Item	Source
AD1	I am satisfied with the number of the devices with which I work.	(Carlopio, 1996)
AD2	I am satisfied with the efficiency of the devices with which I work.	(Carlopio, 1996)
AD3	The quality of my equipment is sufficient to work effectively.	(Lee, 2006)
AD4	I have everything I need in my workplace.	Interview
AD5	Equipment in my workplace can satisfy my work.	Interview
AD6	Equipment in my workplace can satisfy my communication with clients and co-workers.	Interview
AD7	I am satisfied with the lighting in my workplace.	(Carlopio, 1996)
AD8	I am satisfied with the temperature in my workplace.	(Carlopio, 1996)
AD9	In terms of lighting, I feel comfortable in my workplace.	Interview
AD10	In terms of temperature, I feel comfortable in my workplace.	Interview
AD11	I do not feel too hot or too cold in my workplace.	Interview
AD12	I like the intensity of the lighting in my workplace.	Interview
AD13	I like the colour of the lighting in my workplace.	Interview
AD14	I can get access to the Internet easily in my workplace.	(Lättman et al., 2016)
AD15	I seldom meet Internet outages in my workplace.	Interview
AD16	The speed of the Internet in my workplace allows me to communicate with my clients or coworkers smoothly.	Interview
AD17	I can get all information and files needed with the Internet connection in my workplace.	Interview
AD18	I can work in my preferred position in my workplace.	Interview
AD19	Height of my table is fit for me or adjustable.	Interview; (Brisson et al., 1999)
AD20	Height of my chair is fit for me or adjustable.	Interview; (Brisson et al., 1999)
AD21	I have my hand supported in my workplace.	(Brisson et al., 1999)
AD22	I have my feet supported in my workplace.	(Brisson et al., 1999)
AD23	I have my back supported in my workplace.	Interview
AD24	I am physically comfortable in my workplace.	Interview
AD25	I can get food and drink in my workplace.	Interview
AD26	My workplace has good places for break.	(Haynes, 2008)
AD27	After taking break, I can go back to work quickly.	Interview
AD28	I feel relaxed after the workplace break.	Interview
AR1	My workplace is large enough.	(Lee, 2006)
AR2	I have ample storage in my work area.	(Lee, 2006)
AR3	I am satisfied with the organization of my workplace.	Interview
AR4	I am satisfied with the space of my workplace.	Interview
AR5	I like the decorations (pictures, photos, etc.) in my workplace.	Interview
AR6	These decorations motivate me.	Interview
AR7	These decorations make me feel comfortable.	Interview

AR8	These decorations make me want to work.	Interview
AR9	My workplace is free from excessive noise.	(Edwards et al., 1999)
AR10	My workplace provides an undisturbed environment so that I can concentrate on my work.	(Lee, 2006)
AR11	My workplace has many virtual distractions. (R)	(Lee, 2006)
AR12	People in my workplace distract me frequently. (R)	Interview
SC1	I am able to control temperature or airflow in my workplace.	(Lee, 2006)
SC2	I am able to control the artificial lighting level in my workstation.	(Lee, 2006)
SC3	I determine the organization of my workplace.	(Lee & Brand, 2005)
SC4	I can personalize my workplace.	(Lee & Brand, 2005)
SC5	I can adjust, re-arrange, and re-organize my furniture as needed.	(Lee & Brand, 2005)
SC6	I can determine the decorations of my workplace.	Interview
SF1	There is something in my workplace (quotes, pictures, etc.) that inspire me.	Interview
SF2	My workplace is attractive and makes me want to go to work.	Interview
SF3	I like to work when I am in my workplace.	Interview
SF4	I feel relaxed in my workplace.	Interview
SF5	There is something in the workplace helping me keep relaxed.	Interview
SF6	Compared with offices, I feel more relaxed in my remote-work workplace.	Interview
SF7	I do not feel stressful when I am in my workplace.	Interview
SF8	Working in my workplace is easy because I feel comfortable.	(Hoffman et al., 2002)
SF9	I feel alone in my workplace. (R)	(Hoffman et al., 2002)
SF10	I rarely talked to others in my workplace. (R)	(Hoffman et al., 2002)
SF11	I stop to talk to people I recognize in my workplace.	(Hoffman et al., 2002)
SF12	I am familiar with my workplace.	Interview
SF13	When working in my workplace, I feel at home.	Interview
SF14	I feel professional when I am in my workplace.	Interview
SF15	My workplace makes me feel that I am at work.	Interview
SF16	My workplace is designed for work.	Interview
SF17	I have a sense of achievement in my workplace.	Interview
SF18	I feel that I have accomplished a lot when working in the workplace.	Interview
SF19	I have successfully finished some tasks in the workplace.	Interview

