Isabel L. Nunes *Editor*

Advances in Human Factors and System Interactions

Proceedings of the AHFE 2021 Virtual Conference on Human Factors and Systems Interaction, July 25–29, 2021, USA

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Advances in Human Factors and Ergonomics 2021

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Preface

Human Factors and Systems Interaction aims to address the main issues of concern within systems interface with a particular emphasis on the system lifecycle development and implementation of interfaces and the general implications of augmented and mixed reality with respect to human and technology interaction. Human Factors and Systems Interaction is, in the first instance, affected by the forces shaping the nature of future computing and systems development. The objective of this book is to provide equal consideration of the human along with the hardware and software in the technical and technical management processes for developing systems that will optimize total system performance and minimize total ownership costs. This book aims to explore and discuss innovative studies of technology and its application in system interfaces and welcomes research in progress, case studies and poster demonstrations.

A total of eight sections are presented in this book:

1. Security and Crises Management
2. Complex Human-System Interactions
3. User Experience, Affordance and Technology
4. Assistive Technologies and Accessibility
5. Smart Manufacturing
6. Human Functions in Organizational Systems
7. Human Systems and Transportation Applications
8. Accessible and Inclusive Technology

Each section covers research papers that have been reviewed by members of the International Editorial Board. Our sincere thanks and appreciation to the board members as listed below:

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Security and Crises Management

Mental Traps Behind Maritime Disasters

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Abstract. Most accidents, some resulting in technological disasters, have human factors as root-causes. Some of these are mental biases related with human cognitive limitations, while others concern group decision making processes. The case of maritime incidents is of particular interest, due to the typically harsh environment at sea and the likelihood of disasters that may result. The outcomes of maritime accidents involving socio-technical systems – ships and maritime infrastructures – may be classified as severe, if not catastrophic. Analysing known maritime disasters provide insight for prevention, as well as the best way to manage crisis. Incidents with root causes linked to explicit knowledge may be controlled. When causes, however, are grounded on mind bias and subconscious processes, it becomes difficult to foresee the potential disaster, and provide for adequate preventive measures. An analysis of a number of disasters, recent and ancient, provides insight for human factors focused educational and training programmes.

Keywords: Human factors · Mind bias · Safety · Risk · Maritime · Crisis management

1 Introduction

On the 15th of April, 1912, *Titanic*, one of the world finest ships sunk after striking an iceberg. Over fifteen hundredth lives were lost in such disaster. Being realistic the possibility of icebergs presence on the northern maritime roots, why did the decision makers choose such northern route? Was it a rational choice, or were some mind bias at play?

Competent managers, leaders and decisions makers at large fall victims of their own thinking processes, some of them unconscious. The accelerating evolution of society and technology may not have a match on the physical and cognitive evolution of humans.

This mis-adjustment may cause the human brain to create simplifications that, instead of enhancing human survival, are creating unconscious shortcuts that influence decision-making, often with disastrous outcomes. Context dynamics create uncertainty that, in addition to increasing complexity and decision-making under time pressure can be impacted by cognitive factors and biased thinking processes. Decision-making in an inhospitable environment, such as at sea, where time is a critical factor that affects the well-being or survival of the group, can be faced with increased difficulty.

Objective and Methodology: by means of a literature review, the main psychological traps to good decision making are clarified, and a set of maritime related accidents are analysed. The most frequent mind bias that leads to disasters in maritime related cases are identified.

There have been several disasters which could be avoided, had some cognitive bias been timely prevented. From the *Titanic* disaster to the Gulf of Mexico *BP Deep Water Horizon* accident, where many lives were lost together with tremendous damage to the environment, many could be avoided with a more conscious approach and awareness of the human cognitive limitations and related mind bias. The identification of the main bias at play, their classification and analysis, provide adequate insight for recommendations, concerning better approaches for human factors and decision making within maritime related context.

2 Background

Considering a diverse set of systems, especially the more complex or impacted by human action and associated subjectivity, it is normal for accidents to happen which disrupt these systems normal functioning [1]. Accident refers to a short, sudden and unexpected event or occurrence with an unwanted and undesirable outcome, resulting from a direct or indirect human action [2]. When they occur within the maritime environment and produce an incident or casualties, these are referred as maritime accidents. IMO [3] considers that whenever there is a deliberate act or omission to cause damage to the safety of a ship, an individual or the environment, it should not be referred as an accident.

Maritime accidents are characterized by a low probability of occurrence but high consequences, whether in terms of human lives, material and financial means or ecological. Human error is the main cause of maritime accidents, and may be associated with working conditions, procedures, organization, training or individual factors, that determine the actions and decision making of the involved agents [4, 5].

Dörner [6] suggested that there are several "psychological factors" behind accidents. The very nature of complex socio-technical systems with its associated dynamic behaviour, increase uncertainty and the associated fear, which goes against human nature, creating unease and stress. Decisions that go against social beliefs or intrinsic to the individual, provoke internal conflicts, inconsistencies, and cognitive dissonance. The decision maker, consciously or not, will find artificial justifications to justify himself for not making the correct decision. Cognitive shortcuts under crisis situations may aggravate the incident, ending up in disaster. Dörner [6] argues that complexity can be characterized by interdependency, non-transparency, and complex dynamic behaviour over time. If decision-making in a "normal" environment can be affected by psychological factors, then within a crisis situation and complex decision-making environment, there is the pernicious effect of mind bias further biasing decisions.

Hammond et al. [7], describe six general mind traps within organizational management context: *Anchoring trap, Status-quo trap, Sunk-cost trap, Confirming-evidence trap, Framing trap, Estimating and forecasting traps*. Finkenstein, Whitehead and Campbell [8], call further attentions for mind traps originated by: *Pattern (mis)-recognition; and Emotional tagging*. In their book, Bazerman and Moore [9] identify 12 biases, which

emanate from three heuristics: *Availability, Representativeness* and *Confirmation.* Moreover, Russo and Schoemaker [10], suggest two additional relevant bias: *Frame blindness,* and *Group failure.* Dawes [11] elaborates on the consequences of framing effects, suggesting that scenario thinking may be of help for decision making improvement as situations get complex.

Cognitive biases can be amplified by 'groupthink', which is understood as the practice of thinking or making decisions as a group, resulting typically in unchallenged and poor-quality decision-making. Once the cognitive biases are combined with 'groupthink', the biases remain uncorrected and there can be disastrous consequences. Considering the OODA loop, cognitive limitations can impact the search ('Observe') and interpretation ('Orient') of data from the real-world situation affecting the decision-making process itself ('Decide'). Table 1 presents some of the main bias that potentially drove maritime related disasters, according to several authors, which are briefly described.

Defining each of the proposed traps:

1. *Social effect* - stick to the existing state of affairs or assuming decisions of a group or relevant people as good choices. By maintaining the *status quo*, one does not take responsibility for a decision;
2. *Memory retrievability* - accept that the events that we memorize are the most frequent or focus on the events that we remember best get more weight in the decision process, ignoring others;
3. *Emotional tagging* - when emotional information conditions the way the situation is analysed, and whether to pay attention to something;
4. *Sunk cost* - making choices in a way that justifies past decisions. Unwillingness, consciously or not, to admit a past mistake;
5. *Confirming evidences* - seek out for confirmatory information that supports an existing instinct or point of view while avoiding information that contradicts it;
6. *Anchoring* - support decisions on initial values or past events, while not giving enough attention to other information or factors;
7. *Frame blindness* - solving the wrong problem because a mental framework for the decision settled with little thought, which causes the overseeing of best options or lose sight of central ideas;
8. *Estimation misconceptions* - taking fast conclusions, based in partial information and without first taking a few minutes to think about the situation. Underestimating external events and the interaction between them;
9. *Overconfidence* - miss to collect key information because we are too sure about the correctness of the made judgments or the ability to keep in mind all the relevant information;
10. *Track failure* - failure to generate an organized approach to understanding the taken decisions and to keep records to track the results and audit the process.

After the analysis several maritime related disasters, most of these traps were at play, together with a few others like the normativity, and deference to authority bias. However, the decision timescales at the situations from where many of the above references are drawn lack the time pressure imposed by some incidents in maritime related operations and environment. Hence, a greater potential for decision making situations and incidents

Table 1. Decision bias synthesis and proposal.

Russo and Schoemaker [9]	Hammond, Keeney and Raiffa [6]	Finkenstein, Whitehead and Campbell [7]	Bazerman and Moore [8]	Authors' proposal
Lack of frame control Group failure	Status-quo			1. Social effect
			Ease of recall Retrievability	2. Memory retrievability
		Emotional tagging		3. Emotional tagging
Fooling yourself about feedback	Sunk-cost		Hindsight and the curse of knowledge	4. Sunk cost
	Confirming-evidence		The confirmation trap	5. Confirming evidences
Short-sighted shortcuts	Anchoring		Anchoring	6. Anchoring
Frame blindness	Framing			7. Frame blindness
Plunging in	Estimating and forecasting	Pattern recognition	Regression to the mean The conjunction fallacy Misconceptions of chance Conjunctive and disjunctive events bias Insensitivity to sample size Insensitivity to base rates	8. Estimation misconceptions
Overconfidence Shooting from the hip			Overconfidence	9. Overconfidence
Not keeping track Failure to audit the decision process				10. Track failure

to have disastrous outcomes. Obviously, it cannot go without saying that decision makers have different risk profiles, which also affect their risk estimation, and risk-taking propensity within structural factors [13].

3 Disaster Analysis

Decision-making in a maritime related environment has more potential for disaster as compared with general non-maritime contexts, as it usually affects human life together with a sensitive environment, within a potentially aggravated VUCA (Volatile, Uncertain, Complex, Ambiguous) context.

Taking into account human cognitive limitations and the concepts of "bounded rationality" [12] of "limited rationality" [13], is it possible to minimise the effect of such mind traps? Indeed, it is possible, by means of awareness of the bias [6], and with a greater team integration within the concept of "cognitive repair" [14]. Água et al. [15] suggest that better training of maritime related professionals with a focus on critical thinking development and accident analysis helps with mind traps, while for organizational repair it needs a deeper organizational learning. Moreover, Dorner, Nixon and Rosen [16] suggest that it is possible to learn how to deal with networked complex dynamic systems, where uncertainty is a given.

As for maritime related accidents over thirty cases where analysed, with a focus on their context of occurrence, consequences, how decisions were made, and the identification of potential mind bias behind the decisions that led to such disastrous consequences. Table 2 provides a sample of the analysed cases.

Table 2. Maritime-related accident and consequences.

Disaster	Year	Geography	Consequence
Vasa Toll Ship	1628	Sweden	Sunken ship; 50 lives lost
Spanish Armada	1588	Off Irish coast	51 Ships sucken; 20.000 lives lost
Titanic	1912	Northern Atlantic	Sunken ship; over 1.500 lives lost
Battle of Midway	1842	Midway Island, North Pacific Ocean	Japan lost four carriers, a cruiser, and 292 aircraft, and suffered 2.500 casualties
Sheffield warship	1982	Falklands	Sunken vessel, 30 lives lost
Herald of Free Enterprise ferry	1987	Belgium	188 people drown
Macondo Well, *BP Deepwater Horizon*	2010	Gulf of Mexico	11 lives lost; Massive environmental disaster
Fukushima Daiichi nuclear power plant	2011	Fukushima, Japan	Over 15.000 radiation related deaths. Scientists predict 30.000–60.000
Costa Concordia	2012	West coast of Italy, Tyrrhenian Sea	Sunken ship; over 32 lives lost
Sewol sinking	2014	South Korean waters	Sunken ship; 304 lives lost

From the analyses done, it became evident the severity of the consequences of maritime related accidents, both in terms of human lives, environmental impact and economic and asset losses.

4   Results

This section presents some analysis results regarding the main mind bias at play at the maritime-related disasters where they happened. Such identification and classification help point out where to focus learning towards solution finding. Distinct mind biases were at play; however, there are some most common.

The mind biases that seem to be most common are *overconfidence* and e*stimation misconceptions*. Even if both are related, such biases have been detected in several cases, as listed in Table 3.

By studying and analysing these biases it is possible, by several processes, ranging from generic problem-solving methodologies up to systems thinking and system dynamics, to engineer solutions and "layers of protection" to prevent human factor related disasters. Some best practices, ranging from bridge cards to IMO recommended procedures fall under such category.

Table 3. Mind bias at play in several accidents.

Disaster	Bias	Obs.
Vasa Toll Ship	(1) (9)	Frequent requirements change; King ordering directly; Following the status-quo on what naval shipbuilding was concerned
Spanish Armada	(8) (9)	The 'invincibility' image of such a powerful fleet of 130 warships drove leaders to underestimate fleet weaknesses
Titanic	(8) (9)	Overconfidence on a brand-new ship of such dimensions might have been behind the perception of unsinkability
Battle of Midway	(8)	After the Pearl Harbour attack, the Japanese overconfidence drove them into believing they could easily defeat US
Sheffield warship	(7)	Overfocus on a submarine attack. Low flying missile perceived as a torpedo close to water surface
Herald of Free Enterprise ferry	(8)	The outcome of a chain of events leading to an unwanted consequence. Social effect
Macondo Well, BP *Deepwater Horizon*	(1) (8)	Group confirmation bias emphasises that "everyone knows drilling is safe"
Fukushima Daiichi nuclear power plant	(1)	Hierarchical culture in Japan, where ranking bypasses knowledge and experience
Costa Concordia	(1) (4) (9)	Disbelief and overconfidence obscured reality. Normalcy bias and distraction on the bridge reduced the opportunities for timely and efficient muster and departure
Sewol sinking	(5)	The evidence of risks (e.g., warning signs and signals prior to the accident) became invisible to people so that safety margins eroded over time

5 Conclusions

Investigation demonstrated that several maritime disasters could be avoided, had some cognitive bias been prevented. It is possible to minimize the occurrence of disastrous outcomes, by means of redesigning the chances of mind bias taking place during critical decision-making situations in maritime context, where time pressure and stakes are high. Such calls for the need to re-educate the professionals that act in such environments, together with some organizational re-engineering in order to compensate, detect and prevent the effects of mind bias and cognitive limitations in the first place, by means of "cognitive repair". Moreover, a turn from a person-centred perspective, focusing on single events and human errors, to a system-centred perspective helps to develop understanding of the causes behind accidents, and to effectively introduce proactive safety measures. Accidents at sea can be burdensome severely affecting assets, the environment and ultimately human lives [17]. Only by identifying past mistakes through learning processes at individual and organizational levels is it possible to avoid or minimize the consequences of future ones.

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Preliminary Evaluation of Multi-criteria Decision-Making Methodology for Emergency Management

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Abstract. Decision-making related to emergencies and disasters is a daunting process given the dynamic and complex nature of such events, the wide range of factors to manage, and the large amount of information to consider. To address the challenge, the long-term goals of this work advocate for the use of an adaptive intelligent system to assist with these complex decision tasks. This paper provides background for MCDM methods and their uses and develops and proposes a taxonomy of eleven questions for use in selecting MCDM methods within complex decision-making environments such as emergency management.

Keywords: Multi-criteria decision-making · Dynamic multi-criteria decision-making · Complex decision making · Emergency management

1 Introduction

Decision-making is defined as the process of making choices; it is an inevitable and frequently critical component of daily activities [1]. The act of making a decision often consists of several steps: identifying problems, eliciting preferences, evaluating alternatives, and determining the best alternative [2, 3]. At a high-level of abstraction, decision-making can be divided into two realms: rational versus intuitive (naturalistic). With rational decision-making, the decision maker is assumed to operate with perfect information and without time constraints, choosing an alternative that maximizes an expected outcome. On the other hand, with naturalistic decision-making, the decision maker is relying on experience to make a decision where the decision space is uncertain, ill-defined, high-consequence, and time constrained [4].

Decision-making occurs in noncomplex situations, such as deciding whether to go to a certain restaurant, which flight to book, and what item to purchase on e-commerce [5]. In complex situations, such as determining which problem to handle first in disastrous emergencies, the characteristics of naturalistic decision-making render the process more challenging. Decisions are made from the judgement of various [6] that will lead to a solution or a decision over other alternative solutions or decisions; sometimes the criteria can change over time.

Emergencies and disaster relief require the strategic planning and response of emergency management to be able to achieve the goal of reducing disastrous effects of all kinds of hazards, including those caused by humans, natural disasters, or disease outbreaks. Such situations require making decisions related to a wide range of factors. The decisions are extremely difficult due to the dynamic and complex nature of these events, as well as the large amount of information that must be considered.

Emergency management can be defined as the "organized analysis, planning, decision-making, and assignment of available resources to mitigate (lessen the effect of or prevent), prepare for, respond to, and recover from the effects" of emergencies [7]. This definition hinges on the consideration of four distinct phases involved in emergency management: (1) mitigation, (2) preparation, (3) response, and (4) recovery. In this work, the primary focus is on actions involved in the *response* phase. These actions are typically the most complex in terms of uncertainty, timeliness, and risk. Activities involved in responding to an emergency situation "include applying intelligence and other information to lessen the effects or consequences of an incident [8]. Thus, the response phase within emergency management presents a most challenging environment for the application of complex decision-making.

Decisions within emergency management require accuracy, timeliness, and adaptability. Intelligent systems can aid in information processing and decision-making within the four stages of emergency management would not only benefit current emergencies or disasters at hand, but for future ones as well. This paper is focused on the use of Multi-Criteria Decision-Making (MCDM) methods in complex environments. This work presents the need for, and advocacy of, the use of an adaptive intelligent system to aid with the complex decision tasks associated with emergency management.

2 Background

The task of making decisions for real-world problems is already complex, but that level of complexity rises exponentially when the situation involves uncertainty, timeliness, and risk [9]. The more criteria that exist for alternatives to consider, the more complex the problem becomes [6]. Information can be presented and described in different ways with different ranges, such as quantitative and qualitative. The severity of consequence that follows a decision, correct or incorrect, can affect the complexity of the situation. Another aspect that adds to the complexity is the fact that these problems are seldom static; they often have dynamic attributes that lead to the consideration of changing alternatives or criteria. The major characteristics that contribute to complexity include timeliness, number of criteria and alternatives, uncertainty and risk, computation requirements, information input type, severity of consequences, and the presence of dynamic attributes.

Examples of dynamic, complex environments include the fields of disaster relief and evacuation planning [10] as well as emergency management and response [11, 12]. To address challenges faced in the decision-making process in such environments, MCDM has been introduced because of its strength in decision-making in complex domains [6, 13].

3 Multi-criteria Decision-Making (MCDM)

Since as early as the 1950s [13], MCDM (also referred to as Multi-Criteria Decision Analysis [MCDA]) methods have been an invaluable tool in the decision-making process, especially in complex and uncertain environments. MCDM models prescribe a way of evaluating, prioritizing, and selecting the most favorable alternative from a set of available ones that are characterized by multiple, usually conflicting, levels of achievement for a set of attributes [14–16].

MCDM in general is focused on applying a suitable method depending on the decision problem and then determining a final recommendation or selection [2, 17–20].

The MCDM process is described by eight steps in [21]:

1. State/define the problem domain	5. Choose the MCDM method
2. Elicit the criteria	6. Evaluate the MCDM method
3. Screen the alternatives	7. Apply selected methodology
4. Define eval. criteria preferences	8. Evaluate the results

Numerous methods have been derived and evolved to accommodate various types of situations and applications [22]. Additionally, there are techniques that can be used to consider problems with quantitative and qualitative factors involved [13]. When uncertainty exists, many methods benefit by also applying fuzzy set theory to its algorithm [23].

As a way to capture dynamicity, the standard MCDM method has been expanded upon into Dynamic MCDM (DMCDM). DMCDM is the same as standard MCDM, but it can adapt to different situations. A "retention policy" is used for historic data/alternatives, an aggregation functions is employed to compute final score/rank using the historic and current data, and it has a "stopping" criteria [14, 15, 24, 25].

When it comes to selecting an MCDM method to consider and implement, there is not a single method that one could use and follow step-by-step to solve every problem [13]. Not all problems or situations are the same and may require different computations. In fact, there are many MCDM methods in the field, and it can be difficult to determine what method would be the best method to implement [6]. Growing in popularity is the process of combining two or more MCDM methods as a way to optimize the strengths of particular methods and make up for any shortcomings, creating a "hybrid" method [22].

MCDM can be divided into two categories: Multi-Attribute Decision-Making (MADM) or Multi-Objective Decision-Making (MODM) [13, 21, 26, 27]. MADM is used to help decision makers assess and compare a finite number of alternatives, with limited, generally conflicting criteria [21, 28]. Example MADM methods include Weighted Sum Model (WSM), Analytical Hierarchy Process (AHP), Technique for Order Preferences by Similarity to Ideal Solutions (TOPSIS), Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE), Elimination Et Choix Traduisant la REalité (ELECTRE), VlseKriterijumska Optimizacija I Kompromisno Resenje (VIKOR), and Reference Ideal Method (RIM). MODM is focused on the optimization of the multiple objectives of the decision maker, and choices that are composed of continuous criteria are generally infinite or very large. Some examples of MODM

are neural networks, goal programming, and genetic algorithms. As described in [28], MADM is more of a "selection process" and MODM a more "design-like" algorithm. Note that in this work, we are concerned with the MADM category of MCDM methods focused on complex decision-making.

Some of the more notable MCDM applications include: the use of DMCDM for collaborative scheduling in a temporal and dynamic manufacturing environment [25]; a safe route planner that made some improvements relative to Google maps [29]; a system for military logistics decision-making [30]; a framework to select among MCDM methods in applications involving risk and uncertainty [31]; a hybrid MCDM approach comprised of four methods to mitigate disasters by optimizing safety [9]; a route evaluation system for selecting the optimal evacuation route [10]; and numerous others.

4   Discussion

The literature review focusing on the application of MCDM methods in complex environments made it clear that many different methods can be used, depending on the situation at hand. It can be difficult to differentiate which method is more suitable than the other when it comes to handling complex situations. All of the methods have advantages and disadvantages.

Important questions that need to be asked in any research utilizing MCDM are which MCDM method to select and how to make that selection. Various researchers [31–41] have analyzed characteristics and questions that can aid in the MCDM selection process.

While there are various frameworks, tools, and characteristics proposed in the literature regarding selection among the MCDM methods for a given problem, there is nothing focused strictly on the domain of decision-making in complex environments (such as emergency management). A main goal and contribution of this work so far is a proposed taxonomy of 11 questions to consider when selecting an MCDM method for a decision-making problem in complex environments (see Fig. 1). The taxonomy framework combines and extends ideas from by [35, 38–41]; it also incorporates selection questions and characteristics of complexity described throughout the literature. The taxonomy provides an architecture that represents and integrates the relative advantages and disadvantages of each MCDM method. The taxonomy considers the seven MADM MCDM methods highlighted in Sect. 3.

The 11 selection questions used in the taxonomy (Fig. 1) are as follows:

1.   What type of method is of interest?
2.   Can the method calculate criteria weight?
3.   What type of criteria preference types are supported?
4.   Into what type of measurement scale are the criteria input?
5.   Can the method handle uncertainty?
6.   Is there software support for the method?
7.   How easy is the method to use?
8.   What is the processing time/computation power required for the method?

9. How many criteria and alternatives need to be considered in the problem for the method to work best?
10. What is the type of output results?
11. Does the method allow for sensitivity analysis to evaluate for robustness?
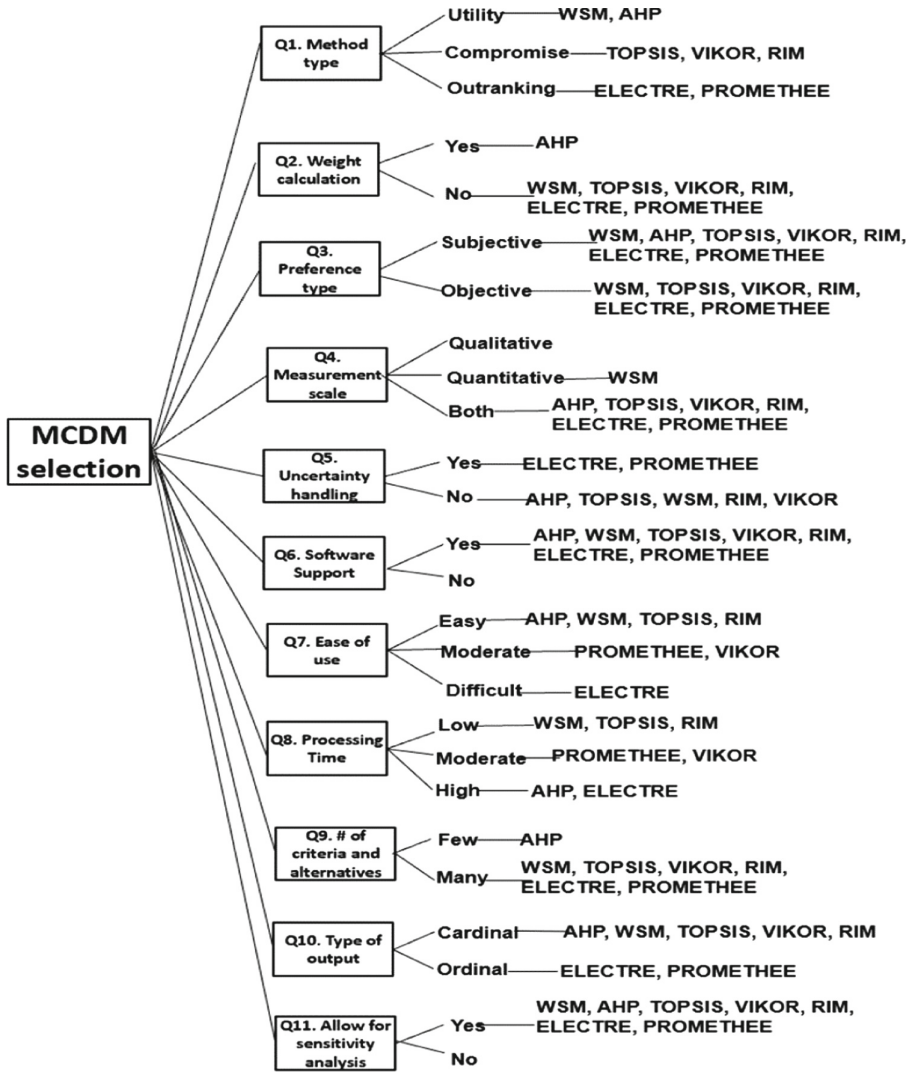
Fig. 1. MDCM question taxonomy

5 Conclusion

Decision-making, especially in complex environments such as emergency management, is an extremely daunting task due to multifaceted characteristics that define the problem. MCDM can be used as a decision aid to help evaluate, prioritize, and select favorable alternatives that are characterized by often conflicting criteria. This work surveyed applications of MCDM in complex environments, and reported on seven commonly used methods (WSM, AHP, TOPSIS, VIKOR, ELECTRE, PROMETHEE, and RIM). The literature made it apparent that there are many suitable methods for complex environments and selecting one can be challenging. To address this challenge, an MCDM taxonomy of 11 questions is proposed to help with the MCDM selection process in considerations to complex environments.

An approach for future research will be to evaluate the effectiveness of this taxonomy and the practical use of MCDM methods in complex and dynamic environments is offered. We propose evaluating the complex decision of identifying the most vulnerable areas in emergency situations with MCDM methods using the CDC Social Vulnerability Index (CDC SVI) open-source dataset. The CDC SVI data uses 15 U.S. census variables that can be categorized into four theme categories: socioeconomic status, household composition, race/ethnicity/language, and housing/transportation [42–44]. These variables will be used as criteria in the MCDM calculations when evaluating alternatives based on vulnerability. The results of this research will lead towards the future development of an adaptive intelligent system that will be able to aid in complex and dynamic environments.

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Linked Open Data Supporting Semantic Integration and Collaboration in Disaster Management Cycle

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Abstract. An increasing number of multiple types of disasters challenge the current role of Disaster Management (DM) support systems regarding the interventions at the different phases of the DM cycle. Disaster Management is known for the heterogeneity of domain's concepts, the kind of resources deployed for disaster response, and the complexity of the information shared among the several organizations participating in a catastrophe scenario. The goal of this work is to envision what seems to be the next evolution of DM support systems towards a better decision-making support along the disasters' management cycle, specifically, concerning the integration of the several available distributed data sources using ontologies and Linked Open Data as tools.

Keywords: Linked data · Disaster Management · Knowledge representation · Domain ontology

1 Introduction

An increasing number of natural and anthropogenic disasters facing the world population have challenged disaster relief organizations, contributing to highlight the importance of Disaster Management (DM) support systems. In fact, the gaps and opportunities related with exploiting IT tools in support of DM have been thoroughly addressed in literature (e.g., [1, 2]). It is often pointed that DM success largely depends on successfully collecting, integrating and processing information regarding disaster incidents, to make better decisions, for example, regarding the prioritization of lines of action and the allocation of resources. Due to the complexity of decision-making in disaster situations intelligent decision-support systems are of utmost importance, particularly when conducting disaster response operations. The information required by such systems encompasses both elicited knowledge regarding the domain and the specific context, and raw data from historical and current operational actions. This information is critical to effectively support the collaboration and cooperation of disaster response teams that converge to an affected area coming from different origins (countries, languages, and cultures), with the aim of providing humanitarian assistance to the affected population. Preferably, the different response entities must effective and efficiently share information regarding incidents. To achieve the interoperability among their distributed systems they must be

able to communicate and use a kind of *lingua franca* of the domain. Therefore, a formal representation of incidents and response assets and actions is useful ensuring that data will be structured in a meaningful way, fit for DM purposes, and even suited to machine processing.

Considering the interagency nature of entities involved in a disaster response effort and the complexity of the decision-making processes, this work proposes an architecture for DM support systems that could provide functionalities such as, the elicitation, coding, and representation of the domain knowledge, the storage of semantic data from multiple sources and formats, as well as the treatment and retrieval of information according to suitable methods and algorithms. As methods for semantic data representation and storage, Ontologies and Linked Open Data (LOD), offer a basis for the semantic integration of the decision support processes applied to DM, specifically supporting the activities of the teams that cooperate in disaster response operations.

The remainder of this article is organized as follows: the next section provides the background of the processes and functionalities expected to be supported by DM support systems. Section 3 overviews the main advances made on ontologies for supporting disaster management, as well as the potential of a platform for sharing data through the web. Section 4 envisions what could be the next architecture of disaster management support systems. The last section offers some conclusions regarding this work.

2 Background

The scope and objectives of the information systems for managing disasters and coordinating activities is contingent on the phases (mitigation, preparation, response, and recovery) of the DM cycle they are meant for. More than one hundred Commercial off-the-shelf (COTS) [3], open source [4], and academic [5, 6] solutions are proposed, aimed at the creation and sharing of a common understanding of the DM phases [7].

The *mitigation phase* requires functionalities that include: (i) gathering relevant information that would be used for risk assessment and for setting strategies to prevent disasters and/or mitigate their effects, through repositories supported by knowledgebases, databases, Geographical Information Systems (GIS), mobile and web-based apps, which store risk reduction and response plans, current and historical data (e.g. weather, river floods) and maps; (ii) disaster risk assessment and management tools, including vulnerability analysis models, policies definition, which encompass data analysis methods (e.g. machine learning and decision analysis) and intelligent systems aimed at increasing resilience through disaster risk reduction.

The *preparation phase* requires a wide range of functionalities from a disaster management system, including the development, availability and/or implementation of: (i) knowledge/databases containing information related to vulnerabilities and response plans, available resources (local, national, regional, and global), skills and contacts of trained personnel, inventory of hazardous materials, etc.; (ii) mobile devices with GPS and build-in cameras, for collecting, updating, and publishing real-time multimedia geo-located data, as well as GIS for advanced spatial analysis, enhancing the decision making process; (iii) monitoring and warning systems, supporting human decision through a network of sensors (land, sea, air, space) feeding complex predictive models based

on simulation and physical models which provide an advanced alert for specific kind of disasters (e.g. tsunami, hurricane, volcano eruption); (iv) training applications, ranging from live simulations to constructive simulations involving synthetic environments (e.g. virtual reality and augmented reality) for generating realistic exercise scenarios (field or tabletop) and collecting data for training and evaluation purposes, risk assessment; (v) Command & Control (C2) tools and infrastructures offering a Common Operating Picture (COP) and situational awareness which allows an effective decision making and resource management through user-friendly interaction interfaces (e.g., dashboards with real-time visualization of key performance indicators); (vi) modeling and simulation (M&S) module to answer "what-if" questions about the real systems and investigate the consequences of complex and uncertain phenomena (e.g. outbreak dissemination, evacuation modeling, fire propagation, flooded area); (vi) intelligent systems, with suitable human computer interfaces, supported by artificial intelligence (e.g., machine learning, data mining algorithms), and multicriteria techniques for analyzing data, and automatic advise on actions to tackle complex scenarios.

The *response phase* requires the extension of the abovementioned C2 functionalities providing communication and information sharing among disaster managers from different origins, supporting the cooperation and coordination of multiple teams engaged on the disaster response operation. These requirements go far beyond the day-to-day needs of interoperability among the local emergency response agencies and can be enabled by technologies such as XML and web services.

The *recovery phase* is a longer lasting continuation of the response phase, presenting many of the requirements of the previous phase; usually engaging a different set of actors and operating conditions. The information recorded during the disaster response operation provides valuable feedback regarding, for instance, the incidents and victims identified, the resources engaged, the actions taken, allowing an assessment of the *dos and don'ts* which support the gathering of lessons learned, which will allow new iterations of the DM cycle feeding the *mitigation* and *preparedness* phases, and contributing to better disaster response operations.

However, a common criticism is that disaster response organizations operate in "silos" due to the lack of interoperability and integration of the proprietary systems used. Even when the internet protocols are used to enable exchange of information among C2 systems, often the solution only addresses the network specificities and not the semantics of domain data. In spite of efforts, such as the one promoted by the OASIS consortium, promoting the EDXL-DE [8] to increase interoperability and openness of data in disasters response, the proposal seems to be simplistic and short in providing semantic interoperability among disaster management systems [6].

The key to overcome this problem could rely on ontologies. Ontologies describe what data means and the properties to be used to characterize and link them. This gives the data a strong, but flexible foundation for interoperability, that can be adapted as the data set grows and the requirements evolve. Therefore, the silos' trap could be tackled with solutions based on ontologies that could provide semantically rigorous specifications, amenable of integrating heterogeneous applications and systems in an unambiguous way.

3   Related Work

The domain of disaster management is known for the heterogeneity of the used means and terminology. There are distinct terms for entities relevant for DM, specifically: names, objects, processes, sensors, systems, applications, data, organizations, and even languages. Given the complexity of DM, ontologies can provide a framework in which categories and relationships among the concepts can emerge [9].

Several proposals were suggested for dealing with disaster management, situational awareness and situation theory. Among them one can refer the O3SERS [10], AOUCKP [11], CONON [12], SOUPA [13], SO [14], SAWA [15], STO [16], and SC [17]. However, many of this ontologies were typically developed in an *ad-hoc* manner and lack expressiveness for supporting relevant properties - such as mereological, causal, and correlation relationships -, and have different representations and interpretations for the same concepts [6]. Hence, they fall short of benefiting from the formal semantics already defined in foundational ontologies (aka upper ontologies), such as DOLCE [18], SUMO [19, 20], BFO [21, 22], PROTON [23], OpenCyc [24], GFO [25], and Sowa Ontology [26]. Moreover, some of them do not follow a pattern-oriented approach that would allow them to structure the complex problem of a certain model into smaller, reusable units, which is the design basis for a sound architecture.

For the sake of attaining strong bedrocks, every proposed ontology must be aligned with foundational ontologies, which provide a high-level and abstract vocabulary of concepts and relations that are amenable to be extended for several knowledge domains. Besides formal definitions of world's fundamental concepts, a foundational ontology, also provides axioms that can be used and extended. A precise alignment of concepts defined in an ontology with the high-level concepts of a foundational ontology, would also allow, if required, the future extension of the derived ontology. That is why more sound disaster management ontologies rely its formal bases in foundational ontologies, such as DOLCE [18] or SUMO [19, 20]. This is an effective choice since those ontologies have already proved to provide a good design and modeling approach for different core ontologies [6]. However, the use of different foundational ontologies for the different disaster management ontologies also brings problems of overlap and redundancies among proposed ontologies, if not inconsistencies and even ontological classification errors.

With the forthcoming of the ISO/IEC 21838 [27], based on the experience of BFO [21, 22], it is expected that this upper ontology, may become the referential hat of other mid-level ontologies. These, on the other hand, could coherently be extended by domain ontologies, ensuring the ontological architecture semantic alignment. This were the steps previously followed by the Gene Ontology (GO) [28], built upon the upper ontology of Basic Formal Ontology (BFO) [21, 22].

Ontologies are also viewed as a major contribution for applications' integration, while underpinning the Linked Open Data (LOD) cloud [29], an infrastructure which lets data be linked from different sources. The LOD refers to a set of best practices for publishing and connecting structured data on the Web. These best practices have been adopted by an increasing number of data providers, leading to the creation of a global data space containing a huge number of assertions. The adoption of the LOD best practices has led to the extension of the traditional Web to a Web of Data, a space

connecting global data from diverse domains such as people, organizations, geographical information, weather reports and forecasts, geological data, online communities, social networks, news from television, radio and newspapers, statistical and scientific data.

The LOD enables new types of applications in several domains, specifically in disaster management. New applications allow users to browse information starting from a data source and then navigate along links into related data sources providing expressive query capabilities over data, similar to the on-premises databases ones, fostering completer answers as new data sources appear on the LOD.

4   Linked Open Data in Disaster Management

The main goal of disaster management support systems is the improvement of situational awareness through an as clear as possible perception of the environment; improved understanding of the meaning of the most relevant elements; enhanced foresight about their status in chosen areas in future time, and understanding how decisions may impact goals. A clear situation awareness may be provided through a well-defined COP. The COP provides a unique and combined representation of relevant information, and a framework in which a collaborative planning can take place. Although providing a unified view of a situation, the COP should also enable different perspectives on it, depending on an actor's role, a merely data entry user, a member of a search and rescue team, a logistical manager, a medical staff member or a C2 coordinator/disaster manager. For each of these actors an optimized user interface should be provided to ensure the usability of this holistic DM support system.

One can expect that the future generation of DM support systems (Fig. 1), besides relying on daily activities operational data and resources management, will be deeply based on information provided by large and diverse collections of sensors as well as data provided by communities of volunteers made available at LOD. For instance, although geospatial information has been created traditionally by government agencies and commercial companies, the widespread availability of smartphones with GPS and cameras, and apps enabling fine-resolution satellite imagery and maps, has allowed volunteers to collect and compile accurate geospatial data to be integrated and disseminated through social media, Web blogs, and the Open Street Map (OSM), enabling applications which make them available to the LOD. The degree of trustfulness of such crowdsourced data should be evaluated and criteria defined to ensure data reliability, namely when faced with time-critical events where other factors should also be considered, such as spatial-temporal proximity, domain knowledge, skills, prior experience of the source agent regarding the reported situation.

Furthermore, during disaster mitigation and preparedness phases, identification and collection of data regarding vulnerable places as well as assets, including population and infrastructure facilities, plays an important role. Early identification and digital transformation of data of such vulnerable infrastructures requires complex activities from governmental organizations involving diversified and heterogeneous data sources, many of them paper based. Hence, a well-developed information gathering system including population densities, geographical areas and disaster historical data should be made available in preparing for disaster occurrences and their consequences. The gathered data

should be related to repositories - such as the DBPedia, WordNet, LinkedGeoData, or Geonames - in the LOD cloud to increase the data relations and generate more information. Evacuation routes can be modeled and inserted at OSM. Data from monitorization or alerts regarding earthquakes' or volcanos' activities (e.g., epicenter/location point, depth, intensity, date/time), in vulnerable regions, should be extracted and updated from time to time in the LOD. Weather data forecasting destructive forces such as heavy wind and rain, or storms and hurricanes at the observed stations with date and time from forecast stations can also be uploaded via the LOD Application Programming Interface (API).
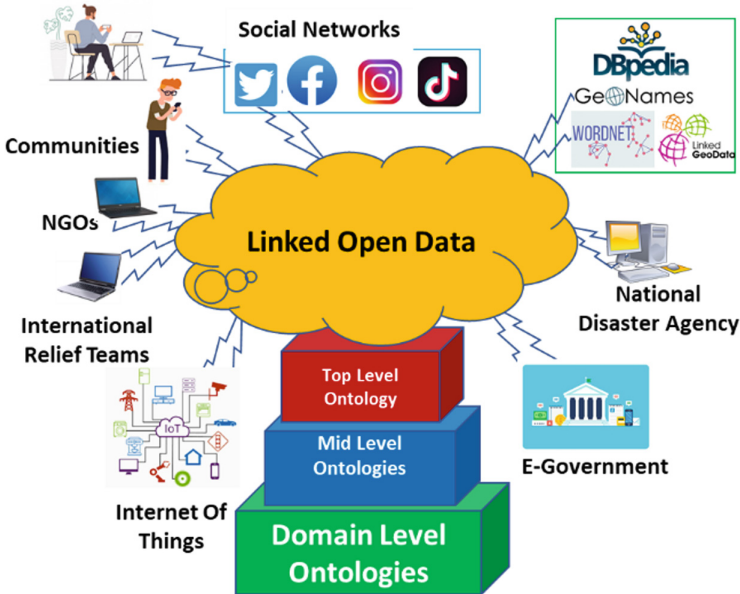
Fig. 1. The architecture for collaborative disaster management support systems

Data lying on different data silos should be shared and interlinked with other related sources. Such sharing is essential for efficient management of disaster events. Consequently there is a need, to extend DM solutions in order to step out of their silos and respond to the challenge of data integration, so that the COP can effectively provide a truly unified view [9]. The Web of Data is a way to break old silos and link everyone and everything and make data and services potentially smarter. LOD provides a bridge to enhance the potential of using disaster data gathered by different organizations and individuals using disaster management systems or any other mechanism in distinct application. Linked data browsers allow users to navigate between different data sources via Resource Description Framework (RDF) links. Therefore, DM users can initiate their data transverse in one data source and then be in motion through a potentially endless Web of Data consisting of RDF triples. So, in this way not only humans but machines or computers can also utilize the information which is shared as LOD [30].

Acknowledging the increasing importance of the LOD's role for disaster manage-ment allows the envisioning of a future DM support systems architecture, as depicted in Fig. 1. However, for an effective data collection automation and coordination of data sources in time-critical situations, the architecture should be grounded by ontologies. The ontologies will also play a role in the integration between human-sourced and arti-ficial sensor-sourced information. A top-level ontology (e.g. ISO/IEC 21838 [27]), will support several mid-level ontologies (e.g. IAO [31]) that in turn, will support the domain DM specific ontologies (e.g. POLARISC [32]).

5   Conclusion

This paper proposes an architecture for disaster management intelligent support systems, meant to support the collaboration of agencies engaged in disaster relief operations, con-tributing to improve interoperability, information sharing and shared situational aware-ness; thus, to a more effective and efficient decision-making in the context of complex disaster situations.

The proposed system's infrastructure relies on an integrated hierarchy of ontologies, which formally conceptualize the domain's terms and establishes relationships among those concepts. Ontologies are also viewed as a major contribution for applications' integration, while underpinning the Linked Open Data cloud, an infrastructure which allows the linking of data from different sources, related with disaster management.

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Human Factors Impact in the Security and Safety of the Maritime Domain

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Abstract. The maritime industry is affected by security and safety problems. Human factors (HF) are recognized as an important root-cause of such problems, which often result in complex crisis – e.g., technological disasters, humanitarian disasters, piracy/terrorism, cyber-attacks –, which require a comprehensive approach, and operations conducted by multiple agencies that combine competencies, frequently at international level. The efficiency and effectiveness of the response to crises depend on the level of preparedness of the agencies involved, both at individual and at joint levels. Preparedness is particularly important for managing offshore maritime crises, since the environment is adverse, access to resources is limited, and tolerance to errors is small. The paper addresses HF factors affecting the maritime industry and provides examples of initiatives and best practices that mitigate the threats and negative impacts to security and safety in this industry.

Keywords: Crises management · Preparedness · Maritime industry · Best practices

1 Introduction

According to UN Conference on Trade and Development [1], over 80% of global merchandise trade by volume and more than 70% of its value is carried by the international shipping industry. Therefore, it is understandable the relationship between the world macroeconomic environment and the demand for seaborne transport of crude oil, petroleum products and dry cargo transported, identified by Michail [2] while addressing the world economic growth and seaborne trade volume relationship. This highlights the global importance of the maritime industry and justifies the creation and strengthening of agencies like EMSA and FRONTEX at European Level, the first focused on maritime safety and the second encompassing security issues.

Shipping, oil rigs and ports are elements of the maritime industry affected by security and safety problems [3–7], and it is commonly recognized that HF play an important role as root causes underneath such problems. Literature has addressed the issue, for instance, in [3, 7–12]. Another example of the analysis of the role of HF in safety is the Dirty Dozen concept, introduced by Gordon Dupon (which refers to twelve of the

most common human error preconditions, or conditions that can act as precursors, to accidents or incidents) that was adapted to the maritime context [13].

Often the mentioned safety and security problems result in complex crisis – e.g., technological disasters (Deepwater Horizon, Costa Concordia), humanitarian disasters (Mediterranean migration), piracy/terrorism (Aquile Lauro, Gulf of Guinea, Horn of Africa), cyber-attacks (Maersk) –, which require a comprehensive approach, and operations conducted by multiple agencies that combine their areas of competence, frequently in international operations. The effectiveness and efficiency of the response to crises depend on the level of preparedness of the agencies involved, both at individual level (e.g., skills, materiel) and at joint level (e.g., organization, communications, interoperability, training, trust). Preparedness is key in all crises management situations, but is particularly important for managing offshore maritime crises, since the environment is often adverse, the access to additional resources is very limited, and the tolerance to errors is quite small. Another issue that adds complexity in the handling of maritime crises is the high number of agencies (national and international) that need to cooperate due to the large network of skills, capabilities and competencies that are required to deal with the situations.

The purpose of this paper is, based on literature and own experience, to address HF factors affecting the maritime industry and provide examples of initiatives and best practices (e.g., education, training, doctrine, concept development and experimentation, information sharing, intelligent systems) that contribute for the preparedness of crises management actors (both decision-makers and responders) and to mitigate the threats and negative impacts to security and safety in this industry.

2 Background

The Maritime domain is one of the Global Commons, meaning that it can be jointly used by the entire humankind, involving many facets that are beyond national jurisdiction. Therefore, the Maritime space, rather than being a barrier, constitutes a bridge connecting all continents, their people, cultures, and economies. Since ancient times, and particularly since the launching of the Discoveries enterprise, by Prince Henry, the Navigator, in the XV Century, the Sea was the media that supported the first Globalization movement. The Maritime domain offers undeniable opportunities for trade, contributing to the wellbeing of mankind; however, it also creates many challenges and threats. Aware of this reality, international community has made efforts along history to rule and regulate the maritime activity. Nowadays, the International Maritime Organization (IMO) is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine and atmospheric pollution by ships, accounting 174 Member States and 50 Conventions and Protocols. Besides this Global agency, regional agencies have corresponding responsibilities and goals.

The list of Maritime Industry stakeholders is hard to enumerate, encompassing, at least, Crews & shoreside employees, Unions, Ship owners & operators, Maritime sector associations, Ship builders & shipyards, Ports, Classification societies, Suppliers, Investors, banks & insurers, International organizations & agencies, Governments & regulators, Security & safety agencies, Costumers, Local communities, NGOs, Academia, Public and Media.

Such stakeholders play different roles (e.g., execution, decision-making, influencing, fruition, benefiting), with distinct impacts in the Maritime Domain security and safety. Particularly the first two roles identified (i.e., execution and decision-making) are directly involved in the core of the Maritime Industry activity; therefore, being more exposed to the situations that may result in incidents, accidents and in disasters.

The investigation of accidents identified a variety of root-causes associated, for instance, with lack of procedures or non-compliance with procedures, inadequate ship and systems requirements or design, lack of situational awareness and risk assessment, wrong decisions and groupthink phenomena, poor safety culture, as well as other human (e.g., physical, psychosocial), organizational and regulatory factors.