29. Voicing Brands: Users' choice of recommended brands in voice commerce and e-commerce

Maria Madlberger
Webster Vienna Private University
maria.madlberger@webster.ac.at

Ekaterina Andreev
BIPA Parfümerien GmbH
ekaterina.andreev@gmail.com

Abstract

In recent years, traditional e-commerce has been complemented by voice commerce where interaction between the user and the information system takes place by means of a voice assistant (VA) instead of written text-based conversation. The audible interaction results in an altered consumer behavior during the customer journey which can impact final product and brand choice. The study at hand acknowledges the higher perceived difficulty of interacting in voice commerce. Against this background, we investigate in what way a VA's brand recommendation impacts a consumer's purchase decision in voice-based interaction compared to text-based interaction and how this decision is moderated by prior brand preferences. The results obtained from an online survey with a quasi-experimental design show that a brand recommendation alone does not increase likelihood of brand choice, however a recommended brand is more likely chosen in a voice-based interaction than a text-based one. A priori brand preferences moderate the impact of the voice-based recommendation in case of the recommended brand. The findings imply that voice commerce can strengthen but not replace existing brand preferences in the purchase decision-making process.

Keywords: Voice assistant, voice commerce, e-commerce, brand preference, recomendation

1. Introduction

Human interaction with information systems is not limited anymore to typing alone. Numerous technological devices either include or are dedicated to voice-based interactions and thus establish conversational agents, often implemented as a voice assistant (VA) or voice-activated personal assistant (Branham and Mukkath Roy, 2019). Most often used in connection to a mobile device, but also operated as a dedicated device (Guy, 2018), these VAs are becoming integrated into our daily lives and serve multiple purposes, such as simple search queries, keeping track of to-do lists, reminding users of upcoming events and meetings, and, if given permission, shopping on the users' behalf (Feng, Fawaz, and Shin, 2017). The way that VAs disrupt consumer-device interactions and consumer-brand communications calls for academic research since it can largely alter consumer behavior in an e-commerce context (Mari, 2019). The effects of the growing acceptance of voice search on a brand's rankings in search engines are being considered in related research, proposing to companies and brands to adapt their search engine optimization and search engine advertising strategies in order to respond to a changing consumer behavior (Rehkopf, 2019). In their very nature, VAs are more natural for humans to communicate with, since they utilize the spoken word, present a faster and hands-free (Branham and Mukkath Roy, 2019) way of searching the Internet. VAs may even almost become equated to real humans due to their real-time adaptation to the way people speak to them (Kietzmann, Paschen, and Treen, 2018).

When being applied for product search, VAs can establish a direct consumer-brand touchpoint which companies can leverage in order to increase awareness, loyalty and likeability of a brand among present and potential customers alike (Mari, Mandelli, and Algesheimer, 2020; Moriuchi, 2019). By doing so, different brands can shape brand preferences which in turn determine the commercial success of the brand (Lowry, Vance, Moody, Beckman, and Read, 2008). When looking towards voice commerce and the application of VAs, there are still research gaps in how brand preference is exhibited when consumers are attempting to make a purchase decision while interacting with a VA. A specific characteristic of shopping via voice commerce is that the purchase decision is not entirely with the user, but being influenced by the choice of the VA which presents brands based on search algorithms, user ratings and previous purchases. Hence, VAs exert a gate-keeping function in relation to the brands, as the purchase decision, by which consumers indicate brand loyalty (Tsai, Chang, and Ho, 2015), will often be left up to the VA (Kaplan, 2018). Even if brand preference is to persist, when shopping via voice, consumers are presented with a situation where they are no longer able to peruse many singular brands, compare their prices and packaging directly, but with an imaginary “shelf”, from which it is more difficult to make a purchase decision from. Such a product recommendation consists only of the VA reading out the brands and product descriptions, which in turn causes even more reliance on the VAs recommendations in regard to possible purchase options.