International bodies, such as IMO or the European Commission (EC), play a significant role on influencing the Industry. For instance, associated with the European Union Maritime Security Strategy (EUMSS) [4] the EU issued a guide for stakeholders, where five key areas for immediate action were identified; the last being 'Maritime security research and innovation, education and training', which points that: "(i) Research and innovation can help reduce situations leading to conflicts and maritime crime; and (ii) Common training modules and joint operations improve the knowledge and skills of maritime security professionals, as does capacity building in partner countries."

In fact, Academia, Maritime Agencies and Associations are playing their part in trying to extract knowledge from such situations in order to: (i) bring light on ways to solve or, at least, mitigate the security and safety risks, reducing the factors that contribute to their occurrence, as well as their impacts, should they occur; (ii) be better prepared to avoid risks and to respond in case of security and safety events; and (iii) address the security and safety problems in an effective and efficient way, particularly when they require a robust interagency and/or international response. Research, such as the one conducted by Berg [3], Galieriková [8], Grech [10], Kristiansen [11] or Widdowson and Carr [12] addressed these problems from a HF perspective. In the same lines, Água et al. [14] analyzed and discussed some mental traps behind maritime disasters. Simões-Marques and Figueira [15] discussed the challenges facing decision-makers in complex contexts and the need for intelligent decision-support systems that help surpassing such challenges. Simões-Marques [16] discussed some of the gaps and opportunities affecting disaster management, which, in fact, are common to many other decision-making situations (e.g., situational awareness, information sharing, collaborative technologies).

There are many ways of raising awareness for the security and safety problems affecting the Maritime Industry, and supporting the critical analysis of a specific situation by stakeholders. An example is UK Maritime and Coastguard Agency's *Human Element Guidance* series. A series' publication, issued in December 2016, notes that most maritime accidents, incidents and errors result from a combination of many different contributory factors ranging from purely technical failures to environmental, systemic, procedural, competence and behavioral factors [13]; and provides a summary of twelve of the most common people related factors (the *Deadly Dozen*) along with tips which, if managed effectively have the potential to avoid and avert accidents, improving maritime safety. Table 1 lists and characterizes the *Deadly Dozen*, which as referred in [13] provides a useful and pragmatic introduction to understanding aspects of human error in

organizations and workplaces, encouraging the direct stakeholders to become familiar with its principles and practices.

Table 1. Significant HF affecting Maritime Safety - Deadly Dozen (adapted from [13]).

Factor	Description	Causes
Situational awareness	Understanding what is really happening and assess its impact now and in the future	Lack of up-to-date information; situation changing too quickly to be understood; new and novel problems that are not understood; insufficient capability and experience of those involved; distraction (e.g., paperwork, interruptions); complacency; fatigue
Alerting	Bringing concerns about actions, situations or behavior to the attention of others in a timely, positive and effective way	Distractions and slips of memory; exceptionally high or low workload
Communication	Transmitting and receiving full and correct information ensuring sender and receiver share the same understanding	• language – different mother tongues • words and phrases can have subtly different meanings in other languages • words make up only 30% of communication, tone, body language, gestures make up the rest • body language and gestures can have different meanings to different nationalities and cultures • colloquialisms, slang, humour, etc. May not be understood by all, and may even be rude or offensive to other cultures • acceptable behavior in some cultures may be embarrassing, rude or offensive in others (e.g., challenging senior colleagues) • people have different language skill levels • people tend to revert to their mother tongue in times of stress or emergency
Complacency	A misplaced feeling of confidence that everything is OK	• the same work has been repeated satisfactorily many times in the past without incidents • the operator has insufficient experience or knowledge to recognize when a situation has changed • poor briefing before taking up duty • forgetting something • inadequate monitoring/checking of the situation • poor teamwork, alerting, communications • fatigue

Table 1. (*continued*)

Factor	Description	Causes
Culture	The blend of understanding, beliefs and attitudes of people and organizations that result in behavior and actions	• personal culture – everybody has their own personal beliefs and attitudes • national culture – cultural norms in different parts of the world. Different 'cultural lenses' • company culture – the beliefs, attitudes and behaviors that are prevalent within a company, which may be different to other companies • professional culture – beliefs, attitudes and behaviors that may be common to professional mariners and acquired during training
Local practices	Behavior and actions applied locally that differ from the official documented practices. Also known as procedural violations	• official procedures and practices are not clear, or difficult to follow or do not work • specified equipment is not available • training is not effective, people may think they are doing it correctly • ineffective supervision and monitoring • the safety culture is not effective or there is a carefree attitude • insufficient people, tools or time to carry out the procedures as expected • shortcuts are more convenient or satisfying • people don't fully understand the risk of their actions
Teamwork	Working together effectively towards a shared common goal	Behaviors, skills and knowledge of ship's crew, shore management, charterers, maintainers and suppliers, port authorities, insurance industry
Capability	The blend of knowledge, skills and attitude to enable effective, safe performance	• technical and professional skills and knowledge (e.g., navigation, engineering, seamanship, ship handling, cargo handling) • non-technical skills (e.g., communication, leadership and management, teamwork, workload management, situational awareness, behaviors, attitude and professionalism, dealing with problems)
Pressure	Real and perceived demands on people	Tight deadlines, schedules, port turn round times, etc., aggravated by changes to schedules, unexpected delays, additional port calls, changes to routes, crew changes, problems with weather and port inspections, all leading to disturbed rest periods, long working hours and increased stress

Table 1. (*continued*)

Factor	Description	Causes
Distraction	An event that interrupts attention from a task	It is easy to become drawn into a distraction and overlook much more critical events
Fatigue	Reduction in physical and/ or mental capability as result of physical, mental or emotional exertion which impairs physical abilities (e.g. strength; speed; reaction time; coordination; decision making; balance)	• natural biological (circadian) rhythms – it is natural to want to sleep at night and early afternoon • length of time awake • length of time working • difficulty of the work (mental and physical) • stress • amount of rest between work periods • amount of adequate quality, undisturbed sleep
Fit for duty	The combination of physical and mental state of people which enables carrying out duties competently and safely	• misuse of alcohol and/or drugs • physical injury • illness • stress, worry, personal problems • mental impairment

3 Examples of Initiatives and Best Practices

The different types of security and safety promotion initiatives and best practices have to be suited according to the stakeholder profile. Nevertheless, as mentioned above education and training is a common key success factor. The definition of sectoral qualification frameworks helps ensuring minimum standards for Maritime Industry professionals. This is the case of the adoption of the IMO's International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW).

It is also possible to find good examples in Academia, which is promoting Higher Education international programmes to raise the level of knowledge and capacitation of Maritime Domain related professionals, across borders and across stakeholders' sectors [17]. Research and Development institutions are playing also a significant role in studying themes related to this industry and proposing solutions to the myriad of problems facing the Maritime Domain, hopefully with a Human-centered focus, ranging from more efficient, safe, environment friendly and sustainable ships, to better technology to generate the most needed Maritime Situational Awareness, detect incidents, or to support responses in crises situations.

The existence of communities of interest (CoI), which study, contribute to and promote understanding and development of maritime security and safety issues, is also relevant. The first author chaired in 2016/2017 the European Coast Guard Functions Forum (ECGFF), which is a CoI focused on maritime issues of importance and of common interest related to Coast Guard Functions across borders and sectors, both civil and military. The Portuguese Naval Academy is member of the European Coast Guard Functions Academy Network (ECGFA NET) [17] which is pointed as another example of good practice, since this ECGFF sub-group supports and offers training actions integrated in an international core curriculum developed in conjunction with European agencies EFCA and FRONTEX.

Considering the preparedness to respond to Maritime Domain crises, which require high levels of Collaboration, Cooperation and Coordination, the training of decision-makers and responders is of utmost importance. An example of joint training operations is the COASTEX series exercise, promoted by the ECGFF, FRONTEX, EFCA and EMSA. This is an event organized to test and validate the concept of "Multipurpose Maritime Operations" (MMO), involving complex simulated scenarios requiring the coordination and execution of activities to combat illegal fishing and illegal trafficking, fight pollution, and conduct search and rescue operations, performed in a multinational and interagency context. This exercise was held twice, the first time in Portugal (COASTEX 17), and the second in Italy (COASTEX 19).

COASTEX 17 deserved special mention in the "Frontex Annual Activity Report 2017" [19] as transcribed in Exhibit 1. The agency concludes "[…] *the exercise was a good opportunity for all participants to test and assess multi-agency command, control, coordination and communication throughout simulated multifunction operations and to prepare for the future common activities in real-life situations"*.

4   Conclusions

Although Industry 4.0 is starting to gain traction in Maritime Industry, giving room to the introduction of unmanned systems, the importance of HF cannot be neglected, not only for these emerging technologies, but particularly for large legacy of systems that will still be in operation for many years, where the dimension and relevance of the human workforce is very significant.

Exhibit 1 – Highlights on Joint Operations and Pilot Projects [19].

Frontex tested practical application of Coast Guard Functions in COASTEX 2017

In partnership with the Portuguese Presidency of the European Coast Guard Functions Forum (ECGFF) in 2017, Frontex took the lead in testing interagency cooperation in the maritime domain. Between 23 and 26 May, the Portuguese authorities hosted the first operational scenario-based drill involving Frontex and the two EU maritime agencies, EMSA and EFCA, and Member States. The drill, which took place in the Atlantic peninsula of Troia, tested the full scope of coast guard functions: border control, maritime safety, security, search and rescue, fisheries control, customs control, general law enforcement and environmental protection. The cooperation was arranged in the framework of the Portuguese Presidency of the European Coast Guard Functions Forum (ECGFF) in 2017.

A Frontex team, composed of various units facilitating COASTEX 17, supported the Portuguese Navy being directly responsible for the operational implementation.

Thanks to combined efforts, COASTEX 17 was the first multifunctional multiagency operation exercise, including workshops and live activities at sea designated to test and promote cooperation, collaboration and coordination among the three Agencies and Member States engaged in the European coast guard functions.

The exercise, which was also co-financed by Frontex, involved 11 vessels and four airplanes and helicopters from Italy, Portugal and Spain plus a naval asset chartered by EMSA. In total, 750 personnel took part, including a Boarding Team of 7 German experts and 90 observers deployed by the border and coast guard authorities of more than 20 EU Member States.

The main objective of COASTEX17 was to maximize the interoperability between all actors involved in Coast Guard functions by identifying gaps and complementarities between EU agencies and national authorities and draw conclusions for future cooperation in this regard.

Frontex, in cooperation with the Portuguese hosts, set up 12 real-life scenario exercises addressing the various coast guard-related functions and mandates of the stakeholders involved. The exercises were tailored to represent the full scope of critical situations that may occur at sea in the context of multiagency, multipurpose operations.

Frontex also provided organizational and operational support with the installation of a Joint Situation Centre (JSC) in the Troia Navy Base and the implementation of the Eurosur Fusion Services during the activities at sea. The concept behind the establishment of the JSC was to provide the means to all stakeholders involved to assess the various critical situations occurring at sea and prepare for the right response in real time to any of the cases simulated during the exercise.

Finally, the exercise was a good opportunity for all participants to test and assess multiagency command, control, coordination and communication throughout simulated multifunction operations and to prepare for the future common activities in real-life situations.

This paper addressed examples of HF factors affecting the Maritime Industry and provided examples of initiatives and best practices that contribute for the preparedness of crises management actors (both decision-makers and responders) and to mitigate the threats and negative impacts to security and safety of this industry.

The final remark is to note that such posture will contribute to fulfill the commitment of UN Member States, in 2015, through the Sendai Framework for Disaster Risk Reduction 2015–2030, to address hazards comprehensively as it applies to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, natural

and man-made hazards as well as related environmental, technological and biological hazards and risks, since the Maritime Domain is key to global sustainability.

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Complex Human-System Interactions

Technology, Growth and Inequality: An agent-based model of Micro Transactional Behaviors and Meso Technology Networks for Macroeconomic Growth

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Abstract. Technology is both an enabler and disruptor for the UN's 2030 Agenda for Sustainable Development. Yet few approaches integrate macro-outcomes with the micro and meso scale activities of human behavior. We instantiate an agent-based model to simulate technology diffusion within a micro-meso-macro scale integrated economy: allowing heterogenous agents to play technology enabled symmetric and asymmetric socio-economic transaction games through various random and preferential social network market typologies to simulate how behavioral technology adoption and societal proliferation impact macroeconomic income, growth and inequality dynamics. By fusing cross-scale theory and simulation modeling in a complex adaptive systems framework, such approaches could provide additional insights on the complex relationships between income, technology and inequality. These can also assist creating the necessary evidence and science-based policy conversations around why, if, how and when societies might achieve their SDG targets.

Keywords: Economic development · Income inequality · Technology proliferation · Evolutionary game theory · Agent-based modeling · Complex adaptive systems

1 Introduction

Almost 60% of the world's population today has access to the internet. Over 3.5 billion people also have smart phones which are more computationally more powerful than all of NASA had in 1969 to send man to the moon. Not surprisingly, technology is both an enabler and disruptor for the UN's 2030 Agenda for Sustainable Development. Technology as an economic enabler defines the boundaries of what is economically possible including 5G infrastructure networks, AI, big data and IOT applications such as autonomous vehicles, smart cities, advanced healthcare and new financial systems. Technology as a disruptor creates new sources of innovation through proliferation, which challenges traditional economic value chains across multiple sectors, creating

new winners and losers in markets and society [1]. While societal economic growth can often be miscast as primus inter pares, growth drives many other sustainable development goals (SDGs), including poverty alleviation, income and gender inequality reductions, improved health outcomes and educational attainment. Whether as an enabler or disruptor, understanding technology's impact on economic growth is paramount, as it determines macroeconomic growth behavior, equilibrium stability and resiliency to exogenous shocks [2].

As innovation continues to enable economic growth, it also intensifies competition in marketplaces, creating new local and global inequalities as well as saturated information environments [3–5]. These implications drive conversations on how we can embrace technology advantages paramount to changing human needs and actions and redirect it as part of the solution for inequality challenges with increased human connectivity and evolving complexity. Fundamental to such outcomes, are unpacking aggregate sums of macroeconomic outcomes into homo economicus: micro human agency and meso interconnected, networked communities and markets enabled by technology to create macro socio-economic value.

2   Related Work

2.1   Macro and Microeconomics

Leveraging off the work of Solow [6], Romer [7], as well as Mankiw, Romer and Weil [8], we disaggregate the macroeconomic endogeneity of technology and total factor production (TFP) embedded within an economy. Here we decompose macroeconomic technology and growth into their respective subcomponents of cross-scale human behavior: micro individual adoption of technology for competitive economic gains within a complex adaptive systems framework [9, 10] of technology proliferation meso networks. This fusion of micro behavioral, meso transactions and macro market behaviors explores scale generative motivations of macroeconomic technology behavior [11–13]. To do so, we instantiate an agent-based model to simulate technology diffusion within a micro-meso-macro scale integrated economy: allowing heterogenous agents to play socio-economic transaction games [14, 15], through various diffusion network typologies, including random, preferential, small world and scale free networks [16] to simulate how behavioral technology adoption and societal proliferation impacts macroeconomic growth outcomes. As technology proliferation drives increasing economic connectivity and complexity, understanding how behaviors and structures couple across micro, meso and macro scales [17, 18] are crucial. We then explore macroeconomic growth behavior, individual strategic behavior and resulting equilibrium stability through simulation to assess path dependence, nonlinear phase transitions and other complexity behaviors [19] where single scale economic growth explanations falter [20, 21].

2.2 Inequality

Endogenous technological change theories [22] interplay the dynamics of income and aggregate economic growth at the macro level. However, empirically we see increasing income inequality despite low unemployment levels coupled with surging and sustaining national economic growth [23]. Explanations include technical change disruption in labor markets, subsequently causing gaps to widen both across and within groups. Such explanations beg understanding at increased scale resolution of human activity. Here we aim to unravel income inequality through a complex adaptive system (CAS) framework to understand individual behavioral activities in meso interconnected markets for explaining aggregated macro-economic environment.

3 Model Design

In human, social, cultural and behavioral systems, connectivity and interdependence means that decisions or actions by any individual, group or entity may impact related individuals and/or systems [9]. As humans are strategic, dynamic and adaptive beings, both constrained and incentivized by their actions and environments, behavior will change and evolve by design [4]. Complexity emerges from individuals' agency, socio-economic production functions and utility maximization which impact spaces possibilities for agent decision-making and consequently contribute to overall macro environments.

A first step in decoding complex systems is to explicitly outline scales of activity, agents' interaction behaviors, and connecting system elements as seen in Fig. 1. In our operational model process map, we identify four types of scale behavior: micro evolutionary, heterogenous socio-economic transaction games, meso social and market networks where such micro games are conducted, the diffusion of technology in such contexts and finally the aggregate sum of all activities to understand the emergence of growth, technology and inequality.

3.1 Dynamic Behavioral Simulation

Our simulation space is designed to capture agents' socio-economic production functions, interactions and dynamic behavioral changes on different networks; each agent has its own unique cognitive process of choosing strategies, with or without technology, that they believe will provide maximum individual economic returns. Of course, this also depends on whether they or their counterparties possess technological advantages in any transactional game. Four different possible interaction games result depending on player types possessing technology or not. The intuition here is that technology can enable synergistic gains and effects in cooperative interactions while conversely maximizing individual gains in non-cooperative, asymmetric technology possession interactions. Such symmetric technology, cooperative games produce higher relative economic gains than symmetric, non-technology enabled games.

I. Micro Evolutionary, Heterogenous Transactional Games

Games with and without technology player types and preference ordering

Player 2 With Tech

Player 1 With Tech	C	D
C	(8, 8)	(2, 4)
D	(4, 2)	(6, 6)

Player 2 With No Tech

Player 1 With Tech	C	D
C	(6, 3)	(2, 4)
D	(8, 1)	(4, 2)

Player 2 With Tech

Player 1 With No Tech	C	D
C	(3, 6)	(1, 8)
D	(4, 2)	(2, 4)

Player 2 With No Tech

Player 1 With No Tech	C	D
C	(4, 4)	(1, 2)
D	(2, 1)	(3, 3)

II. Societal Network Typologies

Market connectivity and economic interdependence

Random [1A Static + 1B Dynamic]   Preferential [2A Static + 2B Dynamic]

III. Meso Bass Diffusion Model

Payoffs and technology diffusion across different network typologies based on agents' heterogenous attributes

P(Adoption) = 1/ (1-e^-k(x1-x0))
P(Network) = 1- sum (weight * (attribute vector)

IV. Macroeconomic Outcomes

Sum agents' individual wealth into societal outcomes

Average Income

Lorenz Curve
Income distribution

Gini Index
Inequality dynamics

Fig. 1. Technology, growth and inequality ABM process

We then instantiate various socio-economic transactional game structures including non-cooperative Prisoner's Dilemma (PD) and coordination games given agent i's attribute and preference ordering vectors (A_i) to agent j (A_j) for any A_{ij} pairs of different player types.

Agents are created with vectors of different societal attributes, i.e. income, education, level of influence and perception of technology, which then conduct transaction games by player types on different network typologies. Random and preferential network typologies serve as proxies for economic interdependence and market sophistication. In addition to technology enabled player type game outcomes, a simple Bass Diffusion model simulates technology proliferation as through increased payoff flows, agents are able to learn from outcomes based on previous strategy choice to determine their next move. At each iteration, we are able to observe impact of agent's decision to changes in income distribution and to overall income inequality. These multiple scale feedback loops increase phenomenological fidelity and allow us to capture new complex behaviors with groups emerge. Pseudo code is as follows:

```
Setup agent socio-economic attribute vectors

Setup societal network typology
["Random-Static" "Random-Dynamic" "Preferential-Static" "Preferential-
Dynamic"]
Agent interactions
{
  Pair up player types into four grouping
 ["tech v tech" "tech v no-tech" "no-tech v tech" "no-tech v no-tech"]
  play game

  for each game [assign agents' preference ordering]
  choose strategy with maximum utility
  if use-tech [deduct income with initial investment]
  add utility to income and calculate total return

  information spread through Bass Diffusion model for agent tech adoption
 }
Update macro wealth
  Sum individual agent payoffs
  Lorenz curve and Gini index
End
```

4 Results

4.1 Baseline – Game Behavior

At each iteration, agents randomly select partner by the four designed groups: both players have technology, A_i has technology and A_j does not, A_i does not have technology and A_j has, and finally both players do not have technology (correspond to graphs from left to right in Fig. 2). A_i strategies are adaptive, which affect A_{ij} pairs locally. Figure 2 shows how agents' strategies simultaneously co-evolve over time, driving changes through feedback process through $t + k$ iterations.

Within a short time frame ($t = 90$), we observe significant differences in game strategy choices across the different groups. In the scenario when both players have technology (P1 tech P2 tech), agents are initially indifferent between cooperate or defect strategies. Later agents choose defect strategies to optimize their return while showing an increasing trend to adopt technology. There are also substantive differences between random and preferential networks as defect strategies become dominant in random typologies, consistent with the Nash equilibrium. Next, when there is only one player type with technology in a game, dominant strategy patterns emerge. Lastly, when both players do not have technology, game plot outcome shows agents are in different between cooperate and defect. As t increases, overall trajectories remain similar across groups. However, there are obvious dynamic changes depending on network typologies. In random networks, we detect a further separation between cooperative and defect strategies while more agents adopt technology in the same time frame, suggesting a more equitable spread of connectivity payoffs and game flows.

4.2 Baseline – System Phase Portraits

Figure 3 displays a panel of average run trajectory slopes and phase shifts across sampled parameter space. Here we focus on the interactive effects of behavior plots given
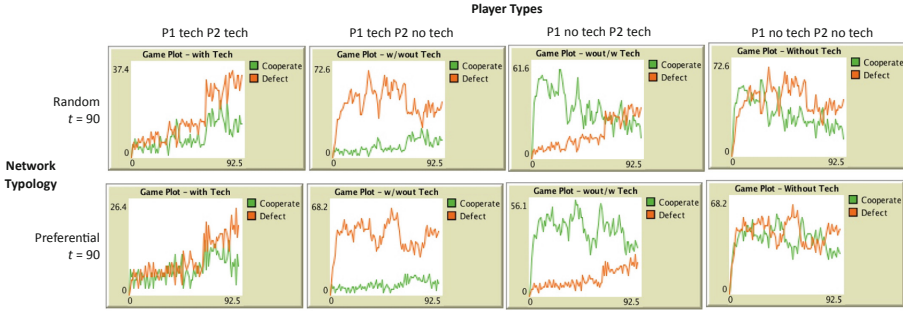
Player Types

Fig. 2. Player types and game outcomes by network typologies

technological impact under various, sparsely populated network typologies. In addition, we include Lorenz curves overtime, indicating status of inequality in the designed macro environment. Here we can see increased inequality in random societal typologies compared to organized and efficient preferential markets. This result aligns with theoretical and empirical evidence [23] where technology innovation while can positively influence agents' income within specific groups but can also negatively cause aggregate societal inequality.
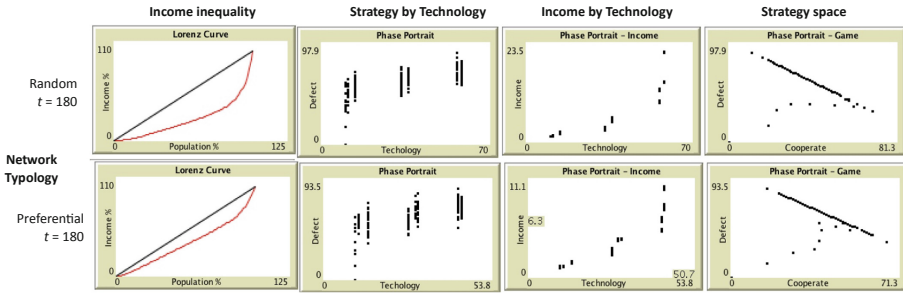
Fig. 3. Lorenz curves with associated strategy, technology and income phase portraits in sparse networks

4.3 Scenario – Fully Connected Network Typologies

Next we explore the potential for co-evolutionary behavior across micro and macro-environments under fully connected networks as shown in Fig. 4. When both players have technology in a fully interconnected network, we observe different strategy trends suggesting that agents are constantly adapting strategies overtime. In a random typology, defect strategies dominate, and inequality emerges faster than in a preferential typology with more reciprocal cooperate-defect strategy pairs. There are also obvious changes in phase portrait trajectories as expected, once agents either acquire or choose technology

adoption, there is an initial push towards agents pursuing defection strategies in asymmetric technology player type games. However, this changes over time as cooperative strategies still weakly dominate in asymmetric, P1 no tech P2 pairs.