The cognitive load is higher for consumers when they are presented with a voice commerce setting compared with written text. This leads the consumers to be more likely to choose the VA’s recommendation (Munz and Morwitz, 2019). In voice commerce, the consumer has to remember the proposed brand choices and then choose the preferred brand based on what has been stored in the short-term memory. In contrast, in a visual presentation (e.g., text-based), any memorization is barely required as the proposed brands are displayed simultaneously. As a result, voice-based recommendations lead to a heightened cognitive load as memory, presentation bias, and the VA’s potentially biased product recommendation all affect the choice of the consumer.

The study at hand aims at investigating how the consumer journey stage of purchase within voice commerce compares to e-commerce with a visual, text-based brand proposition. The study builds on the work by Munz and Morwitz (2019) by investigating the role of brand preference in addition to the pure effects of making a purchase via a VA or via written text, as would be the case in classical e-commerce. In particular, we aim to add to the existing body of research regarding voice commerce by determining whether VA recommendations within a voice commerce setting might not be as readily accepted when a brand preference is established, therefore constituting that brand preference to a given product can combat the users’ tendency to follow VA’s recommendations. Hence, we address the following research question: How does the purchase recommendation of a voice assistant impact a consumer’s purchase decision and what role do a priori brand preferences play in this decision process?

After a review of related work on VAs and voice commerce in the following section, the research framework with the hypothesis development is presented in the subsequent section. Section four outlines the research design of an online survey among 209 participants that has been employed to test the research framework. Section five presents the results which are discussed in terms of research and managerial implications in section six.

2. Literature Review

2.1 Voice Assistants

A VA is a voice-activated technology that utilizes software agents, i.e., speech recognition software systems, based on artificial intelligence, that conduct communication with users in a natural language (Jiang, Jeng, and He, 2013). This way, VAs allow the interaction between humans and computers by talking with them (Hoy, 2018). Patterns and nuances of human speech can be continuously adapted and improved through natural language processing (Kietzmann et al., 2018). The similarity of VAs with real, human counterparts establishes a substantial advantage that resulted in a high degree of adoption (Han and Yang, 2018).

Human-computer interaction with VAs is characterized by several key features that distinguish it from interaction by other means. First, speaking and listening is an easier way of communication than writing or reading. It is also a faster way of asking for information, as an average person can speak 150-160 words per minute, but can only type around 41 words (Rehkopf, 2019). The cognitive load in communication with a VA is equivalent to the one in a conversation with a human (Strayer, Cooper, Turrill, Coleman, and Hopman, 2017). The simplicity of a conversation with a VA, compared to visual information exchange, is further enhanced by a hands-free access (Branham and Mukkath Roy, 2019). This allows for multitasking activities with voice queries on the go or while other activities are carried out, such as cooking (Guy, 2018). Another key feature of VAs is people's tendency to humanize such systems, due to the notion of media equation, which states that humans apply the same rules and sentiments that govern human-to-human interaction onto interactions between a person and a machine, resulting in a parasocial relationship, i.e. a relationship between the user and the VA which is perceived as being like a two-way human-to-human interaction (Liew and Tan, 2018; Whang and Im, 2021). Human-likeness is being attributed when a machine resembles a human, either in a visual or audible way (Robert, 2017). The tendency to humanize VAs also heightens users' satisfaction with performance, feeding into their readiness to interact with these machines further (Branham and Mukkath Roy, 2019). On the other hand, there are factors which can make users reluctant to use VAs as they can disclose personal information in the process. Privacy concerns, security problems, and resulting trust issues have been identified as adoption and usage inhibitors (Bawack, Wamba, and Carillo, 2021). Expectations on the performance which are higher than their actual capability can leave users disappointed and reluctant to interact with them further (Pradhan, Mehta, and Findlater, 2018). A diminishing level of trust towards VAs and resulting adoption has also been observed in case of a failure to understand a given question or command (Branham and Mukkath Roy, 2019).

2.2 E-Commerce, Voice Commerce, and Voice Search

In a shopping context, VAs can play a significant role in the stage of product search and evaluation of alternatives. When shopping in a physical store, consumers are presented with a shelf full of choices from which to pick the product they want to buy. This experience is affected by a consumer's consideration set, meaning that they are more likely to draw from a set of brands they already know well and have developed a particular preference for (Yoo, Park, and Kim, 2018). Shopping in a physical store allows consumers to compare prices easily, therefore determining which brands to include within their immediate consideration set, with the products standing next to each other and the prices being listed just below them. In e-commerce, many of the aforementioned factors become obsolete. Despite often comprehensive product descriptions and images, a consumer cannot know what the item really is like until it is delivered. In this regard, product descriptions are an important factor for product recognition and serve as one of the main touchpoints between brand and consumer (Mou, Zhu, and Benyoucef, 2020).