4.4 Sensitivity

Our quasi-global sensitivity analysis generated over 654,000 experiments to create a pooled OLS sample. All variables are relatively scaled which allow for magnitude and substantive effect interpretation across β coefficients. Table 1 details the interactive parameter effects with income and inequality as dependent variables (DVs) and the four different strategy groups as our independent variables (IVs). Agents with asymmetric technology advantages as well as those who choose cooperate in game has a negative impact on income but positive impact on reducing inequality. Conversely, the same behavior on preferential networks reduces income inequality by almost double and with only half the penalty to total income generation comparatively.
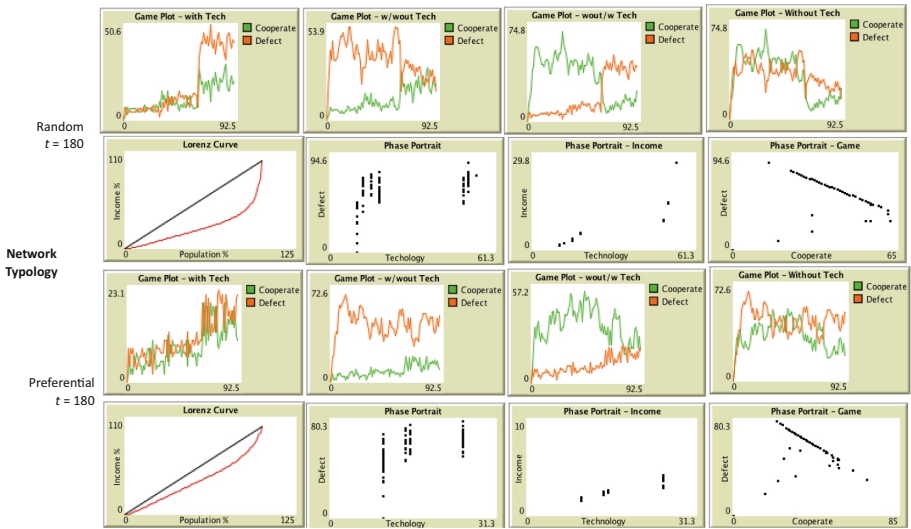
Fig. 4. Fully interconnected societal network model outcomes

This is especially interesting since our model incorporate elements of technology adoption on game structures. Our sensitivity outcomes align with the empirical evidence presented in Romer's Endogenous Growth Theory [7] that endogenous technological change can positively influence long-run economic growth while agents with technology negatively influence Gini index results and increase income inequality. Although not shown here, we find further distinctions between static preferential and dynamic preferential typologies where technology has a larger impact on income in the dynamic preferential network than static preferential typologies which has implications for the tradeoff between sustainable growth and social equality.

Table 1. Pooled OLS sensitivity results in static random and static preferential networks

Variables	Static-Random				Static-Preferential			
	(1) Income	(2) Income	(3) Gini	(4) Gini	(1) Income	(2) Income	(3) Gini	(4) Gini
Cooperate with tech		−0.0450*** (0.000946)		−0.0124*** (2.93e−05)		−0.0247*** (0.000526)		−0.0119*** (2.73e−05)
Cooperate with no tech		−0.00225** (0.000915)		−0.00430*** (2.83e−05)		0.00290*** (0.000561)		−0.00550*** (2.91e−05)
Defect with tech		0.171*** (0.000571)		−0.00849*** (1.77e−05)		0.0960*** (0.000346)		−0.00965*** (1.79e−05)
Defect with no tech		0.0228*** (0.000827)		−0.00959*** (2.56e−05)		0.0150*** (0.000474)		−0.0108*** (2.46e−05)
With tech	0.0671*** (0.000416)		−0.00248*** (1.30e−05)		0.0343*** (0.000220)		−0.00189*** (1.14e−05)	
Cooperate	−0.0580*** (0.000612)		−0.00735*** (1.91e−05)		−0.0303*** (0.000360)		−0.00806*** (1.87e−05)	
Defect	0.0784*** (0.000604)		−0.00755*** (1.89e−05)		0.0459*** (0.000330)		−0.00905*** (1.72e−05)	
Constant	1.329*** (0.0180)	1.525*** (0.0179)	0.795*** (0.000562)	0.787*** (0.000553)	1.442*** (0.00960)	1.526*** (0.00954)	0.801*** (0.000500)	0.795*** (0.000495)
Observations	654,480	654,480	654,480	654,480	654,480	654,480	654,480	654,480
R−squared	0.161	0.173	0.487	0.502	0.132	0.143	0.575	0.583

Standard errors in parentheses

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$

5   Conclusions

Our initial foray into decomposing macroeconomic growth, technology and inequality into the underlying scale variant behaviors seems promising for several reasons. First, it unifies disparate theoretical explanations into empirical behavioral micro, meso and macro scales and activity resolutions. Second, it is a compelling *prima facie* verification on how individual socio-economic transactional agency is constrained or incentivized in the social and market contexts in which they operate. Third, the tradeoff between maximizing wealth creation and minimizing income inequality can vary by societal and market organization typologies obviously, but herein with both measurable and potentially policy nuanced properties.

Some next steps include model parameter calibration and empirical validation given widely available cross national socio-economic datasets. Afterwards, further exploration into detailed equilibrium behavior for income, inequality and technology adoption can occur, coupled with socio, economic and technological market shocks, stability and recovery behavior. By fusing cross-scale theory, generative simulation and empirical modeling, approaches such as ours hope to provide additional insights on the complex relationships between income, technology and inequality. These can also assist creating the necessary evidence and science based policy conversations around why, if, how and when societies might achieve their SDG targets.

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Physical Exertion and Prevalence Assessment of Musculoskeletal Disorders Among Brush Cutter Operators

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Abstract. An Ergonomic Work Analysis was done to assess and evaluate the working conditions among brush cutter operators during vegetation management tasks. The main objectives of this study were: to assess the actual working conditions and the complaints presented by workers that accomplish the task with brush cutters; to quantify the physical exertion during the use of the equipment and to characterize the musculoskeletal symptoms. Nineteen workers agreed to participate in the study answering the questionnaire, while only seven of these participated in the Physical workload assessment. The six body regions with the highest percentage of complaints were the lumbar spine, followed by feet, dorsal spine, right-wrist/hand, cervical spine and right-thigh. Considering physical exertion, the results showed that the workload in this study ranged from low to very high or extremely high.

Keywords: Musculoskeletal disorders (MSDs) · Nordic Musculoskeletal Questionnaire (NMQ) · Ergonomic Work Analysis · RHR · PHRI · Brush cutter

1 Introduction

Forestry occupations are known to be physically demanding [1]. According to the European Agency for Safety and Health at Work the employees of the forestry, farming and fishing sectors are among the occupational groups with particularly high Musculoskeletal disorders (MSD) risk. MSD are the most frequent diseases related with jobs, occurring in all activities sectors in European Union [2, 3].

Following the data published by Eurostat [4] more than 60% of employees in the whole EU ($\approx$65% in Portugal (PT)) are exposed (at least 1/4 of work shift) to repetitive activities, about 43% ($\approx$48% in PT) adopt painful or fatiguing positions and 32% ($\approx$24% in PT) carry and lift heavy loads [4]. In some professions, there may occur long-term standing or walking (more than 70%), as well as exposure to vibration (25%). All abovementioned occupational risk factors are the potential cause of the development of MSD.

Despite these information does not specify that the MSD occur exclusively in forestry, most often concern the joint sector of agriculture, hunting and forestry.

Regarding the sixth European Working Conditions Survey (EWCS), in 2015, around 25% of the European workers considered that their work affects their health, corresponding to 32% of the Agricultural workers [4]. Globally, 43% of the European workers reported suffering from back pain. This result is higher among workers in agriculture/forestry sector (57%). The same source reported that the situation is quite similar for muscular pain, as about 42% of the respondents considered that their work causes them muscular pain (neck or upper limbs). Once again this rate was higher in the studied sector (55%) [2, 4].

Vegetation management tasks usually demand the adoption of awkward and uncomfortable postures for long periods of time, which may stress and fatigue supporting muscles and tendons, leading to the development of MSDs. In addition to the physical suffering of workers, MSDs cause an important economic impact for the society as a whole [2, 5].

Several studies that investigate the physiological workload among workers in the agriculture/forestry sector, show that some activities impose a high workload [1, 6–9].

An Ergonomic Work Analysis (EWA) was done to assess and evaluate the working conditions among brush cutter operators during vegetation management tasks. The main objectives of this study were:

- to assess the actual working conditions and the complaints presented by workers that accomplish the task with brush cutters;
- to quantify the physical exertion during the use of the equipment (brush cutter).

2 Method

2.1 Study Location and Sample

This study was carried out from Jul 2020 to Nov 2020, with the workers of a Private Portuguese Enterprise responsible for the operation and maintenance of road infrastructure.

Nineteen male workers, from 7 concessions, agreed to participate in the study answering a questionnaire. Out of these, seven participated in the physical workload assessment authorizing the recording of heart rate during the work. In both situations an informed written consent was previously obtained. The confidentiality of data was always guaranteed.

2.2 Questionnaire

Working conditions and the complaints reported by workers were assessed through a questionnaire specifically developed for this purpose, which was applied as an interview.

The questionnaire was based on the adapted version of the Nordic Musculoskeletal Questionnaire (NMQ) [10], similarly to other studies [2, 11], and information provided by the company. The questionnaire intended to identify key parameters for the workers'

characterization, evaluate their perception of the real working conditions, as well as to identify self-reported symptoms in terms of physical annoyance, discomfort or pain. The questionnaire comprises three sections (A, B and C).

In the *Section A* were integrated items to better characterize workers' gender, age, anthropometric data (height, weight), dominant upper limb; data that characterize the relationship with the organization (seniority, number of work hours worked per day/week, schedule type, practice of work breaks and second job,…); this section, also, included items, to better characterize the workers' health, sport and physical activities, smoking habits, and presence of chronic illnesses. In the *Section B* were integrated items to determine the presence of musculoskeletal symptoms. Subjects were asked about the musculoskeletal symptoms (annoyance, discomfort and physical pain) over the last 12 months and the last 7 days. To finalize this section, the workers were asked to identify possible relationship between MSD symptoms and characteristics of work; *Section C* integrates items to better characterize the workers' perception about Work Activity and Conditions of Realization in terms of organizational conditions (time available to perform the work, work schedule).

2.3 Physiological Measures - Heart Rate

Physical workload data were obtained through heart rate measurement. For this purpose, polar Vantage M brand pulse time meter and the compatible chest-belt was used.

The physical exertion was assessed by heart rate response considering both parameters: The Relative Heart Rate (RHR) and the percentage of heart rate increase (PHRI).

Heart rate was recorded for the entire working day, including during the main rest break at the middle of the day. Subsequently, the RHR and PHRI were determined for the effective working time (discounting the lunch period and the time spent traveling to the front of work).

RHR allows for the estimation of the relative physical work demands of workers during a work period, such that comparisons between workers and/or worksites are possible. The RHR and the PHRI were obtained by the application of Eq. 1 and Eq. 2, respectively:

$$RHR\ [\%] = \frac{HR_{work} - HR_{rest}}{HR_{max} - HR_{rest}} \times 100 \tag{1}$$

$$PHRI\ [\%] = \frac{HR_{work} - HR_{rest}}{HR_{rest}} \times 100 \tag{2}$$

Where:

HR_{work} is the heart rate (in beats/min) measured during work; HR_{rest} is the heart rate obtained from the value corresponding to the 1st percentile (P1) of the monitored period (in beats/min), and $HR_{max} = 220$-age (in beats/min) [12].

Additionally, and in order to assess whether the work is being carried out within acceptable workload levels, we evaluated the maximum time allowed based on maximum

acceptable work time (MAWT) proposed by [13] using the Eq. 3.

$$MAWT(h) = 26.12 \times e^{-4,81 \times RHR} \tag{3}$$

Workloads were classified into very low, low, moderate, high, very high and extremely high according to Çalişkan and Çaglar [7] and Grandjean [14] (Table 1).

Table 1. Workload classification considering RHR and PHRI.

RHR [%] [7]	PHRI [%] [14]	Workload classification
10–20	0	Very low (resting)
20–30	]0–36[	Low
30–40	[36–78[	Moderate
40–50	[78–114[	High
50–60	[114–150[	Very High
>60	>150	Extremely High

Finally, MAWT (h) was related with the Work Time Duration (T_{work}) (h) obtaining the Exposure Dose (D) (Eq. 4). D > 1 is indicative that the work is being done outside acceptable load levels.

$$D = \frac{T_{work}(h)}{MAWT\ (h)} \tag{4}$$

where

T_{work} is the effective duration of the work (in hours); MAWT is the acceptable work time obtained by the application of the Eq. 3.

2.4 Data Analysis

For data processing the SPSS© software was used and descriptive analyses were performed using measures of location and dispersion. To assess associations between variables (demographic/work-related characteristics) and reported MSD symptoms, the Chi-square test and Cramer's V coefficient were used. A significance level of 0.05 was adopted as a criterion to reject the null hypothesis.

3   Results and Discussion

Considering the socio-demographic data the age of participants ranged from 24 to 53 years (mean = 35.8 years; SD = 8.45 years). In general, the participants had: an average weight of 80.89 kg (SD = 12.27 kg; range: 55–100 kg); an average height of 174 cm (SD = 6 cm; range: 160–187 cm); and an average BMI of 26.88 kg/m^2 (SD =

4.72 kg/m^2, range: 20.02–35.94 kg/m^2) where, at least 58% of the operators were Overweighted. In terms of Seniority $\approx$50% of the workers had more than 3-years' experience in the functions assessed. 47% of the operators reported that they were not involved in regular physical activities or sports. 53% of the participants were smokers and $\approx$90% of workers consumed caffeine daily. Thirty-two percent of the workers had chronic health problems of which 38% related to MSD. The majority of the workers (95%) were right-handed. Fifty-three percent of the participants had a regular education level. In terms of Job, 84.2% of the workers were conservation assistants and 15.8% were conservation officers.

In terms of working time organization: all workers should complete 8 h daily; 95% of the workers reported that usually took rest breaks (5–10 min) varying between 1 to 6 times throughout the day. Only 2 of the respondents had suffered an accident at work, in the last 2 years.

3.1 Self-reported Symptoms

The body regions with the highest percentage of complaints were the lumbar spine (95%), followed by feet-right (79%) and left (74%) and, with the same ratio, the dorsal spine and right-wrist/hand (58%), and the cervical spine and right-thigh (53%) (Fig. 1). These results are similar to those of other studies [11, 15, 16] where lumbar spine is reported as the region with higher prevalence of complaints. The presence of complaints in the knees and feet is also common among workers who operate on sloped surfaces [17, 18].
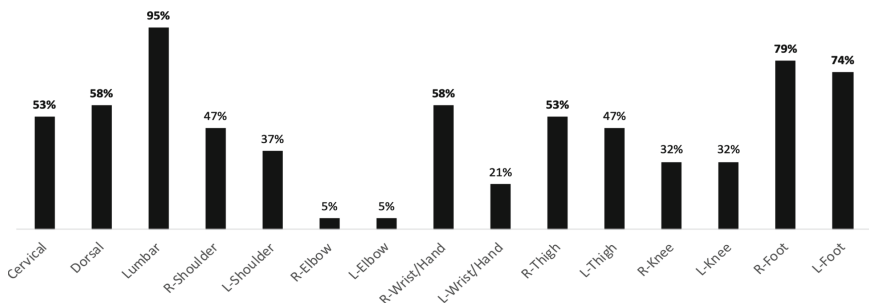
Fig. 1. MS Symptoms (prevalence of physical complaints - annoyance, discomfort or pain) registered per corporal region.

Regarding the intensity of complaints, it was found that the highest level of the scale (very high) is present in the 6 most affected regions in a proportion that varies between 7 to 36%. It is also noteworthy that there were regions, such as the knees and the left hand/wrist, which despite not showing a prevalence of complaint as high as the other regions ($<$50%), presenting very high intensity (with records $\geq$ 50% of cases). All regions presented at least more than 4 complaints/year in a proportion $\geq$ 50%. Figure 2 shows the comparison between self-reported symptoms in the last 12 months and in the last 7 days. It should be noted that most of the complaints, in the lumbar region, thighs

and feet, were related to the work on the *Talude* (sloped surface). Therefore, the low percentage ($\leq$50%) of the complaints reported in the last 7 days for the aforementioned regions could be related with the fact that the workers were not doing work of this nature in the past few weeks. The workers associated their pain level with the working conditions in particular with: sloped surfaces, the repetition of movements of hands/fingers and arms, the standing posture and the rotation and inclination of the trunk.
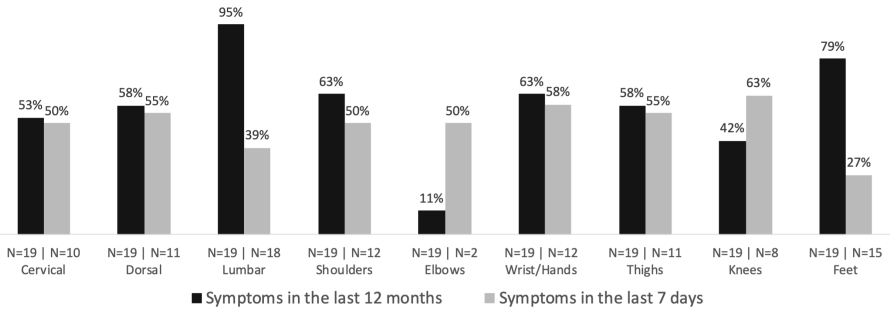
Fig. 2. Comparison between self-reported symptoms, in the last 12 months and in the last 7 days.

3.2 Associations Between Demographic/Work-Related Characteristics and MSDs Symptoms Reported by Body Region

In general, there were no statistically significant associations between the MSD symptoms and the variables (demographic/work related characteristics) ($p > 0.05$). The only three associations found were in the shoulder and in cervical region. It is important to highlight that in majority of the cases Cramer's V test revealed moderate and strong associations (>0.60). From the analysis made, it is possible to draw the following conclusions: a) for the shoulder region there was a positive association with clinical history ($\chi^2(1) = 5.115; p = 0.044$) and BMI ($\chi^2(3) = 9.330; p = 0.014$). Thus, we can conclude that the presence of some type of disease seems to be associated with the complaints revealed in this body region; on the other hand, complaints are more prominent among operators who fall outside the normal body weight category; b) the complaints presented on the neck seem to be associated with the quality of sleep revealed by the participants ($\chi^2(1) = 9.972; p = 0.021$). However, from the analysis of the data it is not possible to define a clear pattern.

3.3 Workload Assessment

The results obtained in this study showed that the RHR ranged from 24% to 75% and the PHRI ranged between 24% and 131%, which means that the workload ranged from low to very high based on the physical workload classification. Figure 3 shows the proportion of the workload obtained according to the Workload Classification obtained by each evaluated parameter: RHR [%] and PHRI [%].
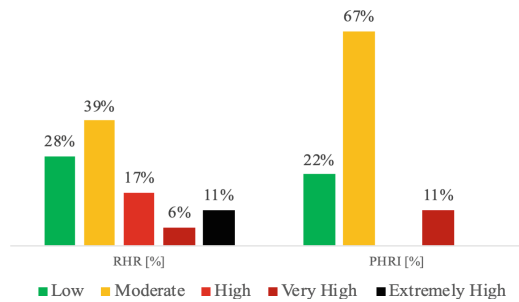
Fig. 3. Proportion of the workload obtained according to the Workload Classification obtained by each evaluated parameter: RHR [%] and PHRI [%].

These results are a consequence of the nature of the work performed in each day and the individual characteristics of each operator. The climatic conditions may also have had an influence on the results. Additionally, the tool used can also explain the differences found since the lowest (heart rate) records were found in workers who handled, or when handling light tools. These results suggest that further investigations should be made to better characterize the situation, allowing future improvements in the working conditions.

Considering de Exposure Dose (D) parameter, 44% of the evaluations performed are above 1 suggesting that the work is being done outside acceptable load levels.

4   Conclusion

This cross-sectional study was conducted in a Private Portuguese Enterprise responsible for operation and maintenance of road infrastructure. The intensity of MSDs symptoms (in all regions) among the operators was assessed as high or very high, emphasizing the need of ergonomic interventions for improving the working conditions. These results are similar to those of other studies [11, 15–18].

All regions assessed presented at least more than 4 complaints/year in a proportion ≥ 50%. The results also showed that the majority of the participants did not experience MSDs symptoms over the last 7 days in the lumbar spine, thighs and feet; which could be related with the fact that workers were not doing work on the *Talude* (sloped surface), in the past few weeks.

Considering the physical exertion, the results showed that workload ranged from low to very high. In 44% of the evaluations, the work was being done outside acceptable load levels. These results are similar to those obtained by [1, 6–8]. This study revealed that the work done by these workers entails risks factors, which may be responsible for the development of musculoskeletal disorders. As a limitation of this study, we can highlight the sample dimension, which can explain some of the results.

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Comparative Studies of the Variations in the Spatial Location Processes Generated by a Weak-Visual Person in Two Works Systems

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Abstract. Weak-visual users carry out various types of temporary interaction processes through a wide range of work systems to perform heterogeneous activities of daily living as well as to obtain specific information. One of the processes that are more complicated for a weak-visual person, by the investment of time as well as the activation of various sensory mechanisms, is the spatial location. It has been detected, through static network techniques, a difference in the hierarchy of the temporal micro-processes that the Weak-Visual person performs in the interaction with two different work systems, in this sense, it was observed that the spatial location for the weak-visual person can be originated by two kinds of processes: from the Sound Interaction (Is) and the motor exploration (Img). In the interaction processes executed by the weak-visual person, it was observed that the user could make a spatial location in work systems started with the sound interaction. In this process of interaction, a lower activation of sensory mechanisms were observed. On the other hand, in work systems that involved a motor exploration were observed a greater activation of sensory mechanisms. In the same way, it was perceived that work systems that promote spatial location starting with Is generates more time in the precise location of virtual objects., While work systems that promote spatial location from motor exploration generates higher levels of stress. Our objective is to reflect on the analysis of those patterns that can generate a better interaction in the relationship: Weak-visual person - Work devices, to improve the execution of the activities of these users in a precise and autonomous way.

Keywords: Spatial location processes · Weak-visual person · Work systems · Design · Processes of interaction

1 Introduction

Today a diversity technological device has been implemented in various environments to solve different kind of problems. These implementations modify, in a greater or lesser level, the way in which activities of daily living are accomplished. Most of the technological developments of Industry 4.0, that have permeated various spheres, have very specific characteristics. Among could be named: allow broad interconnectivity, just in

time processes, relativization of time, among other factors, which generates increasingly precise processes in less time.

However, these technological developments in a wide range of artifacts are also changing the way in which various activities of daily living are carried out. The afore-mentioned artifacts have shown a high level of usability and adaptation for normal-vision users, but for people who don't have vision as the dominant sensory mechanism like weak-visual persons, still should be done various developments and studies that allow them to carry out their activities autonomously and efficiently.

In previous studies it has been observed that the interaction processes that the weak-visual person performs in the work systems of technological artifacts were by substitution of dominant sensory mechanisms. That process of adaptation implicates a considerable variation in the processes of interaction with an object, generating a constantly process of adaptation of the user to the sensitive qualities of the object and modifying the attentional processes as well as transfer of information, interoceptive responses, just to mention a few processes [1].

One of the most used work systems in a university educational environment in Mexico are laptops. Through them, a Weak-visual person must perform a set of tasks to be able to access to the system information as well as perform a diversity of activities. Although this technological device will continue to be used in classrooms, the trend in universities will be an update of technological tools to improve processes. However, this will generate new adaptations and new possible problems in people with damages in the visual system.