The consumer experience changes yet again in the situation of voice commerce as consumers show more trust in the VA and allow it to make the purchase instead of directly choosing a brand or product themselves. Product descriptions might affect voice commerce differently than e-commerce as the product description is read out to the consumer instead of the consumer reading it themselves (Mou et al., 2020). The choice between two products is more difficult for a consumer when presented in an auditory manner as opposed to when it is presented in the learned form of written text (Munz and Morwitz, 2019). Voice comparisons require a larger cognitive load for the user because they require a person's memory to be used more actively. The consumer has to remember all suggested products and then make the pick as opposed to the choices presented via text, where barely any memory is required as the two kinds of information are presented simultaneously (Munz and Morwitz, 2019).

Hence, VAs have a limited set of options to work with, as they cannot present a user with an entire page filled with all kinds of possible answers or options for a given search query. The way VAs determine which brand to purchase for a consumer is referred to as "incidental loyalty". It implies that consumers tend to shift away from specific brands by allowing the VA to choose the brand instead (Kaplan, 2018). Therefore, the algorithm that "dictates" a VA's recommendation is not only affected by a classical type of search engine ranking, whereupon the most relevant or most advertised result shows up first but is also governed by past purchases or even the operating system to which the VA belongs.

To bypass a VA's incidental loyalty, brands can invest in search engine optimization in order to become ranked higher or even on top of the VA recommendations. One constant hurdle to this attempt is VA's bias towards their makers (e.g., Amazon) since the underlying algorithm is determined to recommend private labels or other favored products more strongly than others, which may result in largely foregoing the organic ranking of a given item (Mari, 2019).

When a brand and its product are stripped to being merely a sentence read by a robotic voice, it is key that the customer recognizes the brand by name and reputation, sees the product in front of their eyes even in absence of the physical packaging, and enforces their brand preference over the assistant's bias towards their own ecosystem, search rankings, and competitor brands, thus emphasizing the importance of brand knowledge and brand loyalty. Marketers therefore need to adapt to the alterations to a brand's touchpoints with the consumer that are being caused by the rise of voice search.

3. Hypotheses Development

In an empirical study, Munz and Morwitz (2019) found that voice commerce purchase decision tasks are perceived more difficult as they require more information processing capacities and memory. This would imply that not only does voice commerce create a higher cognitive load for the participants, but that the participants are also aware of the difficulty of decision making that comes with such an interaction with a VA. Hence, we seek to replicate this notion in the present study and hypothesize:

H1: Users rate the voice condition as more difficult to navigate than users within the written condition.

Since voice commerce is a result of voice search, by which search queries are posed in the form of spoken words and directed towards a given VA (Van Bommel, Edelman, and Ungerman, 2014), it applies the principles of search engines and thus, the user tendencies exhibited in classical search contexts are expected to also hold true in voice search. In text-based searches, the vast majority of users only considers results on a search engine's first page after a keyword search (Nagpal and Petersen, 2021), hence, the order of recommendations matters largely. In voice search, this tendency should be further underlined by the findings of Munz and Morwitz (2019), by which users choose to purchase the first option recommended to them by a VA. Therefore, we hypothesize for the written and voice setting:

H2: Users are more likely to choose a recommended purchase option over a non-recommended one.

Given the cognitive load of voice search, which is caused by the interaction with a VA, consumers are expected to be more likely to accept the VA's recommendation over a second proposed option (Munz and Morwitz, 2019). It is therefore expected that participants of the present research will choose the recommended option more frequently in the voice condition than in the written condition.

H3: Users are more likely to choose a VA's product recommendation in the voice-based setting than in the written setting.

Marketing research has pointed at the relevance of brand preference in consumer behavior. Brand preferences constitute the basis for consumer purchase decisions (Tolba, 2011; Tsai et al., 2015) and result from consumer's prior interactions and experiences with a given brand and the perceived quality of a given brand and its products and services (Tolba, 2011). Due to the difficulty of decision making that is posed by voice commerce and the absence of familiar stimuli like product images or written product descriptions (Lemon and Verhoef, 2016), we contend that brand preference will exhibit a noteworthy influence on the user's choice in a voice-based and text-based setting. Perceived human-likeness turned out to mediate the impact of a voice setting on acceptance of a recommended product due to evoking a parasocial relationship (Whang and Im, 2021). We postulate that the impact of the recommendation in both settings will be moderated by the user's brand preference insofar as the impact of recommendation will be stronger in presence of a prior brand preference of the recommended brand.