Therefore, it is relevant to study this phenomenon precisely to be able to focus the use of technology appropriately to vulnerable sectors of the population, not only in different environments, but also for the resolution of activities that allow to a weak-visual user an autonomy in solving a wide kind of tasks.

2   Process Description

In previous studies it was observed that the variation in the activation of the sensory mechanisms was directly linked to the characteristics of the work system. Also, on this previous studies, it was detected that each variation in the technical and sensitive func-tions in an input device, generates a constant des-habituation in a weak-visual person [2]; In this sense, it can be seen that each sensitive variation in the work system affects various micro-processes of temporal interaction such as Focal Attention Processes, hybridization of temporal micro-processes, as well as the generation of break points in the PAFs. Infor-mation that may be relevant to improve the accessibility of certain artifacts in relation to the user. The comparative studies were carried out from the use of two technological devices: a laptop and a multipoint sensor. Static networks were used to represent Case 1. In which the activation of sensory mechanisms and responses given by the user during the process of interaction with the work system of a laptop were registered. And the representation of Case 2, which shows the relationship between sensory mechanisms and the responses given by the user during the process of interaction with the multipoint sensor work system.

2.1 Methodology

The methodology used for these studies was the comparative analysis of data and the use of static networks for the visualization of the information. For this study, the interaction processes carried out by the user in both technological devices were considered in the construction of the networks, as well as the registration of the responses given during the process. The use of this methodology was applied in both cases. The following Tables and Figures describe the analysis process (Table 1):

Table 1. General nomenclature.

Sign	Description	Sign	Description	Sign	Description
Img	Gross motor Interaction	Prop	Propioception	BP	Break Point
PAF	Focal Attention Process	Em	Emotion	AS	Selective Attention
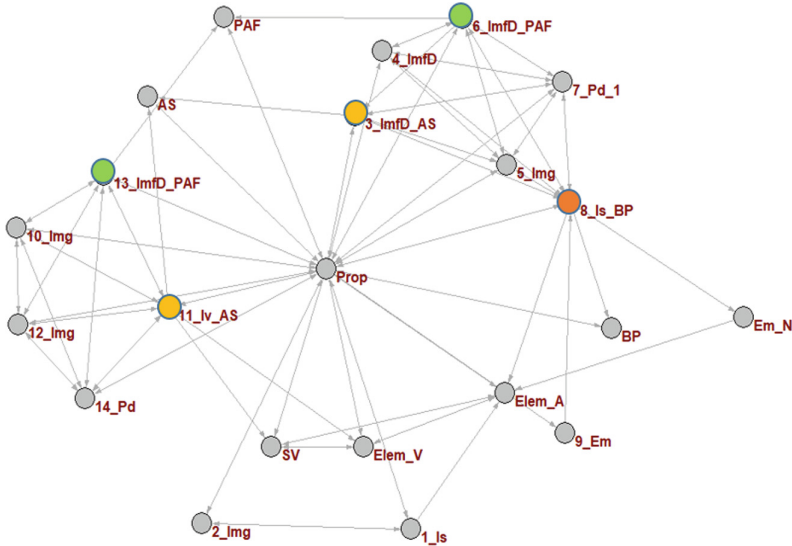
Fig. 1. Static network. Shows the relationship and distance of the sensory mechanisms in the process of interaction with the work system of a KeyBoard. Elaboration Olmos P.L & Gil T.J. 2020.

Figure 1 shows the breakdown of the systemic process performed by the user in the keyboard work system. Which requires precision for the execution of tasks. Likewise, it was observed the activation of the sensory mechanisms of visual interaction (Iv), proprioception (Prop), gross motor interaction (Img), fine motor interaction with fingers (ImfD), digital pressure (Pd), Sound interaction (Is) and the generation of Interoceptive responses were observed. The sensory mechanisms related to spatial location in the user's exploratory interaction processes were: Prop, Iv, Img, ImfD and Pd. Likewise,

with the visualization of the figure, It was noticed that the interaction processes were not carried out continuously, but through multiple temporary micro-processes of systemic interaction and multiple clusters of actors that integrate, in turn, micro-process subsystems that change over the time, a product of internal and external factors to the user. In this sense, it was observed that the user generated mostly fine motor exploratory activities and it took a total of 117.29 s to enter the correct information through the keyboard. This process could be divided into two phases considering information input: In the first phase the user took 63.92 s to enter the information. Being a wrong answer to the system with this the user triggered a stress response. In the second phase, the user took 53.37 s to enter the information correctly.
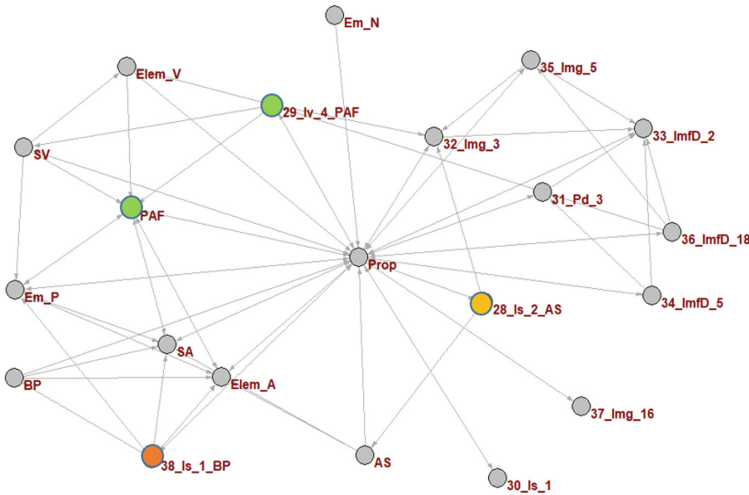
Fig. 2. Static network. Shows the relationship and distance of the sensory mechanisms in the process of interaction with the Weak-visual person with a multipoint system.

Figure 2 shows the breakdown of the systemic process carried out by the user in the multipoint work system. Which handles, compared to the keyboard, a slightly wider range in the precision for the execution of tasks. Likewise, the activation of the sensory mechanisms of visual interaction (Iv), proprioception (Prop), gross motor interaction (Img), fine motor interaction with fingers (ImfD), digital pressure (Pd), Sound Interaction (Is) and the generation of Interoceptive responses can be observed in the process. The sensory mechanisms related to spatial location in the user's exploratory interaction processes were: Prop, Iv and Img fundamentally.

In the same way, it was perceived that the interaction processes were not carried out continuously, but through multiple temporary micro-processes of systemic interaction and multiple clusters of actors that integrate, in turn, micro-process subsystems that change over the time, a product of internal and external factors to the user. In this sense, it was observed that the user generated mostly gross motor exploratory activities due to the sounds the work system generated. In relation to this phenomenon, the user had four moments or phases of rupture with an average in the Focal Attention Processes of

2.75 s observed during a period of 300 s of interaction. Most of the processes carried out were for the spatial location using the Is as a reference point. The user in 300 s could not spatially locate the virtual object from the interaction processes with the multi-point work system, however no generated stress responses.

3 Results

Based on the comparative data analysis the following results were observed: In the first case, it was observed that the user generated mostly the activation of four sensory mechanisms for a spatial location in the keyboard's working system, which were: Prop, Iv, Img, ImfD and Pd. Likewise, the generation of stress responses derived from the precision of the activity were observed. In this sense, it can be seen that the activation of sensory mechanisms in the weak-visual person served in the location or spatial ubication of the user in relation to the components of the work system. Based on this, it was observed that the attentional processes were generated from the activation of various sensory mechanisms, not only the visual one. Despite the fact that during the interaction processes, stress responses were generated, the user was able to execute the task.

In the second case, there was a considerable reduction in the activation of sensory mechanisms in the spatial location of the work system, which were: Prop, Iv and Img. Likewise, it was observed that the user performed his activities in a less precise way due to the characteristics of the work system. Based on this, it was observed that the attentional processes were generated from the activation of various sensory mechanisms, not only the visual one. Despite the fact that no stress responses were generated during the interaction processes, the user could not execute the task in 300 s.

4 Conclusions

The comparative analysis carried out in this document corroborates observations made in previous studies. Each work system offers a sensitive diversity of qualities and this originates multiple adaptation processes of a weak-visual user during the interaction processes. These adaptations require investment of time as well as memorization of spatial data, which can generate high levels of stress due to the precision of the information required by the work system. Likewise, it was observed that attentional processes can be accomplished by the activation of various sensory mechanisms that are dominant at the time, not only by visual ones.

In these studies, it was possible to perceive a clear hierarchy of various temporal micro-processes in a sequential way. In this sense, the spatial location precedes the processes of fine motor interaction. At the same time, it was observed that the construction of the micro-processes of spatial location can be carried out by the weak-visual user from the use of various sensory mechanisms. However, for those work systems that require greater precision, the weak-visual person requires a greater use of sensory mechanisms in relation to the spatial location. For those work systems that require less precision, the weak-visual user requires less sensory mechanisms in activities related to a spatial location. This studies shown an approximation to the way in which the Weak-visual user has to generate a great kind of habituations depending on the sensory characteristics of the

work systems. Similarly, it was observed that the spatial location factor is essential for a weak-visual person in the execution of various activities like the interaction with a precise work system until the performance of activities with less precise work systems. Likewise, a considerable variations were observed in the activation of sensory mechanisms. In turn, there are indications to think that a weak-visual user does not generate modelling activities as frequently as a normal-vision person does, this may be due to the fact that the construction of the mental models of the weak-visual person are always dynamic, that is, this kind of users requires the construction of the mental model in action, in present tense.

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The Hierarchy in the Temporary Interaction Micro-processes that Precede the Breaking Points of Focal Attention in an Object of the New Media

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Abstract. Normal-vision users carry out various types of temporary interaction micro-processes through a wide range of New Media Objects and their work systems, for the execution of several activities of daily living as well as to obtain information. In Mexico, cultural studies have been carried out to obtain an approximation to the phenomenon. A great diversity of characteristics have been observed in the interaction processes in the relationship: user - technological device - object of the new media. Hierarchy of three temporal micro-processes has been detected through static networks techniques in the process of interaction of a user with a Website object with screen technology. In this sense, it was observed that the breaking points in Focal Attention Processes are linked to internal factors related to the user from the activation of specific sensory mechanisms such as motors. In turn, it was observed that the activation of some motor mechanisms are linked to emotional responses. In the same way, it was observed that the emotional responses of the user in the interaction processes with the work system are hierarchized by a hybridization of two temporal micro-processes, and they are joined with the sensitive qualities of the visual symbols. The objective of these studies is to promote reflections on the use of a great variety of technological devices and their heterogeneous objects with a better focalization in different environments such as learning, work, entertainment, among others. As well as in areas of knowledge such as Design, Human Factors, Cognitive Ergonomics, just to mention a couple of them.

Keywords: Temporal interaction micro-processes · Focal Attention · Website · Design · Objects of the new media · User · Normal-vision users

1 Introduction

Nowadays, an increase in the use of a wide range of technological devices can be observed in various Activities of Daily Living (ADL's). Which originates in users the modelling of behaviors, rituals, tasks, kinds of socialization, construction and distortion of reality, among others. These modellings can be appreciated in a great diversity of environments

like those relating to work, to education, to industry, just to mention a couple of them. Particularities of this changes can be observed from the way in which these technological tools are being used for the resolution of various ADL's like: the way in which they are used to design, the hybridization of processes that are carried out, the interaction time, the emerging of new types of problem solving, injuries, new kinds of fatigue, new types of stress, just to name a few examples.

In Mexico, based on cultural studies, it was detected that in a university environment an average of 5 to 10 daily technological devices are being used to solve a diversity of activities of daily living, including educational ones. These technological devices include the use of cell phones, laptops and televisions. It is important to mention that the type of technological devices that are mostly used by this sector belong to the so-called Industry 4.0. In this sense can be observed that this kind of technological developments are, in nature, interdisciplinary technologies that are generating a diversity of cultural-modelling processes depending on, among other factors, the level of knowledge and understanding of the users of the language used by these technological tools, as well as the economic and technological developments of the country to which we refer.

In countries like Mexico, various sectors are investing resources for the generation of an infrastructure that allows expanding a wide range of technologies to a large number of heterogeneous sectors and environments. Which was potentiated with the COVID-19 pandemic. However, there are still very few resources and studies focused on observing the possible effects that the use of these devices of intercultural genesis are generating in a user and group of users. Therefore, it is relevant to study this phenomenon precisely in order to focus the use of technology appropriately, not only in different environments but also for the resolution of various activities and problems. From this perspective, one of the problems that must be studied is the generation of a possible cultural modelling in the use of various devices, mostly linked to recreational and entertainment activities in university sectors, also the use undifferentiated of the technological tools.

In this sense, one of the most common new media objects used for a sector of University students in Mexico are Websites with screen technology. In the observation of the processes of interaction with the users, they were detected a plural series of temporary micro-processes. Likewise, it was observed that the break points in the Focal Attention Processes (PAF) were linked to factors internal to the user from the activation of specific sensory mechanisms.

2   Process Description

In previous studies it was observed that the variation in the activation of sensory mechanisms were directly linked to the characteristics of the Object of the new media and the technological device [1]; This in turn affected various micro-processes of temporal interaction such as Focal Attention Processes, hybridization of temporal micro-processes, as well as the generation of breaking points in the PAFs. The comprehension of this information could be relevant in Art and Design learning environments for the construction of reflections in the correct use of heterogeneous technological tools as well as the use of a great diversity of virtual objects based on specific studies. The analysis of this process was divided into two phases: the first phase was related to the interaction processes

carried out with the object of the new media and the second one was related to the observation of the behavior of temporal micro-processes in the user.

The studies were developed starting from the observation of the interaction processes carried out by 12 persons with normal vision (Nv) with a Website object. The users are from a University sector belonging to the design areas. The device used was the cell phone. Static networks were used for the representation of Phase 1. In which the relationship of the sensory mechanisms and their relationship with the responses given by the user during the process of interaction with the object and its work system was shown. In Phase 2, the behavior of the temporary micro-processes of interaction was observed and statistical techniques were used for their visualization of data. The object of the Website did not have audible information.

2.1 Methodology

The methodology used for these studies was the comparative analysis of data and the use of static networks and statistical techniques for the visualization of the information. For this study, the interaction processes carried out by the user from the Website object and the answers given during the process were considered in the construction of the networks. The users performed the following tasks: 1. Locate the object of the new media in the work system 2. Enter to the object of the new media. 3. Perceive the information of the object of the new media. The following tables and Figures describe the analysis (Table 1).

Table 1. General nomenclature.

Sign	Description	Sign	Description	Sign	Description
Img	Gross motor Interaction	Prop	Proprioception	BP	Break Point
PAF	Focal Attention Process	Em	Emotion	AS	Selective Attention

Figure 1 shows an example of the decomposition of the systemic process carried out in each user. Likewise, it shows the activation of the sensory mechanisms of visual interaction (Iv), Proprioception (Prop), Gross motor interaction (Img), Fine motor interaction with fingers (ImfD), Interoceptive responses (Intero), sound interaction (Is). From its visualization, it could be seen that the dominant mechanisms throughout the process were visual interaction (Iv), gross motor interaction (Img) and proprioception (Prop), and they were the processes which corresponded the highest degree. Likewise, it was noted that the interaction processes were not carried out continuously but through multiple temporary micro-processes of systemic interaction and multiple clusters of actors that in turn integrate sub-systems of micro-processes that change throughout of time, product of internal and external factors in the user. In this sense, the analyzed group had ninety-four moments or phases of rupture with an average duration of 14.6186 s in the Focal Attention Processes observed in a period of 300 s. The BPs in turn generated the affectation of other temporary micro-processes such as Selective Attention in a cyclical way. With these results, it was possible to appreciate a hierarchy of three temporary

micro-processes of interaction of the user group in relation to the activities carried out with the Website object linked to the search for information with the use of technology screen. The three temporary interaction micro-processes identified were: Selective Attention, Focal Attention Processes and break points in a sequential way. On the other hand, it was detected that the sensory mechanism that gave rise to the temporal micro-processes of the AS was the Img. In the case of the temporal micro-processes of the PAFs the sensory mechanism that gave them rise was the Iv, and the sensory mechanism linked to the BPs was the Img. In the same way, it was observed that the sensory mechanism that was most related to emotional responses were internal to the user, whose effects were perceived from the activation of the Img. Likewise, it was observed a relationship of emotional responses with factors external to the user and linked with the activation of the Is. In turn, the activation of the Img and the Is were found strongly linked to symbolic factors of the analyzed object and external to it. A distance 1 of the proprioceptive processes (Prop) was perceived with each and every one of the active sensory mechanisms during the process, as well as the responses given by the user. Which indicates its centrality.
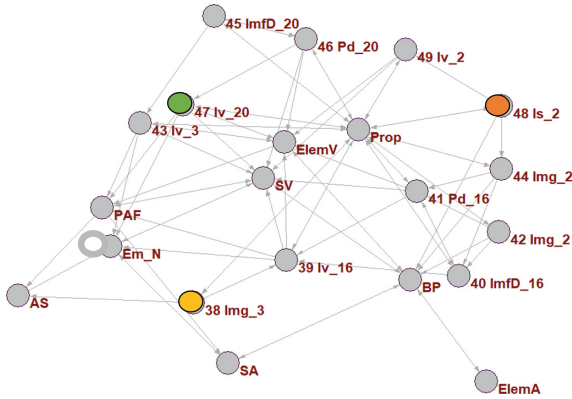
Fig. 1. Static network. Shows the relationship of the sensory mechanisms in the process of interaction with the Website Object. Elaboration Olmos P.L & Gil T.J. 2020.

3   Results

Based on the comparative data analysis the following results were observed: In the first phase, it was observed that the group of users generated mostly the activation of the sensory mechanisms related to: Proprioception (Prop), Visual Interaction (Iv) with a high degree. Likewise, the activation of sensory mechanisms of gross motor interaction (Img) was observed as a result of specific micro-processes. In this sense, it was observed that the activation of sensory mechanisms of a higher degree are related to the spatial location or spatial ubication of the user in relation with the visual symbols. Based on this, it was perceived that the temporary micro-processes of interaction of the PAFs were generated after the AS, whose genesis is basically spatial, and was broken from internal and external

factors in the user. These results had already been shown in analyzes of other objects of the new media [2]. Likewise, during the temporal micro-processes of the PAFs, the link with responses of the Interoceptive type (Intero) were observed in the user, which were linked with Emotions. Sensory mechanisms directly related to emotions were classified into two large groups: in relation to their functions and in relation to the user. From this perspective, the function of the mechanisms were directly linked to the construction of spatial micro-processes as a pattern that has been observed in other studies [3]. In relation to the user, the activation of the mechanisms were identified resulting in two kinds of responses: 1) Internal to the user, based on gross motor interaction responses. 2) Responses given by factors external to the user, related to stimuli that are capable of activating sensory mechanisms that break with temporary micro-processes of the PAFs and were mostly linked to the activation of the Is processes.

In the second phase, it was also observed that the emotional responses of the user in the processes of interaction with the object were hierarchized by a hybridization of two temporal micro-processes: AS and PAFs linked to visual symbolic factors. Consequently, the Interoceptive responses (Intero) of the user were more likely to be generated by Visual Interaction (Iv) through visual Symbols (Sv). Therefore, Emotions were directly related to PAFs. In relation to the process that precedes the AS, the PAFs and the interoceptive responses, it was observed that the BPs were further away from these micro-processes of temporal interaction as observed in (Fig. 2), however they behave as a latent factor and always increasing once the micro-processes that precede them have started (Fig. 2).
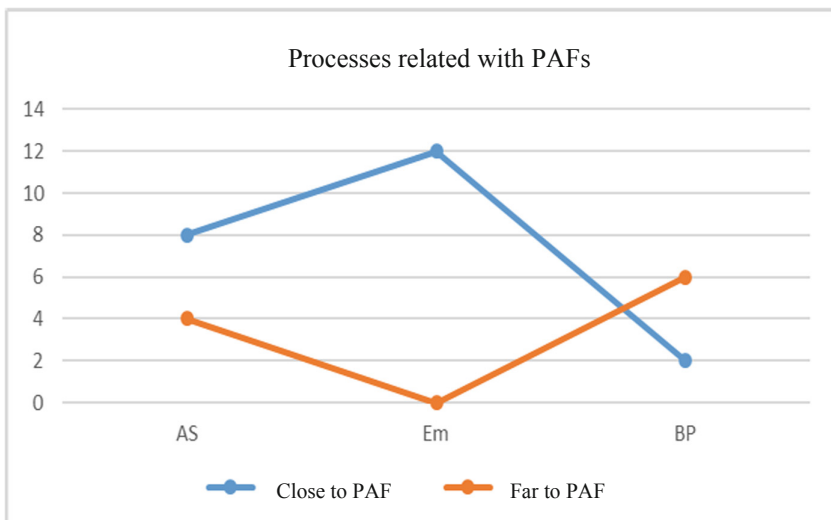
Fig. 2. Relationship of the temporal micro-processes of interaction. Elaboration Olmos P.L 2020

4   Conclusions

These studies show a specific analysis related to the use of a one kind of technological device and the diversity in the objects it host, which can provide a prospective for their use in certain environments such as learning environments. In this sense, now is important to consider not only problems related to usability, accessibility, human factors but also the studies must be addressed in the possible effects that are being generated with its use and the construction of possible modells.

Also, in these studies, it was observed that there were at least 3 temporary micro-processes that precede a breaking point during the interaction processes carried out by a group of normal-vision users with the Website object. These processes were: selective attention, processes of focal attention and emotional responses.

Likewise, it was possible to perceive a clear hierarchy of these temporary micro-processes in a sequential way. Based on this, Selective Attention and Focal Attention Processes are the first temporary micro-processes that precede the breaking points. Both micro-temporal interaction processes are related to the construction of spatial factors. It was also observed that the AS had a general spatial location functions and the PAFs were linked to specific spatial factors. Based on this, it can be affirmed that the BPs that were generated in the micro-processes of interaction that precede them were basically spatial. Likewise, the interoceptive responses of the user were directly linked to the PAFs and can be expressed as emotional responses that were originated from the hybridization of interaction processes related to two factors: the temporary micro-processes of interaction carried out during PAFs as well as with the activation of sensory mechanisms that were mostly viso-spatial, and the temporal micro-processes of AS that precede them. Which were basically spatial, determined by the activation of sensory mechanisms of the Prop, Img and Iv.

With these observations, in turn, a correspondence with other studies carried out on the YouTube object were linked. From which was observed that in the first phase of interaction with the YouTube Object, user interaction processes related to spatiality were generated, and in the second phase, interoceptive responses were generated in the user related to the focus of the objects [1].

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User Experience, Affordance and Technology

Comparison of Touch and Touchless Zoom Control Methods for Single-Handed Mobile Interaction

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Abstract. We conducted a user study comparing the accuracy and speed of three zoom methods for touch-screen devices. The comparison was between touch and touchless zoom methods. One method is GyroZoom which uses the mobile phone's rotation to zoom in and zoom out. It is named after the gyroscope sensor in smartphones to detect the angle and amount of device rotation. We constrained our research to single-handed interaction. The pinch-to-zoom method, also tested, is the standard touch-screen gesture method. VolumeZoom was the third method and does not require the user to touch the screen. Instead, the user presses the physical volume buttons that are normally used to increase or decrease volume; they were reprogrammed to perform zoom operations. The user study engaged 12 participants and employed a Google *Pixel 3a* smartphone. GyroZoom was 18.1% faster than the traditional pinch-to-zoom method and it was more efficient. VolumeZoom was the most efficient method of the three but was 18.9% slower than pinch-to-zoom. Participants gave favorable and preferential ratings for using GyroZoom and VolumeZoom over pinch-to-zoom in a single-handed usage scenarios.