H4: Users' likelihood of accepting a VA's product recommendation over a non-recommended one is larger in presence of a prior brand preference for the recommended product.

4. Research Methodology

4.1 Research Design

For the hypothesis tests, an online survey with a quasi-experimental design has been conducted. The research design consisted of two experimental conditions. Experimental group A was allocated the written condition, in which participants were asked to make a purchase in a text-based e-commerce setting. Experimental group B participated in the voice-based setting, in which the purchase was made by listening to an audio clip of a VA reading out the product descriptions, partly replicating the survey design by Munz and Morwitz (2019). To minimize bias, product descriptions and ratings that have been presented in the experimental conditions, were real and taken directly from Amazon.de and Amazon.co.uk. An alteration was made to the price indication in order to remove the influence of price on the final purchase decision.

Both conditions presented the participants with a set of scales aimed to measure brand preferences within a low-involvement consumer goods product category, i.e., sunscreen. It is a seasonal product with prices ranging from five to ten euros for one regular package. There are several known brands available. The seasonality of the product category allows for assuming a medium degree of brand preference since the product is not used throughout the whole year. Brand preferences were measured in order to determine an underlying preference for the brands named within the questionnaire prior to the experimental treatment (i.e., presentation of the text-based or voice-based recommendation).

The dependent variable has been measured with a 7-point Likert scale in which the likelihood of choice of the preferred brand over a second brand which was presented by the text or voice stimulus as an alternative (however not recommended) was indicated. Brand preference has been measured by using the scale by Paharia and Swaminathan (2019) which draws on purchase intention. For the purpose of this study and in line with previous research (Laurent, Kapferer, and Roussel, 1995) it is assumed that the most preferred brand is the one most likely to be bought. Finally, the study has measured the perceived difficulty of the voice commerce-related purchase decision making (Munz and Morwitz, 2019) by using a scale adapted from Anand and Sternthal (1990).

4.2 Sample

A total of 260 questionnaires have been collected by recruiting the sample on the Amazon Mechanical Turk (MTurk) platform in the German-speaking area. This respondent recruitment strategy is increasingly used and established in social science and behavioral research (Moriuchi, 2019; Whang and Im, 2021). The participants have been randomly allocated to the experimental conditions by utilizing the respective settings in the online survey tool, Qualtrics. Out of the collected questionnaires, 51 answers had to be omitted from the data due to incompletion. The final data consisted of 114 responses for experimental condition A (text) and 95 responses for condition B (voice). Table 1 shows the sample description. The demographic data from the two experimental groups was compared using Pearson's Chi-Square. The two groups did not statistically differ in regard to gender ($\chi^2 = 4.105$, $p = .250$), age ($\chi^2 = 3.590$, $p = .464$), and occupation ($\chi^2 = 6.956$, $p = .138$). A statistical difference was found in education ($\chi^2 = 20.018$, $p = .001$), yet was chosen to not be an obstacle for a comparison of samples.

5. Results

To test the hypotheses, t-tests were conducted to test H1 and H2, followed by a multiple regression analysis to test H3 and H4.

H1 (users rate the voice condition as more difficult to navigate than users within the written condition) was tested by running an independent samples t-test with perceived difficulty as the dependent variable and the experimental condition as the independent variable. The data was unsplit for the purpose of investigating the perceived difficulty overall, with the only difference sought being the two conditions. The results stand in support for H1 with M = 5.86 for the text condition and M = 5.0 for the voice condition (95% CI [.504, 0.50], $t(415) = -5.235$, $p < .001$). The mean for the text condition lies closer to the value 7, indicating that the text condition was rated as simpler than the voice condition, supporting the findings by Munz and Morwitz (2019).

		Text	**Voice**			**Text**	**Voice**
Gender	Female	59%	61%	**Age**	18-24	29%	25%
	Male	40%	36%		25-34	55%	57%
	Other	1%	3%		35-44	6%	10%
					45-54	5%	3%
					55-64	4%	4%
Education	Less than high school diploma	23%	3%	**Occupation**	Full-time	57%	57%
	High school diploma	42%	12%		Part-time	16%	8%
	Bachelor's degree	32%	43%		Unemployed	4%	4%
	Master's degree	1%	40%		Student	19%	25%
	PhD	2%	2%		Other	4%	5%

Table 1: Sample Description

For H2 (users are more likely to choose a recommended purchase option over a non-recommended one), a one-sample t-test was run to test whether the purchase decision mean significantly differed from the value 4.0, representing the middle of the 7-point Likert scale used to measure the purchase decision and thus the absence of a tendency towards the recommended (> 4 on the scale) or the alternative product (< 4 on the scale). The mean purchase decision score (M = 3.55, SD = 2.30) within the text condition was shown to differ from the test value of 4.0, with a mean difference of .44, 95% CI [.02; .87], $t(113) = -2.08$, $p = .040$. For the voice condition, the mean purchase decision score ($M = 3.60$, $SD = 1,81$) was also shown to significantly differ from 4.0, with a mean difference of .41, 95% CI [.04; .78], $t(93) = -2.21$, $p = .030$. Despite the significant results, H2 cannot be supported because the means lie closer to 1, the alternative option. Therefore, participants were not more likely to choose the recommended purchase option, but the alternative brand.

To test H3 and H4, a multiple regression analysis with 10,000 bootstrap samples has been run which includes the brand preferences (measured as a priori purchase intent) of the recommended and alternative brands, the experimental condition (measured as a dummy variable coding text-based as 1 and voice-based as 0) for testing H3, and the interaction terms of condition*brand preference recommended brand and condition*brand preference alternative brand for testing H4. Table 2 shows the regression models, displaying the direct effects of brand preferences on choice in Model 1, adding the condition in Model 2, and the interaction terms in Model 3. In all models, no autocorrelation and multicollinearity could be identified.

As the results show, all models have explanatory power whereby Model 3 shows the highest adjusted R^2 (.118, $p < .001$). The a-priori brand preferences exert a significant impact on the brand choice after the exposure to the text-based or voice-based recommendation. The negative B values for the brand preference alternative are consistent since the brand choice was measured on one scale where the choice of the alternative is the opposite of the choice of the recommended brand. The condition alone does not exert any significant impact and reduces the explanatory power of Model 2.

The addition of the interaction terms yields a significant negative B value for the condition ($p < .05$) implying that the voice-based condition results in a higher likelihood to choose the recommended brand, compared to the text-based condition. This effect, however, is small, as it turned significant only in the bootstrapping procedure and the CI spans across zero. Hence, concerning H3 (users are more likely to choose a VA's product recommendation in the voice-based setting than in the written setting), we can cautiously support the hypothesis.

In the test of H4 (users' likelihood of accepting a VA's product recommendation over a non-recommended one is larger in presence of a prior brand preference for the recommended product), a significant effect can only be found for the moderating impact of brand preference for the recommended product ($p < .1$), but not for brand preference for the alternative product. Hence, we can partly support H4 and conclude that the presence of a priori preference for the recommended brand increases the impact of the recommendation on the final choice. The addition of the moderators enhances the explanatory power and turns the direct effect of the condition significant.

6. Discussion

The findings show that users do make different experiences in a voice commerce setting, compared to classical text-based interaction. That users perceive voice commerce as more difficult to deal with has implications for the general acceptance of voice search and VAs in voice commerce. If simplicity of use is a prerequisite for acceptance, as stated by the UTAUT (Venkatesh, Morris, Davis, and Davis, 2003), the diffusion of voice commerce is being challenged as the existing text and image combinations in e-commerce are more familiar and present more stimuli for the consumers to base their purchase decision on (Lemon and Verhoef, 2016). Further, this finding implies that the communication with a VA is not in fact just as easy as conversing with another human being (Strayer et al., 2017). Further, the support of H3 suggests that the voice-based conversation induces users to follow the recommendation to a larger extent than a text-based one. However, the significance tests suggest that this finding has to be interpreted with caution and more research is necessary to achieve more robust evidence of this impact.