Keywords: GyroZoom · VolumeZoom · One-handed · Single-handed · Zoom method · Zoom control · Rotation · Volume · Mobile-interaction · Human-computer interaction

1 Introduction

Mobile devices offer multi-touch capabilities that allow users to perform gestures to perform various operations. Zooming is one of the most highly performed operations on mobile phones. It is vital to have a natural and smooth strategy to change levels of zoom. One notable interaction technique that was introduced in 1999 and later commercialized by Apple in the *iPhone* is commonly known as pinch to zoom [1]. It facilitates users to zoom by a two-finger pinch, which usually requires two hands: One hand holds the device while the other performs the pinch gesture. It is a widely used and works accurately until you are asked to operate it with a single hand. Holding the phone and using the same hand to do a pinch gesture to zoom in and out becomes difficult and inefficient. Furthermore, requiring two hands makes pinch gestures unrealistic when users are moving, walking, or on public transport. Although, other techniques of interaction such as double-tap and

two-finger tap are available for zoom control they are not as intuitive and flexible and also are equally challenging to perform with a single hand.

There are multiple ways to perform pinch interaction for zooming. In Fig. 1a, the user holds the device in one hand and performs the gesture using the other hand. In Fig. 1b, the user holds the device in both hands and uses both thumbs to perform gestures. In Fig. 1c, the user single-handedly performs a pinch-to-zoom gesture and holds the device. However, this last procedure causes an abnormal and uncomfortable hand posture. Users are frequently compelled to play out the pinch-to-zoom motion using one hand. Most cell phones additionally utilize a double-tap gesture which takes into consideration zooming in or out by double-tapping a zone of interest. While this strategy functions admirably with one hand, it just considers zooming by a discrete amount instead of a flexible interactive zoom.
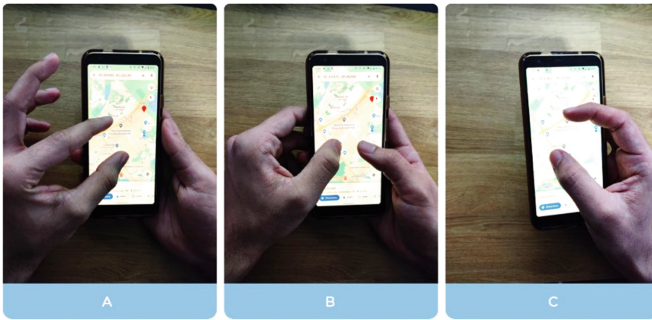
Fig. 1. Three ways to perform pinch-to-zoom gestures. See text for discussion.

According to a user survey on user habits and preferences on mobile usage, 66% of 228 users preferred using single-handed interactions while 9% of users preferred both hands for gestures and 23% did not express a preference [2]. We are currently constraining our research to strictly single-handed interaction.

In this paper, we introduce VolumeZoom as an alternative zoom method. Volume-Zoom uses the volume keys in a mobile device to perform zoom interaction. In Fig. 2, the volume-up key is used to zoom in and the volume-down key is used to zoom out. This is potentially an effective way to utilize the volume keys for zooming, as the interaction is easily performed using a single hand.

We introduce another new method called GyroZoom which does not involve any button press or touch gesture on the screen. In Fig. 2, it is shown that GyroZoom utilizes the gyroscope sensor of the mobile device to calculate the rotation of the device in real-time. Depending on the angle and direction of rotation, it zooms in or out by a corresponding amount. Clockwise rotation results in zooming in and the angle of rotation controls the amount of zoom. Similarly, anti-clockwise rotation results in zooming out and the angle of rotation controls the amount of zoom.
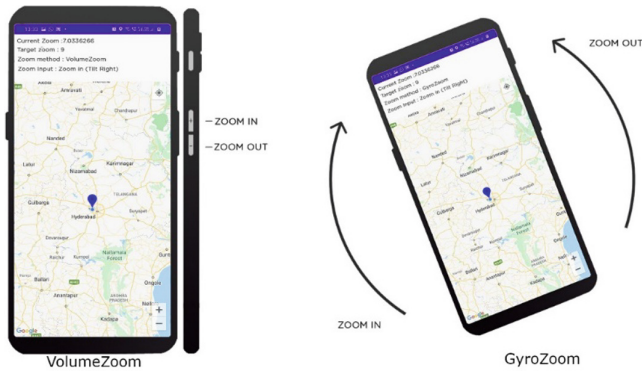
Fig. 2. VolumeZoom and GyroZoom method demonstration.

In this paper, we evaluate and compare the performances of touch and touchless zoom control methods. Hence, user performance for VolumeZoom (touchless button control) and GyroZoom (touchless) are evaluated. The results are compared to the standard pinch-to-zoom (touch) method demonstrated above when performed single-handedly.

2 Related Work

Table 1 summarizes the results from five publications where user studies were performed utilizing zoom methods to interact with the device.

Farhad and MacKenzie [3] compared the performance of two zoom methods when performed with a single hand. The results from tap-and-drag were generally good for single-handed usage. Also, tap-and-drag performed slightly worse in accuracy but over time, as participants become more familiar with tap-and-drag, performance improved.

Ti and Tjondronegoro [4] assessed a collection of tilt-based input methods for single-handed zooming. They analyzed the outcomes against traditional touch-based zooming and found that tilt-based methods are better than touch-based methods when performed with one hand. All participants found the traditional touch-based methods inferior due to the uncomfortable hand posture when performed with one hand. Nonetheless, they favored using pinch-to-zoom when two hands were accessible.

Lai et al. [5] assessed a single-handed partial zooming procedure. ContextZoom permits users to point to any spot on a display by long-pressing the location as the zooming focus (i.e., focal point). When the area is set, the user moves their thumb on the display to zoom in or out. Panning is disabled while zooming. The results were acceptable, with the completion time and the number of discrete activities, by and large, low. Participants likewise announced more significant levels of apparent adequacy and overall satisfaction.

Boring et al. [6] proposed Fat Thumb, a single-handed method that utilizes the thumb's contact size as a type of recreated pressure. The contact size takes into consideration toggling between panning and zooming relying upon the contact area.

Harrison et al. [7] presented a technique called Lean and Zoom that detects a user's proximity to the display using a camera and magnifies the on-screen content proportionally. Results from the user study indicate that users believe this interaction technique is intuitive, increases comfort, and improves performance.

Table 1. Summary of zoom interaction user studies

1st Author	Type	Handedness	N	Notes
Ti [4]	Touchless	Single	15	Flip Gesture performed significantly better than touch-based controls (1.83 s faster). Tilt and Hold was slower than touch-based control, but their difference was not significant
Lai [5]	Touch	Single	23	ContextZoom outperformed two-finger tap in both task completion time and number of discrete actions
Farhad [3]	Touch	Single	12	Tap-and-drag performed 17.9% better in terms of speed and 47.2% better in terms of efficiency as compared to the traditional touch method (pinch-to-zoom)
Boring [6]	Touch	Single	24	User study of panning/zooming revealed that Fat Thumb is fast (especially when large zoom factors are required), non-fatiguing, and the preferred technique, all while maintaining the offset rates of other techniques
Harrison [7]	Touchless	Hands-Free	10	The Lean and Zoom system detects a user's lean position and proportionally magnifies on-screen content. Results from a study indicate that users believe this interaction technique is intuitive, increases comfort, and improves performance

3   Method

A user study was conducted to compare the three user-interactive zooming methods for one-handed interaction. The goal was to compare the three zooming methods in terms of quantitative measures, user preference and ease of use.

3.1   Participants

Twelve participants were recruited remotely from different universities across Canada. Six were male, six were female. Ages ranged from 22 to 26 years. All participants were comfortable using smartphones. Participants were compensated with $20 for their assistance.

3.2 Apparatus

The experiment was conducted on Google *Pixel 3a* running the Android (11.0) operating system. The device has a 5.6-inch OLED display with a resolution of 2220×1080 pixels and a density of 441 PPI. The weight of the device is 147 g.

The software was developed in Java using the Android SDK in the Android Studio environment. The experimental application was developed specifically for this research. Three zooming methods were implemented in the application.

The application begins with a configuration activity that prompts the user to select the participant code and other experimental parameters, like the zoom method and a group code (for counterbalancing). Once configured, the user presses a START button to initiate the testing process. The main activity contains a map zooming user interface.

The text software presented the participant with the desired zoom direction and target zoom and stated the direction and amount of zoom required for completing the trial successfully. The user interface also displayed the real-time current zoom for the user to match with the target zoom. After the current zoom matches the target zoom, the user pressed the FINISH button to end the trial and advance to the next trial.

3.3 Procedure

Participants were informed and explained the purpose of the user study. They were requested to keep the Internet switched on during the entire experiment. They were shown videos explaining each zoom interaction method. They were also given a few practice trials. For testing, participants were seated and instructed to do the trials single-handedly. They were also asked to use whichever hand they feel comfortable with within trials. Arm support or any kind of armrest was not allowed.

With this brief introduction, testing began. Participants completed five trials per zoom method. Each trial consisted of a randomized sequence of combinations of zoom direction (in or out) and zoom level (low, medium, high). Each participant took about 15–20 min to complete the experiment. The data were stored in a remote database in Google *Firebase* over the Internet. The data were analyzed later for meaningful insights.

After the testing was complete, the user was prompted with a questionnaire to gather feedback on their preferences of the zoom methods.

3.4 Design

The user study employed a $3 \times 3 \times 2$ within-subjects design. The independent variables and levels were as follows:

- Zoom method (GyroZoom, VolumeZoom, Pinch-to-zoom)
- Zoom level (low, medium, high)
- Zoom direction (in, out)

Each participant completed 5 trials for each zoom method. The total number of trials was 12 participants $\times$ 3 Zoom Methods $\times$ 3 Zoom Levels $\times$ 2 Zoom Direction $\times$ 5 Trials = 1080.

To offset learning effects, participants were divided into three groups to counterbalance the order of testing the zoom methods. The zoom level and zoom direction conditions were chosen at random. The dependent variables were completion time per trial and efficiency. A detailed explanation of the calculation of efficiency is given in the results section.

4   Results and Discussion

All trials were completed successfully. The data were later imported into a spreadsheet tool where summaries of various measures were calculated and charts were created. The analysis of the variance test was performed using the GoStats [8] application.

4.1   Completion Time

The grand mean for completion time was 7.45 s. By zoom method, the means were 6.58 s for GyroZoom, 8.26 s for VolumeZoom, and 7.51 s for Pinch-to-zoom. As seen in Fig. 3, trials using GyroZoom were 18.1% faster than the traditional pinch-to-zoom method. VolumeZoom was seen 18.9% slower than pinch-to-zoom. There was a clear pattern in the data showing that the zoom-out operation in VolumeZoom was always faster than zoom-in. This could be due to the ease of accessibility and reach to the volume-down button compared to the volume-up button.

An analysis of variance was done to examine the mean completion times of the 12 participants while doing the zoom trials. The effect of zoom method on completion time was statistically significant ($F_{2,22} = 110.6$, $p < .0001$). The effect of zoom level on completion time was also statistically significant ($F_{2,22} = 888.0$, $p < .0001$). However, the effect of zoom direction on completion time was not statistically significant ($F_{1,11} = 1.27$, $p > .05$). The zoom method $\times$ zoom level interaction effect was statistically significant ($F_{4,44} = 9.46$, $p < .0001$), as was the zoom method $\times$ zoom direction interaction effect ($F_{2,22} = 5.71$, $p < .05$). The zoom level $\times$ zoom direction interaction effect was not statistically significant, however ($F_{2,22} = 1.002$, $p > .05$). Group effects were not statistically significant.

4.2   Efficiency

Efficiency is a measure of how usable or effective a zoom method is. It is defined as the number of zoom switches performed per trial. For example, if a user is required to zoom-in until the current zoom equals the target zoom, but, by mistake, the user zooms in more than required, then performs a zoom-out operation to finish the trial successfully, the extra zoom transition is counted as 1. Obviously, lower scores are better.

In Fig. 4 it is clearly seen that VolumeZoom has higher efficiency than the GyroZoom and Pinch-to-zoom. Pinch-to-zoom is the least efficient method according to the user data. From the analysis of the variance, we found that the effect of the zoom method on efficiency was statistically significant ($F_{2,22} = 162.2$, $p < .0001$). The remaining effects were not statistically significant.
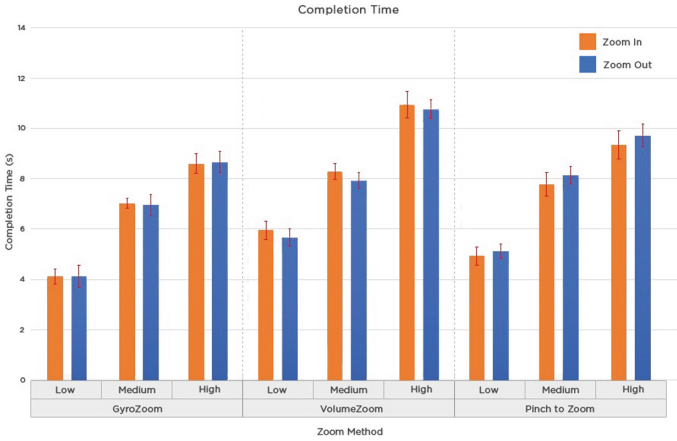
Fig. 3. Completion time (s) by zoom method, with error bars shown in red.
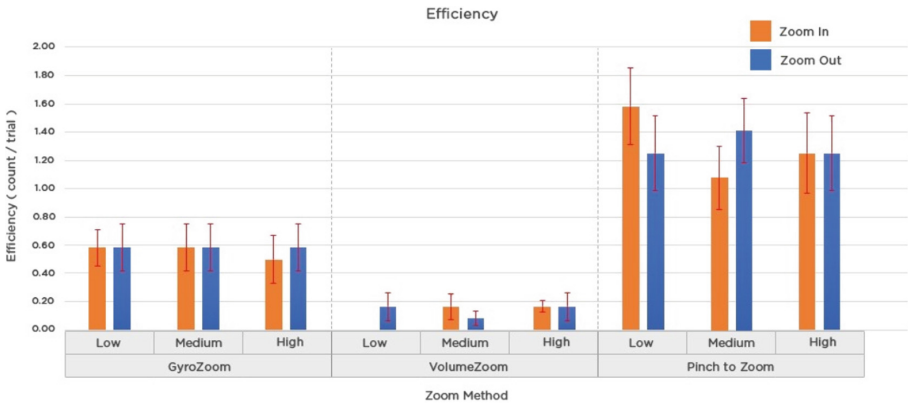
Fig. 4. Efficiency by zoom method, with error bars shown in red. Lower scores are better.

4.3 Participant Feedback

In the post-experiment questionnaire, participants were asked their preference of the zoom method on a scale of 1–5. A Friedman test was performed using the GoStats [8] application. The differences by zoom method were significant ($\chi^2 = 15.395, p = .0005$). Using a post hoc test, it was observed that the pairwise comparison of GyroZoom with Pinch-to-Zoom and VolumeZoom with Pinch-to-Zoom were statistically significant.

Most participants stated that they find single-handed pinch-to-zoom extremely frustrating to use as it results in an awkward hand posture. They found it easier using both hands. Some expressed concerns about dropping the phone while performing pinch-to-zoom by a single hand. One participant noted.

> *GyroZoom is an innovative method while I am walking, and I
> need to single-handed perform zoom operations. I also find
> VolumeZoom to be easy to use.*

Overall, participants praised both VolumeZoom and GyroZoom in subjective feedback and indicated a preference for these over the traditional pinch-to-zoom method. The average ratings for GyroZoom and VolumeZoom were 4.3 and 4.2 on a scale of 1–5.

5   Conclusion

An experiment was conducted comparing the performance of three zooming methods when performed using a one hand. The results for our newly introduced methods were significantly better compared to the traditional pinch-to-zoom method (performance using a single hand). GyroZoom performed 18.1% faster than the traditional pinch-to-zoom method and was more efficient. VolumeZoom was the most efficient method of all three, but was 18.9% slower than the pinch-to-zoom. Overall, the participants gave a favorable and preferential ratings for using GyroZoom and VolumeZoom over pinch-to-zoom for one-handed interaction.

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The Influence of Icon Color and Style on Mobile Menu Icon Search

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Abstract. Graphical user interface design, ICONS are widely used. Icon background color and icon form have a certain influence on icon identification and usability. At present, the research on icon style and color is mainly in the theoretical level, but lack of practical experimental research to investigate how they affect users. According to the search time of users, through statistical analysis, the experimental results showed that, for ICONS without schemata association, the linear icon in monochromatic background had the shortest reaction time, followed by monochromatic background icon, polychromatic background linear icon, and polychromatic background polychromatic icon. The results of this study can provide references for future mobile phone icon design and help to achieve a better search environment in line with human vision.

Keywords: Icon color · Icon style · Search speed · Cognitive load

1 Introduction

1.1 Icons

As an essential part of the Graphical User Interface (GUI), an icon is a graphical or semantic symbol on the screen of a computer or electronic device that prompts the user to perform an action [1]. The most important feature of an icon is the referential nature, being one that corresponds to a tool, object or function.

Scholars have studied factors influencing the speed of icon cognition from different perspectives. In terms of the physical structure of icons, the shape, color and internal features of icons (text, symbols), the style (flat, anthropomorphic), the size (large, small and medium size), the complexity of color, the array of different icons, etc. all affect people's fixation time, search speed and accuracy.

1.2 Visual Search

Visual search refers to the search of a specific target object in a background is not only acquired through People's Daily behavior [2]. External information and processing of an important way, but also many special important components of the gating task, such as map reading, luggage X and so on. Icons have the ability to overcome language barriers and effectively reduce usage household cognition and memory burden, easier recall and recognition than text, and beautification of the interface.

2   Content and Hypothesis

This study focuses on the physical influences of icons, and intends to examine the differences between icon shapes and background colors from the perspective of cognitive speed. In the first phase of the experiment, a reaction time experiment was conducted for the combination of color and shapes of interface icons of mobile phones. The second stage was a subjective evaluation test. Four influences were present in this experiment. a. Multicolor background × linear icon b. Monochromatic background × linear icon c. Multicolor background × faceted icon d. Monochromatic background × linear icon. All four experimental situations are shown in Fig. 1.
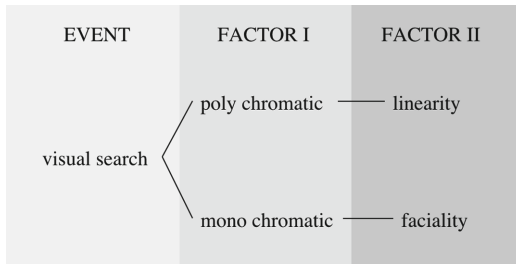
Fig. 1. The main variables of visual search

This study investigates whether icon background and icon symbols affect menu selection time. The hypotheses are as follows:

Hypothesis 1: The background color of the icons affects the selection time
Hypothesis 2: The symbolic form of the icons affects the selection time
Hypothesis 3: The background color and the symbolic form of the icon have an interactive effect on the selection time of the menu
Hypothesis 4: Linear icons have less recognition search efficacy than faceted icons in monochrome backgrounds
Hypothesis 5: Linear icons have greater recognition search efficacy than faceted icons in polychromatic backgrounds

3   Study 1

3.1   Icons Recognition

Given that the picture icons of existing mobile devices are relatively common and uniform in meaning, users interact with the icons frequently. Therefore, controlling variables and eliminating common icon content can minimize the interference of usage habits for selection time. According to Leung et al. [3], icons with a high level of figuration can avoid the recognition load added by abstract icons, which reduces the efficiency of icon search [3]. And each group of graphics was outlined and filled in black. Figure 2 presents the linear "cherry" graphic symbol (left) and the face icon (right). Icons are 26 * 26 mm
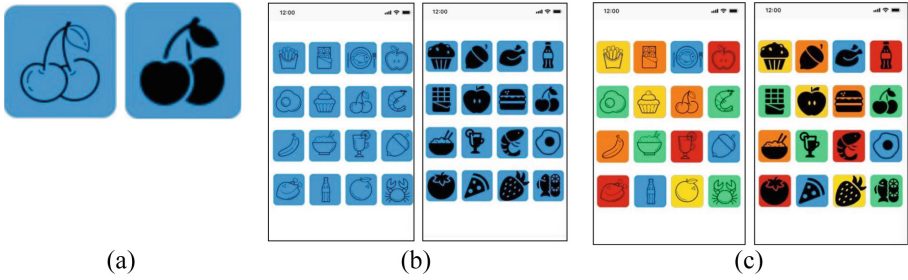
Fig. 2. (a) Cherry linear icon (left) and face icon (right); (b) Monochrome background linear icon (left) and faceted icon (right); (c) Polychromatic background linear icon (left) and faceted icon (right).

in size on the screen. The size of the icon frame is 80 pixels * 80 pixels and the size of the icon is 55 pixels * 55 pixels. The size of the grid menu is 4 * 4.

Species colors that can be quickly distinguished by the human visual system, based on the HSB pattern. Brightness, uniform saturation 90%, brightness 90%, polychromatic background selected the following colors: Yellow, Orange, Blue, Green.

3.2 Subjects

Twenty students were enrolled in a university in Jiangsu. Among them, 10 were male subjects, age from 22 to 26 years. All subjects had visual acuity (corrected visual acuity) of 5.0 or higher and were right-handed, and were familiar with the use of computers and mobile devices with no color blindness or color weakness.

3.3 Procedure

The computer used for the experiments was a 13.3-inch MacBook Pro with a display resolution of 1280 × 800. Photoshop 2019 was used to create 64 icons. Icons were used for the formal experiment as shown in Fig. 3 E-prime 2.0 software were used to collect data.
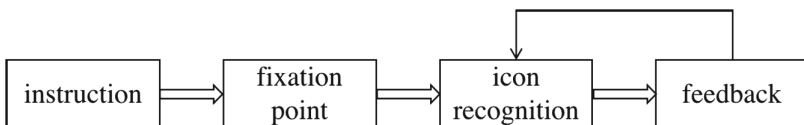
Fig. 3. Process of a formal experiment

At the beginning of the formal experiment, a 500-ms fixation point was presented in the center of the screen as in Fig. 4. Then the stimulus icon was presented at the same location, and the experimental interface with a 4 * 4 grid appears simultaneously above the stimulus icon code. The stimulus icon kept appearing until the subject responded correctly and clicked on the icon in the interface.
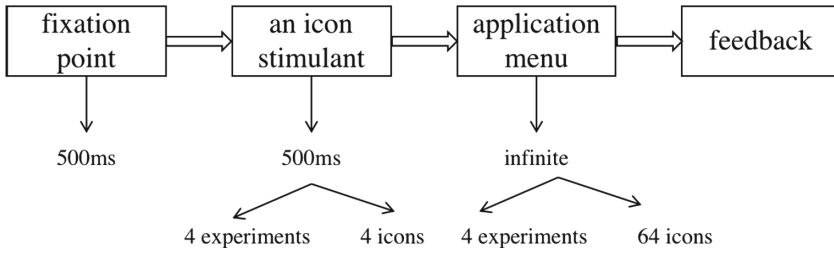
Fig. 4. Reaction time test flow.

3.4 Results

Table 1, presented in the form of box diagram through ANOVA analysis. The background color of the icon had a significant effect on the menu selection time, $f(1,127) = 0.54$, $p < 0.05$. Note that regardless of the icon image, the icon with a polychromatic background color has a greater reaction time ($x = 2.94$, S.D. $= 0.14$) than the monochromatic background (Fig. 5).

Table 1. Descriptive statistics of experiment

No.	Background color	Icon style	Mean per second	Standard deviation
1	Polychromatic	Linearity	2.60	0.80
2	Monochromatic	Linearity	2.58	1.60
3	Polychromatic	Faciality	3.36	1.15
4	Monochromatic	Faciality	2.94	0.72
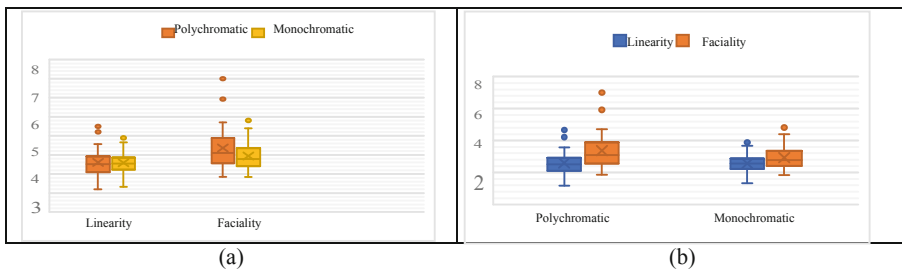
Fig. 5. (a) The linear and faceted icons for the average response time; (b) The polychromatic and monochromatic background for the average response time

In addition, Fig. 8 shows that image form has a significant effect on menu selection time, $F(1,127) = 2.36$, $p < 0.05$. No matter what the background color of the icon is, the shape of the icon will affect the selection time of the menu, in which the face pattern takes longer to search than the linear pattern (Table 2).