	Model 1 [95% CI]	Model 2 [95% CI]	Model 3 [95% CI]
Intercept	2.777*** [1.845; 3.700]	2.756*** [1.723; 3.713]	3.821*** [2.435; 4.952]
Brand preference recommendation	.411*** [.247; .573]	.412*** [.249; .580]	.243* [.035; .465]
Brand preference alternative	-.320*** [-.472; -.159]	-.321*** [-.478; -.156]	-.363** [-.572; -.137]
Condition (text vs. voice)		.035 [-.483; .574]	-1.799* [-3.440; .056]
Brand preference recommendation*Condition			.296⁺ [-.025; .610]
Brand preference alternative*Condition			.070 [-.256; .379]
Adjusted R^2	.113***	.109***	.118***
Durbin-Watson	2.441	2.441	2.462
Tolerance (excl. interaction terms)	.871	.869-.998	.383-.386
VIF (excl. interaction terms)	1.148	1.002-1.151	2.526-2.608
⁺ p<.1, * p<.05, ** p<.01, ** p<.001 Note: p values and CI are based on bootstrapping procedure with 10,000 bootstrap samples			

Table 2: Regression analyses

Concerning the influence of the use of voice in a product search context, the rejection of H2 contrasts with the notion of Munz and Morwitz (2019) as the recommended brand is not significantly more often chosen than the alternative. The results can be indicative of the tendencies of advertising avoidance (Li, 2019). If customers perceive a recommendation as a paid or advertised search result, they may show less trust in it than in an organic result (Berman and Katona, 2013), which would be a contrasting effect to the cognitive load found by Munz and Morwitz (2019) that induces customers to choose the recommended option in voice search. The strong and significant impact of a priori brand preferences shows that the literature on the key role of brand preferences does hold true in a voice commerce setting, too. Brand preferences establish a brand equity in the consumer which encompasses all positive or negative notions that the marketing efforts of the named brands had created (Lowry et al., 2008). Brand preference is an emotionally driven and opinionated phenomenon (Tolba, 2011), which results in the finding that recommendations, irrespective of the condition, are less impactful than the underlying brand preference of the consumer. These underlying brand preferences then may also affect general tendencies within search engine usage and imply that it is not only advertising avoidance which deters users from choosing the first suggested option (Berman and Katona, 2013; Li, 2019), but it is also a subjective favoritism towards a certain brand or product that keeps users on their search path until the preferred outcome of a query is found.

From a managerial perspective, the findings suggest that it needs to be acknowledged that users perceive a text-based search differently than a voice-based one. The higher cognitive load may both stimulate the choice of a recommended brand, but may also trigger customers to stick to their original brand preference, hence “overhearing” a different recommendation. The moderating impact of brand preference further shows that brand preference can strengthen the tendency of voice search to follow a recommendation, if the respective brand is being preferred by the user. Hence, brand manufacturers as well as search engines or online shops that employ voice search (such as Amazon with the VA Alexa) should not overestimate the effect of voice search. In contrast, voice search appears to support a strong existing brand preference, but cannot be employed to replace it.

7. Conclusion

The study at hand sheds some light on user behavior in the context of voice search. In particular, it confirms the existence of a direct and moderated impact of existing brand preferences. The choice of a brand that is recommended by a search engine is marginally further impacted by the underlying format whereby a voice setting increases the tendency to choose the recommended product. In line with previous research (Munz and Morwitz, 2019), the study could further confirm the higher cognitive load of processing the results of a voice-based search, compared to a text-based one.

Like any research, this study has several limitations. First, it is based on a sample that is small in size and lacking generalizability. Although the socio-demographic variables which were used as control variables did not show any significant impact, there is a bias risk due to lacking representativeness of the sample. Further, the research context was limited to one product category in which consumers may display specific attitudes. More research that involves different product categories is needed.

Research on impacts of voice commerce on consumer behavior is still at its infancy. Several extant studies point at specific interrelations between voice commerce and brand engagement as well as loyalty (McLean, Osei-Frimpong, and Barhorst, 2021). Further research is needed on relevant contextual factors such as product involvement which is strongly interrelated with brand preferences (Arora, Prashar, Parsad, and Vijay, 2019) and social contexts. Since voice commerce is a growing component in the evolving research field of customer journeys in an omni-channel environment (Lemon and Verhoef, 2016), VAs as a key touchpoint need to be better understood as a part of the customer journey. In this context, further technical and HCI-related specifics of VAs and, in a broader sense, conversational agents in a purchasing situation need to be investigated in a commercial and product recommendation setting (Puntoni, Reczek, Giesler, and Botti, 2021).

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7. Authors index

Authors are listed in the alphabetical order of their family names with their papers' numbers