Table 2. Two-factor ANOVA tables

Difference source	Degree of Freedom	F value	P value
Background color	1	2.04	0.04
Image type	1	2.36	0.03
Interacted	128	6.88	0.17

The result of ANOVA analysis showed that the interaction $P = 0.17$, the background color and image type of the icons had no significant difference, and the menu response time was not affected by the two factors.

4   Study 2

4.1   Subjective Experiment

Experiment 2 asked subjects to make a subjective evaluation of their recognition in order to examine the factors influencing the gender of the diagram and the subjective preferences of individuals, and to compare it with the previous behavioral measurement experiment.

4.2   Procedures

Combined with the previous experimental results, the question (i.e., "How recognizable do you think this interface is") was presented on the phone screen, and four interface images were presented in order. According to the Lister scale, a score of 5 indicates strongly satisfied, 4 is satisfied, 3 is fair, 2 is dissatisfied, and 1 is strongly dissatisfied. Each subject scored from 1–5 for each question [4].

4.3   Results

The statistical results of the subjective scores for the recognition of the icons are shown in Figs. 10. It can be seen from the figures that the highest mean scores were obtained for the polychromatic background × linear pattern, and the lowest mean scores were obtained for the monochromatic background × linear icon. The alpha value was 0.873 (Table 3).

Table 3. Subjective ratings of four questions in terms of discrimination

	Average	Standard deviation
Polychromatic × Linearity	4.37	0.33
Polychromatic × Surface	4.19	0.42
Monochromatic × Linearity	3.86	0.48
Monochromatic × Surface	3.18	0.60

5   Conclusion and Discussion

5.1   Conclusion

The aim of the study was to investigate whether the background color and pattern of icons had an effect on menu search time. The results showed that both variables (icon background color and icon form) had significant effects.

(1)   The background color of the icon has a significant effect on the search time of the menu. The response time of monochromatic background search is longer than that of polychromatic background search.
(2)   Icon symbol form affects menu selection time. The linear symbol has shorter reaction time than the surface symbol.
(3)   Icon background color and icon symbol form have no interaction with menu selection time.
(4)   On monochromatic background, linear icon recognition is more effective than face icon.

5.2   Discussion

As far as the icon style factor is concerned, we can also subdivide the sub-factors such as the lightness and saturation of the icon style. In addition, the study subjects are young and familiar users in China, and the test subjects generally have bachelor degree or above, without considering the possible influence of different nationalities, different ages and cultural levels, whether the findings of this study have the same external validity can be further explored in future studies.

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A Complex Form Design to Improve the Efficiency and Emotional Experience During Information Entry

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Abstract. As a basic common component, forms are ubiquitous in user interfaces. When designing a form page, it appears to be a combination of basic components such as buttons, input boxes, and prompt messages. However, in the actual case, there are countless details that can be deliberated, especially complex forms due to their relatively important function. As the filling process is complicated, some factors such as unclear level and information, or unreasonable interactive feedback, which can greatly reduce the efficiency of information input and cause a very frustrating experience. In order to solve these problems, this article studies the design strategies of complex forms from the perspective of information entry efficiency and emotional experience. First, we disassemble the complex form into basic elements and propose how to choose the appropriate form type and layout. Then we proposed some help and guidance to avoid making users encounter difficulties. Finally, we shared some interactive feedback strategies and some design details.

Keywords: Form design · Efficiency and Emotion · Interface design

1 Introduction

A web form page is a human-computer interaction interface running on a computer browser. Compared with ordinary pages, its notable feature is that it allows users to input and transfers the information with the target server [1].

The 21st century is an open and diversified Internet era. Users have become important participants and creators of Internet content. The popular Internet applications and the rising self-media have enabled more information exchange between users and platforms. In some business scenarios, people establish websites and use registration forms to achieve user conversion and ultimately obtain commercial benefits [1]. Q&A communities and knowledge forums use form functions to edit and release new content, exchange opinions, and enable users to share each other's experiences and insights. Office automation systems use forms to improve office convenience and work efficiency.

When designing a form page, it appears to be a combination of basic components such as buttons, input boxes, and prompt messages. However, in the actual case, there are

countless details that can be deliberated, especially complex forms, due to their relatively large fields and unique functions [2]. The use of complex forms is complicated. Once the level is unclear, the information is unclear, and the interactive feedback is unreasonable, which will limit the whole process of information exchange and produce a bad experience and impression for users. Therefore, this article aims to study the design strategy of complex forms, combining relevant literature and personal actual project experience, hoping to form a reference method for complex form design, effectively improving the efficiency and emotional experience during information entry.

2   Choose the Right Form Type

There are two types of forms in common use: step-by-step forms and grouped forms.

Step-by-step forms are often used in scenarios where there are many input items, the business itself is process-oriented, and users need to submit information step by step. Step-by-step forms can improve user filling efficiency and reduce users' psychological burden. It divides a lengthy form task into multiple steps and guides users step by step, effectively alleviating users' resistance when they need to fill in more content. The step-by-step form allows users to focus on the content filled in at each step by splitting the steps. So users can focus on the current task and improve the efficiency of information entry, and which relieve anxiety by reducing the information pressure on the vision. Finally, it also makes users to clearly know where they are in the task, and what they have completed and unfinished. But it also has disadvantages. Users cannot prepare all the information that needs to be filled in at one time, because only after completing this step can they know what needs to be filled in the next step.

Grouped forms are suitable for the scenario of submitting large quantities of data at one time, but in order to reduce the user's filling pressure, it is necessary to apply the similarity principle of the Gestalt principle to visually group the related filling contents to reduce the cognitive difficulty and ease the anxiety of filling out long forms for the user. Since this type of form is submitted only after one-time filling, the platform needs to provide a real-time save function so that users who exit in the middle can find the draft and continue to complete it [3]. In addition, if the form is too long, the form can also provide a folding function, and the user can fold it after filling to reduce visual information. If you do not need to browse between modules at the same time, you can also design the folding function as an automatic mode, that is, only the first module is expanded by default. If the user expands other modules, the last expanded module is automatically collapsed. This function greatly optimizes the visual length of long forms and reduces the visual pressure of users. Long forms no longer require long scrolling operations, and only need to click to switch between modules freely (Fig. 1).

Fig. 1. Step-by-step forms and Grouped forms.

3   Choose a Reasonable Layout

There are two common layout methods for forms: Single-column Layout and Multi-column Layout.

Single-column Layout: At present, more and more forms use single-column layout. Its main advantage is that the single-column layout can make the user's filling path a straight line from top to bottom. This single, direct and clear visual path can improve user browsing and filling efficiency. From a psychological point of view, the single-column layout will make the form longer. If you have completed some input, you need to scroll the page. Scrolling the page represents "forward", which will give users a psychological hint that they are moving forward and have a lot of progress. This kind of psychological suggestion will ease users' anxiety when filling out long forms.

Multi-column Layout: Multi-column layout will cause the user's visual path to become longer. Users need to follow the "Z" to complete the form. Compared with the single-column layout, users are more likely to make mistakes, omissions, and be interrupted. If you want to use a multi-column layout, you must pay attention to the distance between the rows is greater than the distance between the columns, so as to guide the user to consciously fill out the form horizontally and enter the content orderly (Fig. 2).

Fig. 2. Single-column layout and Multi-column layout.

Regarding the layout, in addition to the single-column layout and the multi-column layout, one more thing to consider is the alignment of the form labels [4]. The form label is responsible for the interpretation of the input items. Since each input item needs a label, the alignment of the label also affects the layout and efficiency of the entire page. There are three common alignment methods for labels: left alignment, right alignment, and top alignment. The following figure is the feature comparison of the three label arrangements (Fig. 3).

	Top alignment	Right alignment	Left alignment
Completion speed	Fastest	Moderate	Slowest
Near the input box	Closest	Moderate	Close
Eye movement direction	Down	Down to right	Down to right
Time when the label moved to the input box	50ms	240ms	500ms

Fig. 3. Feature comparison chart of the three label arrangements

According to the chart, the efficiency of browsing and filling in the top alignment is the highest of the three alignment methods. With the top alignment method, users only need to browse down one by one, which conforms to visual movement, but its disadvantage is that it will occupy more vertical space. In addition, with the top-alignment method, attention should be paid to the distance between each group of form label and input box and other groups to avoid visual confusion.

4   Help and Guidance

A user-friendly form design needs to anticipate various difficulties that users may encounter, and solve them in advance. If difficulties cannot be completely resolved, it is necessary to notify users about the details in advance and help users overcome difficulties as much as possible. Here we purpose some guidances as follows:

1   Use selection instead of input. Making choices is easier than typing.
2   The label should use the most concise and understandable language.
3   The width of input box implies the length of the content. In actual cases, designers often use the same width of input box, which will look more uniform in terms of visual effects, but it is actually not a good experience. The width of input box should imply the length of the content to reduce the burden of judgment. As we can see in the picture below, the well-scattered right picture seems to be more comfortable than the neat left picture, because visually it is easier for us to regard the space and content of the right picture as a harmonious object. However, the over-alignment of

the image on the left gives people the illusion that a large part of the space on the right is missing (Fig. 4).
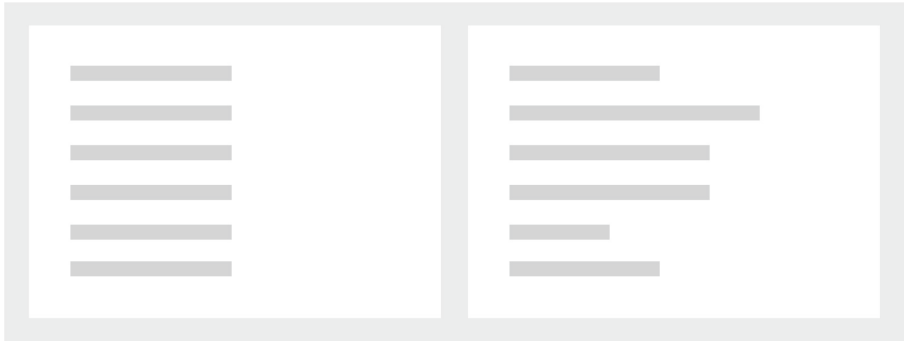
Fig. 4. The same length and different length.

4 The placeholder text should be a complete sentences as a weaken reminder.
5 Make a clear distinction between optional and required items. If you have to add optional items, you must also clearly inform users which items are optional and which are required. The number of required items is usually much larger than that of optional items, so please do not use "*" or any other visual symbols on the required fields. Because once there are numerous symbols, it will become a visual disturbance.
6 Important explanatory text should be displayed directly rather than collapsed. When filling in a form with a large number of fields, reading and filling in the form are equally time-consuming and labor-intensive. If we hide all the prompt information, the user will not find it. Besides, clicking or hovering to view the prompt information will wastes a lot of time. Therefore, the important prompt information should be displayed directly on the page instead of hiding it. Unimportant reminders can be put away in the comment symbol.
7 Give a reminder before filling in. For lengthy and complex forms, you should briefly explain the business goals of the form and the approximate time it will take before the user starts to fill in.
8 Automatic division of phone numbers is necessary. If the user enters a phone number, the number should be divided intelligently with spaces to improve the readability and reduce the error rate.

5 Feedback and Verification

5.1 Real-Time Verification

Reminders to inform users of filling errors should be timely. The purpose of this is to reduce the number of subsequent revisions. For long forms, it would be a disaster to

wait until all the forms are submitted and then prompt the error messages uniformly. Therefore, the platform should immediately verify the entered information every time the user completes an item. If it does not match, it will prompt immediately to facilitate the user to modify it in time.

5.2   Feedback

After the user submits the form, form needs to inform user whether it was submitted successfully. If the user quits midway, the platform shall automatically save the content entered. If it cannot be saved, it shall warn the user of the consequences of quitting and ask him if he is sure to quit. The form usually involves the upload and deletion of files, and these operations require corresponding feedback. If the content is incorrect, the user should be informed of the reason for the error and how to correct it.

5.3   The Reason for the Failure of the Audit Result Should Be Clearly Informed

There are a large number of form audits and circulations in the middle of the enterprise. If the form submitted by the user fails to pass the audit, the user should be clearly informed of the reason for the failure of the audit and guided to modify it.

6   Conclusion

With the in-depth development of Internet informatization, the entry of complex information is unavoidable. To deal with complex information, it is necessary to seek reasonable designs and principles from complexity. In order to solve the user's resistance to the long form with complex information and the ease the difficulties of use of the form, this article starts with introducing the basic elements, types, layout of forms. Then we give some help and guidance. To better use of forms, we purpose verification and feedback of the form and try to read the information from the user's sight. From the perspective of flow and reducing users' cognitive difficulties, a theoretical design strategy is proposed, which hopes to improve the efficiency and emotional experience during information entry.

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Assistive Technologies and Accessibility

Improving On-Campus Digital Mental Health Support for Underrepresented University Students

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Abstract. Recent studies have shown a growing demand on college campuses for mental health support and services. At the same time, Black and Latinx students have a higher incidence of unsatisfied needs for mental wellbeing and are more likely to encounter difficulties with mental health services. A technological approach for the navigation of mental health services on campus is a promising approach to meeting Black and Latinx students' mental health needs. This paper presents the results of an exploratory study that focuses on understanding the technology habits and preferences correlated with students' mental health and how those relate to what is presented by college and university counseling center websites. Findings illustrate how the college students' preferences for applications that integrate with their current on-campus programs clashed with the easily available offerings of campus counseling centers. These results demonstrate the disconnect between Enterprise UX and modern college students' technology practices.

Keywords: Digital support · Mental health · Underrepresented students

1 Introduction

Black and Latinx university students find it more difficult to navigate mental health offerings due to stigma within their communities [5, 6] and inability to find resources on campus that suit their needs [17]. With the recent campus closures during the COVID-19 pandemic, students are adjusting to significant changes in their academic and social settings and are experiencing increased feelings of isolation. Recent reports of police brutality [1, 2] and disproportionate rates of COVID-19 fatalities in Black and Latinx communities [15] have heightened and intensified mental health issues among these students. With Black and Latinx groups enduring long-term impacts of systemic racism in America, university students who belong to these communities are seeking safe and welcoming environments [16, 17] to address their mental health issues. It is critical that these students feel supported at their respective institutions and have reliable access

to resources that will help them navigate cultural barriers and lack of representation in institutions of higher education. On-campus resources can help address the needs of students by making school-wide systems and programs more accessible, and more culturally responsive in ways that would further encourage a diverse student population to utilize resources that fit their needs.

Mental health initiatives have been used to develop online communities and resources for university students [16] in the form of digital interventions such as web and mobile applications [14]. In this study, we present findings from an exploratory survey study, which reveals how Black and Latinx graduates view the efficiency of their campus counseling center's services and offers insights into technological solutions that may fill the gap in accessibility. We also present findings from a content analysis of campus counseling center websites from the top 20 ranked of each of Predominately White Institutions (PWI), Hispanic Serving Institutions (HSI) and Historically Black Colleges and Universities (HBCU) for 60 total sites. Study findings show that students have a difficult time navigating mental health resources on campus and indicate the need for holistic mental health and wellness support.

2   Related Work

The HCI community has become increasing interested in technical approaches to improve the mental health of university students. HCI experts have developed widespread technologies and online support solutions to help university students improve their mental health. Students at universities endure a lifestyle that puts them under great academic stress, often coupled with social stressors such as living away from family, friends, and traditional support systems for the first time. Cultural stigmas [3] also make it difficult for students from certain backgrounds to seek out-person mental health support. Thus, digital mental health interventions and the relative convenience, accessibility, and anonymity that they provide have promising opportunities in higher education for people from these groups [17].

Various mHealth apps have been designed to support work-life balance and to help users access mental health resources. Researchers have investigated and established online support groups in the HCI community, such as mindfulness-based text messaging [11, 12] and smartphone applications [4, 14], web apps [13], as well as wearable devices [7]. Health researchers have also explored the use of technologies to increase awareness about mental health. A study in Frontiers of Psychiatry identifies advantages and drawbacks of using personal computing systems to support university students' mental health [10]. Research in this area illustrates how technology-based mental health programs must be adapted for smartphone use.

Our study leads to understanding the experiences of university students using technologies to promote their mental health, but focuses solely on the perspectives of minority students. Thus, it is impossible to disentangle minority status and experiences from the contrasts among the individualistic models of mental health technologies represented by much of the literature, the fragmented approach of university counseling center websites, and the needs expressed by the students for a more integrated approach.

3 Methods

This research used two complimentary methods to examine the experiences of minority students accessing mental health care on campuses. We first used an exploratory survey to understand how Black and Latinx students navigate campus counseling resources and what these types of technological tools these students would like to have access to. The survey was electronically distributed through a listserv composed of university students in various educational programs led by the office of access and inclusion at the University of California, Irvine. A total of 36 university students (25 undergraduate and 11 graduate) who self-identified as Black and Latinx and currently enrolled in a degree program participated in the survey study. The survey was anonymous and did not contain any identifying information (i.e. name, school, major) and was hosted on Qualtrics survey platform.

After finding the degree to which students requested an integrated, systemized approach to health technology that contrasted with the largely personal and app-based model more common to mHealth research, we sought to understand more about what universities appeared to be offering in this vein to students. To answer these questions, we conducted a content analysis of 60 U.S. college and university counseling center websites. Sites analyzed included the 20 top-ranked each of Predominantly White Institutions, Hispanic Serving Institutions, and Historically Black Colleges and Universities (as ranked by US News and World Report in August 2020). A google search on "college/university name" + counseling center used to find the counseling website of each specific school. Then the researchers navigated to the highest-level web page for the counseling center to begin their analysis. The researchers identified the initial categories of analysis based on a combination of their combined knowledge of mental health resources provided by universities and the thematic categories identified through coding the student survey responses. We started out with an initial code book of 18 codes and all three researchers coded a subset of 6 sites. The team of researchers then met to compare their results, discuss the coding process, and identify codes that needed to be clarified, expanded, collapsed, added, or deleted. Based on that discussion, the researchers arrived at the final operational definitions for 16 codes. The researchers then added an additional six sites and re-coded the first six, for a total of 12 (20% of the total sites to be coded) with an interrater reliability of .86 (93.06% agreement). Finally, each researcher independently coded an additional 18 sites for a total of 60 sites.

4 Results

As in prior research [9], participants of this study had barriers to accessing mental health care such as access to resources and tools to help them cope. By examining both student perceptions and counseling websites together, we can identify some clear areas of synergy as well as some disconnects. In this section, we highlight these points of synergy and conflict in terms of a holistic wellness approach to mental health, notions of community, and considerations of identity, particularly the often intersectional identities of non-white students, whether on campuses in which they are minorities within the campus population or not.

Our findings demonstrate that of the multiple resources presented to students on campus (e.g., psychiatric services, individual counseling, etc.), students were most interested in having more resources focused on addressing their health care needs holistically. Wellness, for example, was a central focus of concern for students. For example, student survey respondents requested "healthy tips to deal with different types of mental health issues", "mood tracking," and "Healthy exercises for mental health improvement, meditation/calming practices." These approaches were well-represented in counseling center websites, with 53 out of 60 (88%) offering some form of wellness-related resources to their students, and 41 (68%) were coded as having a wellness ethos (as opposed to a more traditional medical model [8] pervading the entire site.

Participants expressed a desire for local community resources and counselors that were external to campus, such as "How to find local black counselors and professionals, resources for local groups, self-care tips, hotline numbers, 24/7 communication line." Notably, in this quote, the respondent describes not only the types of resources needed but also hints at the need for cultural competency by explicitly calling out the need for "black counselors and professionals." In contrast to students' expressed desire for community-based forms of support, our content analysis revealed that only 39 of the 60 sites analyzed provided such resources. Additionally, even when provided, none of these resources connected directly into online offerings from those groups, provided mapping directly to them, or included any other integrated services students have come to expect from a modern customer-centric web experience.

Students care about the identities held by their counselors and expressed wanting to learn more about them before scheduling an appointment. Student survey respondents expressed having access to counselors who they can relate to in culture and identity (i.e. ethnicity, gender, and sexual orientation). Alternatively, student survey respondents expressed wanting access to counselors that they can relate to. To illustrate, one participant explained that they would like to see which therapists on their campus identify themselves as a person of color, queer, or both, while another expressed a desire specifically for access to Black mental health professionals. Similarly, a different student asked for photos of nearby professionals wanting, "names and number of nearby professionals with pictures." Despite students' clear preferences for finding mental health professionals with whom they feel some form of connection or affiliation, our content analysis revealed that finding this information and making these connections was not well-supported. 18 sites (30%) had no bio information for counselors at all. For others, the information was often buried or difficult to find. Specifically, they were often text-only (i.e., no photos), contained minimal information, and/or only included name and professional degree. There were, however, some clear exceptions, where bios were more expansive and included the names, photos, and specializations of the mental health professionals.

Collectively, these findings indicate the growing need for more comprehensive and customized approaches to mental health support for students. Technologies have the opportunity to fill gaps in existing support for wellness, community, and identity concerns; however, these technologies must be leveraged as part of an integrated strategy across digital, human, and physical resources.

5 Conclusion and Future Work

This research explores the mental health needs of Black and Latinx university students and the ways in which counseling centers currently present offerings in response to these needs through their primary online presence, their official website. This research contributes to human factors and ergonomics literature to recognize distinctive mental health services and technology practices defined by Black and Latinx university students: enhanced access, expanded emphasis on wellness, peer-to-community support, and culturally aware mental health choices. Given the fragmented nature of support reported by students in this work, future work should look beyond official websites to digital marketing and social media, recommended applications and external supports, and peer communities. Likewise, a more in-depth analysis of individual websites, as well as comparisons among them, may indicate differences in approaches for different institutions and would enable researchers to explicitly interrogate whether these differences are appropriate and supportive of the goals of those specific institutions.

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Sensor-Based Toilet Instructions for People with Dementia

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Abstract. Care for people suffering from cognitive impairment is demanding and requires a high level of personnel attendance by nurses and driving costs as well as the need for additional human resources. Specifically, the toileting process is a neglected area and taboo topic that has not been tackled so far. People with cognitive impairments like dementia often cannot go to the toilet on their own. Instead, caregivers need to accompany them to provide assistance. We present a computer vision solution which detects the current pose of a person on the toilet based on privacy-preserving 3D depth data. Instructions of the next step the user needs to perform is provided on a screen. The proposed toileting guide is regarded to be useful in terms of increased autonomy, especially for persons with mild dementia. Additionally, time is expected to be relieved care givers which leads to improvement of work load and efficiency.

Keywords: Computer vision · Human-computer interaction · Motion detection · Privacy protection

1 Introduction

Nearly 9.9 million new cases of dementia emerge each year worldwide, implying one new case every three seconds [1]. Since occurrence of dementia rises with age, the ageing population leads to an increase of people with dementia [2]. Furthermore, we have a nursing job crisis due to ageing of the workforce, difficult working conditions and weak career development [3]. It is estimated that by 2030, a shortage of 2.3 million nurses in EU28 will occur [4]. Persons with dementia frequently need help from others to perform basic daily activities like food intake, toileting or cleaning [5]. Especially toileting is a highly private task, where requiring assistance can lead to a feeling of decreased dignity [6]. The reason for needing support in the toileting process is disorientation or black-outs leading to the person not knowing what to do next [6].

To support care staff in their work and to ensure safety and privacy of patients, technologies in the field of Active Assisted Living can be used for routine tasks or for detecting when a patient needs special care or assistance [7].

In order to improve autonomy for persons with dementia and to remove workload from care staff, we propose a technology-based solution which detects the current pose of

a person on the toilet and provides instructions of the next step the user needs to perform on a monitor. To our knowledge, the toileting area is a neglected field so far, which we tackle by using privacy preserving 3D technology. The proposed human-machine interaction model is regarded to be useful in terms of increased autonomy and dignity, especially for persons with mild dementia.

Section 2 of this paper presents the current state of the art of technologies supporting people with dementia. Section 3 describes the methodological approach of the proposed system, while Sect. 4 summarizes and discusses the results. Section 5 concludes the paper.

2   State of the Art

Supporting the autonomy of older people is increasingly being addressed in scientific research. One area which affects autonomy is personal hygiene. König et al. [8] focus on this topic by developing a virtual assistant based on artificial intelligence to help older adults with dementia perform hand washing without the help of nurses. The virtual assistant observes the person and provides audio-visual cues when the person no longer knows what to do. Another work supporting the process of hand washing using a prompting system is presented by Mihailidis et al. [9]. The prompting system, also called COACH, uses artificial intelligence to provide audio and/or audio-video based instructions. Six older adults with moderate to severe dementia were interviewed to evaluate the system. The adults with moderate-severe dementia were able to complete an average of 11% more handwashing steps with COACH. In addition, they required 60% fewer interactions with a nurse or caregiver when COACH was in use.

A systematic review of intelligent assistive technologies (IATs) used in Alzheimer's disease and other dementias is presented by Ienca et al. [10]. The review reveals that most of the researched applications in IAT is supporting people with cognitive impairments in activities of daily living like eating, bathing, dressing, toileting and continence. The technologies for supporting toileting focus solely on stand-up support on the toilet and hygiene (e.g. and water flow detection in handwashing [11]). Sitting down and standing up from the toilet is another task where older person with motor impairments often need support. The iToilet project, introduced by Panek et al. [12, 13], has developed a new type of modular toilet system capable of assisting older people to go to the toilet. The main component of the toilet is a height- and tilt-adjustable commode chair that can be placed over a toilet bowl and connected to the power supply.

Regarding toileting hygiene, Gresham [14] presents a utility analysis of the use of an electronic toilet bidet in an Australian nursing home. A pilot study with 122 people is carried out, which shows that the use of such a device can reduce caregiver workload, positively influence resident toileting behaviour and reduce constipation rates. The downside of the bidet found in the study is the possibility of a higher urinary tract infection rate.

Keen et al. [15] investigate the effectiveness of an animated toilet training video for children with autism. The result of the study shows that visual support through toilet training has a positive effect on the children's behaviour, as the children in the treatment group urinate more in the toilet than the control group.

The literature review shows that approaches to improve the independence of people with dementia through technology have been investigated by different authors. While the described methods focus on hand washing, stand up support or toileting hygiene, our proposed approach investigates the possibility of supporting the entire toilet process. To our knowledge, no scientific papers are available that investigate the use of a privacy-preserving 3D depth sensor which provides instructions on the toilet.

3 Methodology

In order to provide instructions how to use the toilet for people with cognitive impairments, we propose a *toileting guide* consisting of two main components: 1) a 3D sensor technology controlled by a Raspberry Pi and 2) a monitor/tablet. The 3D sensor is used to detect a person and its current position and movement, while the monitor provides instructions based on the detected stage of the toileting process. The use of a depth sensor enables privacy protection, since it delivers information based on the distances between objects and in contrast to an RGB camera does not reveal a person's identity [16]. Figure 1 gives a schematic overview of the toileting guide, showing the arrangement of the two components.
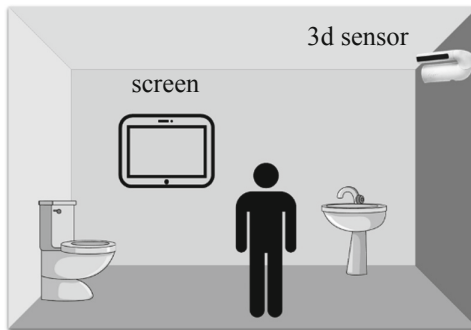
Fig. 1. Schematic overview of the toileting guide

3.1 Feature Definition

As a first step, the toileting procedure is defined. Therefore, we collaborated with a day care centre for dementia. The outcomes resemble the toileting steps described by Yamane and Tsuchijima [17] (translated by Uchimoto et al. [18]). The main steps can be defined as: *(1) entering the toilet room, (2) undressing (taking off pants and shorts), (3) sitting on the toilet, (4) excreting (urinating and defecating), (5) cleaning, (6) getting up from the toilet seat, (7) putting on clothes, and (8) leaving the toilet room.* Within a workshop with the daily care centre, scenarios have been found where people with cognitive impairments tend to get stuck regularly. On the basis of these scenarios, the features described in Table 1 are selected to be implemented in the proposed system.

Table 1. Features to be detected by the proposed system.

Feature	Description
Entering/indecisive	A person enters the toilet room and does not carry out a "logical" toileting sequence (in regards to the above defined steps) within a defined period of time. The person does not go to the toilet
Person is in front of the toilet	A person is near the toilet (within a defined radius), but does not sit down within a defined period of time
Person sits on the toilet seat	A person sits (independent of the previous actions) on the toilet seat
Person stands up from toilet	After a person was sitting on the toilet seat, he/she stands up again

3.2 Feature Detection

Features shall be detected in real-time in order to provide direct help. To accomplish this, precise methods for detecting movement are used. Otherwise, no or even wrong instructions could be transmitted to persons with dementia. In the worst case, this could lead to injuries (e.g. false sit-down instruction could lead to a fall). All parts of the software need to work in real-time. If they do not, instructions are given at the wrong time, which leads to the same risks.

We use the 3D depth sensor Orbec Astra for analysing the scenario. The 3D sensor captures images with a resolution of 640×480 pixels and is controlled via OpenNI2. Figure 2 shows exemplary depth images in a test setting. The software is implemented using the Qt development framework with a graphical user interface (GUI). The predefined features (see Table 1) are detected and according to the current state of the person, videos or images are shown. When starting the software for the first time, an initialization of a person sitting on the toilet needs to be done. After that, all further calculations are distance-based.

The person tracking software is based on the method of Pramerdorfer et al. [19]. This approach uses background subtraction in order to detect moving objects. Via feature extraction and a Random Forest classifier, persons and objects can be distinguished. Using the location of a person allows to calculate the distance to the toilet. When a person is sitting on the toilet, the distance from the centre of a person is smaller than if the person stood upright in front of the toilet. This enables to distinguish between those two states.

Fig. 2. 3D depth images of one/two person(s) in the toilet room.

3.3 Interaction Module

The feature detection is now combined with an interaction module. Depending on the detected position, a defined video/image is displayed on a monitor. We present two different options of giving instructions to user: 1) a 3D animated avatar and 2) simple instruction images. Additionally, the system provides to possibility to play audio files as well (e.g. recorded instructions). The avatar is created with the software Blender, together with the MBLab add-on. This add-on is free and enables realistic-looking 3D models. Open-source libraries are used that provide animations, which, when applied on the existing 3D model, allow the movement of every joint. For every motion the avatar shall carry out, a video sequence is generated. The video sequences are then displayed, corresponding to the scene analysis. Figure 3 shows an example image of the avatar and a simple instruction image.
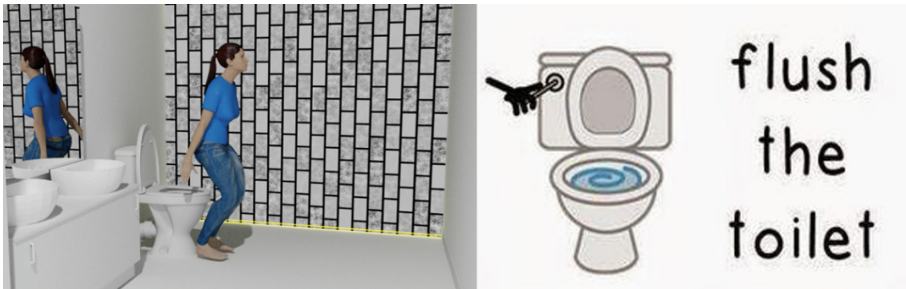
Fig. 3. 3D avatar sitting down on the toilet (left) and simple visual and textual instruction (right).

3.4 Toileting Guide

The feature detection and interaction modules are combined using a self-designed controller unit based on C++ and Qt 5.14. This unit analyses live changes in parameters of the 3D data and thus, adapts the corresponding visualization of user instruction. If one of the defined features is detected by the sensor, a variable containing the feature name is

sent to the visualization module, which then displays the corresponding video or image. This means that the 3D images are only processed locally on the Raspberry Pi and are not stored or transmitted to the visualization module.

This framework can be carried out on Windows and Linux systems. It is easily expandable with more features and visualizations.

4 Results and Discussion

In the course of developing the toileting guide, parameters have been found that influence the performance. Thus, the following conditions are required:

1. The room is constantly illuminated.
2. The person enters the room in an upright position.
3. The person is detected by the sensor throughout all the time.
4. The person sits or stands and is not in another position (e.g. squatting).
5. The areas important for detecting the different scenarios are fully viewed by the sensor.

For validating the toileting guide, a test set-up is created (see Fig. 2), which is similar to the future application area. The scenarios shown in Table 2 are carried out. For each scenario, the correct behaviour of the system is tested. Therefore, each scenario is tested three times and the validation is regarded as successful, if the system behaves wrong once per scenario at maximum. In total, more than 90% of scenarios need to be correctly detected for a positive validation.

During the development of the toileting guide, exchange with a dementia day care centre is established in order to present and discuss different software versions to improve the system. Two feedback workshops are held and one final presentation and discussion.

Table 2. Validation scenarios

Scenario	Description	Expected outcome
1	Person enters toilet room	The system detects a person
2	Person moves towards toilet	The sensor detects an upright person near the toilet for a defined amount of time, then the framework shows the "sit down" video/image on the screen
3	Person sits down on the toilet	The sensor detects a sitting person for a defined amount of time. The framework shows the "stand up" video/image on the screen
4	Person stands up from the toilet	The sensor detects an upright person near the toilet
5	Person leaves the toilet room	The system does not detect a person

While the guide was not working stable in the beginning, this could be improved in later versions. In the final validation, the system reacted correctly in all scenarios.

When presenting the proposed toileting guide to care givers from the dementia day care centre, expected benefits of the system could be gathered. At first, it is regarded to be useful in regards of increased autonomy for one third of their clients, who are mainly persons with mild dementia. Additionally, time is expected to be relieved in formal and informal care givers which leads to improvement of work load and efficiency.

Apart from the main vision (active instructions as mean of support in toilet usage), also other functionalities are regarded as useful. For example, passive monitoring and alarming care givers in the case of a blackout is seen as useful. Furthermore, toilet usage and duration or occurring blackout could be automatically transmitted to the care documentation. This could be useful for long- and medium-term detection of trends. The acceptance of technology in the area of personal hygiene is expected to be high due to the desire of privacy and autonomy in this area.

A point that should be considered is that care staff could fear that a toileting guide like the proposed one could lead to decrease of staff and loss of the job. Providing explanation of the technical solution to user groups, relatives and care staff is considered to be highly important in terms of acceptance rate.

5   Conclusion

With this work, we lay a basis for autonomous toilet usage in persons with early-stage dementia, which has the potential to improve life for end-users and decrease workload for caregivers, and thus making available time for social tasks.

The final validation was carried out with two different project members. For further development of the toileting guide, validation for diverse user groups is essential to ensure proper performance independent of age, body shape, skin colour and gender. Future work will also include a broader variety of possible user prompts and a possibility to configure the system based on individual user needs. Furthermore, user pilot studies will be carried out to get feedback from the field in order to develop a practical and high-performing solution.

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Software for Diagnostics of Mitral Valve Prolapse: Economic Implications

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Abstract. This paper proposes innovation through "translation" of phonocardiogram signal obtained from electronic stethoscope into an algorithm, procedure and software that gives an opportunity to each primary-care physician either in town or hardly reachable countryside to reliably and cost effectively diagnose mitral valve prolapsed (MVP) without engagement of resources such as highly specialized diagnostic methods that are available only in modern clinical centers, expensive equipment and complex training of experienced cardiologists for interpretation of results together with high maintenance costs analysis its cost-effectiveness. Till now very few research address the cost-effectiveness of various approaches to the patient undergoing medical evaluation, so this paper analyses the economic feasibility of MVP software application through cost-benefit framework. The payback period of the invested funds is 4 years and it represents a good investment, while critical sales price is 159 euros per software license and switching number of installations is 429 units.

Keywords: Mitral valve prolapse · Software · Investment · Cost-benefit

1 Introduction

Mitral Valve Prolapse (MVP) is the most common condition affecting the valves of the heart that refers to a malfunction where the two leaets prolapse into the left atrium and prevents the mitral valve to close properly [1]. MVP is a clinical entity that is not fully understood, despite being known for more than a century [2].

In MVP a typical auscultatory finding is mesosystolic click and late systolic murmur as in Fig. 1 [3].

It is considered MVP to affect from 0.4 to 35% of the certain population depending on gender and age [4, 5]. Its diagnostics usually takes years to acquire and refine due to the fact that no unique set of physical symptoms exists to diagnosis that also results with associated cost of a final visit to a cardiologist in amount around $1000 in the United
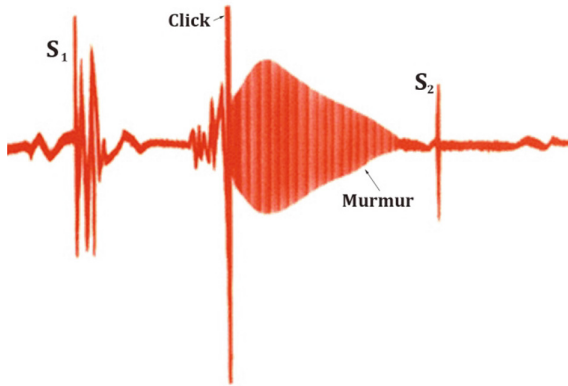
Fig. 1. Late systolic click and/or a late systolic murmur [3]

States [6]. Necessary equipment includes 2D or 3D transthoracic and transesophageal echocardiography, chest X-rays, color Doppler ultrasound and/or cardiac catheterization [7]. The development of digital electronic stethoscope and the application of PCs, enables the emergence of new diagnostic methods in specific domains of medicine and the digital processing of biomedical signals makes possible, widely available, simple and inexpensive. Todays' electronic stethoscopes are able to record, memorize and send digitally processed audio to a PC where the phonocardiographic record can be analyzed and memorized if adequate software is developed. Phonocardiogram (PCG) signal, despite certain imperfections and facts that it has never been accepted as a routine clinical method, or given importance in clinical research, can represent the main mean for achieving an important goal - early detection of MVP (it is especially important in children cardiology).

There are more than 25 patents with the keyword MVP at WIPO base (https://worldwide.espacenet.com/ [8]) which are proposing devices/apparatus for different purposes. Regarding phonocardiogram as keyword there exists around 70 patents. Patent WO2016206704 (A1) 2016-12-29 deserves attention since it uses memory-heavy machine learning approach and Viterbi algorithm (and requires heavy and expensive equipment hardly available to everyone) to build prediction model on collected sounds. Also, although not in field of phonocardiogram but electrocardiogram patents WO2014123438 (A1) 2014-08-14 and US20170049346 should be mentioned. Electrocardiograms as more demanding equipment are not available in all primary care units worldwide. However, it could be noticed that to date, an adequate algorithm nor software that uses PCG as a non-invasive, simple, easily applicable and inexpensive diagnostic method of MVP has not been developed.

2   Previous Research

By reviewing published scientific papers in the field of recognition of physiological and pathological heart murmurs, a small number of proven and functional algorithms are

detected. Thus, the contribution of a large number of studies based on Fourier's transformations is reduced by the introduction of Heisenberg's principle of indeterminacy [9, 10], because the temporal and frequency resolutions can not be determined at the same time. The Wavelet Transformation comes in response to the resolution problem in the Fourier transformations, but has the presence of serious problems at low frequencies [11]. Neural networks and Markov's model were also applied to the automated classification of acoustic heart signals, however, with the constraints of the time complexity of the observed algorithms, that is, the speed of performance, and the process forces and memory as well as the control of the boundaries between false positive and false negative results [12]. The method based on the support vector machines and similar machine learning approaches show something better in controlling the boundaries between false positive and false negative decision-making results, but are memory intensive approaches [13]. The results of available studies show sensitivity between 51–93% and specificity 82–94%.

Consequently, software application that is certainly innovative and that will help to diagnose PMV in a way that none of existing methods or tools cannot - in accurate, cost effective and reliable manner using only electronic stethoscope in primary healthcare is certainly needed.

3 Proposed Innovative Solution: Software for MVP Diagnostics

Therefore, software application that is certainly innovative and that will help to diagnose PMV in a way that none of existing methods or tools cannot - in accurate, cost effective and reliable manner using only electronic stethoscope in primary healthcare is certainly needed. On the basis of the fact that the occurrence of noise in the last third of the systole is of crescendo type, with or without mesosystolar clicque, innovative solution could be possible to establish and prove the theorem on the mean integral value which gives a good frame for controlling the absorption function of monotonicity of amplitude, and where its square behaves as a corrector of point absorption in a given interval. Also, an algorithm for detecting PMV considering the nature of cardiac anomalies is needed. Idea is that the algorithm heuristics will include few steps in aim to find as low as possible number of points in PCG signal spectrum. The first one is processing e4k files with check of the first and lasts seconds of the signal due to device sensitivity. Next step corresponds to the mathematical model with the aim of detecting spectral characteristics. Integral calculation follows with the memorizing of the original maximized mean value. Finally, we expect to obtain results of MVP detection, as shown in Fig. 2 with sensitivity and accuracy over 92%.

The main global benefit and the main positive impact is the possibility of MVP early diagnostics that results in tangible societal, public, management and economic impact. Suffering, lower quality of life or shorter life span cannot be easily quantified in monetary terms, but are closely related to public policies development and standards, management principles in health field etc. WHO in 2020 data [14] show that cardiovascular disease (CVD) is no longer just a health issue, but a major economic burden, since more than 17 million people throughout the world die from cardiovascular diseases each year. By 2030 the total global cost of CVD is set to rise from approximately US$863 billion in
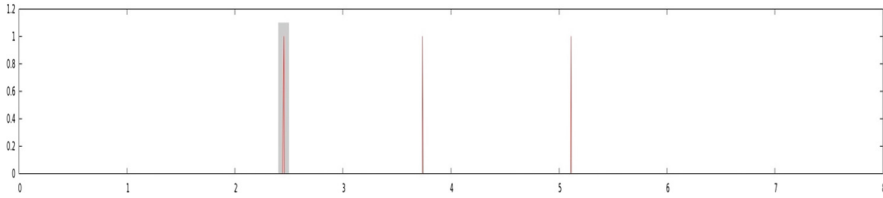
Fig. 2. MVP detection.

2010 to a staggering US\$1,044 billion. By 2030, it is estimated that 5 million Americans and 6 millions of European will have moderate to severe mitral valve problems. For other parts of the world there are no predictions, but it is evident that this project result has huge social impact and very large market potential.

MVP is not easily recognized due to the fact that in many cases, it does not cause symptoms or interfere with everyday life for certain period. Because of this, it often is not diagnosed until adulthood resulting in the clinical symptoms of the disease connected with instability of the autonomic nervous system. Accordingly, there is a favorable economic impact for medical systems and physicians and an improved quality of care and living for patients that forces fast market uptake. The software would analyze the phonocardiogram and point to a possible occurrence of MVP, so that such software could be of great help to family doctors, general practitioners, as well as sports medicine physicians in the early diagnosis of MVP, or the differential diagnosis of other heart diseases. This is especially important for young habitants in rural and underdeveloped areas, where the availability of computers and this software package would be the only thing doctors could use. The gross national income (GNI) per capita of developed countries (\$27 000) is nearly 25-fold that of developing countries (\$1100) [15]. Furthermore, developed countries devote twice as much of their GNI (10%) to health care compared with low- and middle-income countries (6%), that results in about a 40-fold difference between developed and developing countries in funds devoted to health care. It is obvious that beside developed ones developing countries and their national health systems where small percents of the country's gross national income are invested in health systems, will greatly benefit for innovation proposed herein.

4   MVP Software Economic Appraisal

For the assessment of economic feasibility of development and use of medical software in practice the most commonly employed approach is cost-benefit (CB) framework.

Very few data address the cost-effectiveness of various approaches to the patient undergoing medical evaluation of a cardiac murmur, but it is evident that optimal auscultation is done by examiners who can recognize an murmur with confidence results in less frequent use of expensive additional testing to define [16]. It is known that the cost effectiveness ratio of ECG plus history and physical versus no screening is \$76,100 per life years saved, with utility adjustments this increases to \$111,000 per quality adjusted life year saved [17]. On other side, there is data for home blood pressure monitoring as early diagnostics method that shows return on investment of \$19.34 per dollar invested in the long run [18].

The initial investment costs include costs of the software development is amount 80.000 euros. The maintenance costs varying from 281 euros in the first year to 625 euros in the last projected year. It is expected to use software at least 8 years (the lifetime of exploatation), and to sell software installations in those 8 years. Also, it expected to have savings of at least 500 euros due to replacement of currently used methods.

Social-economic effects are measured throw the savings that are consequence of installation of the MVP software. Savings are calculated as the difference between operative costs of exploitation of novel and conventional solutions. The economic assessment was conducted through a cost-benefit methodological framework. The economic flow table is calculated based on the constant prices for an exploitation period of 8 years. The investment costs are located in two periods. The first period is initial costs before the start of exploitation of the software. The second period, at 8 years of exploitation assuming that by that year, the hardware of the system will be fully depreciated. It is predicted that in 8 years, the user of the solution will have to buy new solution. The net effects of system exploitation are positive for the entire period of system exploitation except in the first year. Table 1 gives an overview of all economic costs and benefits due to development, sales and usage of MVP software.

Table 1. Economic costs and benefits of the exploitation the MVP software (€)

Year	0	1	2	3	4	5	6	7	8
Total value of the project – R&D costs	80000								
Software maintenance costs		281	312	469	625	625	625	625	625
Total costs	80000	281	312	469	625	625	625	625	625
Sales revenue		11250	12499	18748	24997	24997	24997	24997	24997
Savings per year (difference between new and conservative solutions)		500	556	750	750	750	750	750	750
Total benefit	0	11750	13054	19498	25747	25747	25747	25747	25747
Net economic benefit	−80000	11469	12742	19029	25122	25122	25122	25122	25122
ENPV	47283 €								
EIRR	17%								

The economic net present value amounts EUR 43170 while economic internal rate of return is 16.4%. Discounted economic pay-back period is reached after 4 years. With discount rate of 5.5%, the critical number of installations is 149 units with switching price of 159 EUR per installation.

5   Conclusion

This paper assesses the economic justification of innovative solution of software for MVP detection.

It has been shown that its' development, installation and operation is economically feasible after 4 years while critical price is 159 EUR if only 429 software installations are sold.

The net present value for the exploitation period of 8 years is EUR 43170 and the internal rate of return (average annual profit rate of invested funds) is 16.4%.

The appraisal shows that the purchase of the specified software is cost-effective and justified.

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Assessing the Emotional Reaction to Negative Pictures Through Electrodermal Activity Data

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Abstract. We are constantly exposed to countless visual stimuli that trigger different emotions and reactions in individuals. Assessing one's own reactions to visual stimuli can be a powerful tool for diagnosing a person's psychological state, as well as to evaluate, objectively, the effects of one's interaction with the environment. Currently, the measurement of this emotional responsiveness to visual stimulation is mostly carried out by means of self-reporting questionnaires, which lead to a quite subjective assessment of the emotional impact of the presented stimuli. The aim of this study is to investigate the use of Electrodermal Activity (EDA) to predict the level of emotional response of individuals to negatively charged pictures. With this purpose, we collected EDA signals from 25 participants, while they visualized a sequence of 75 emotional response pictures, from the International Affective Picture System (IAPS). The most relevant EDA parameters, such as amplitude, area, skin conductance levels and the number of specific responses were statistically confronted with the arousal and valence of each image. This analysis showed the expected increase in the first three parameters for high arousal pictures. We also found that more neutral valenced ones had higher amplitude and skin conductance levels than pictures with negative valence. Those results show that the Electrodermal Activity can be used as an objective indicator to evaluate emotional arousal, as a response to viewing negative pictures. In addition, it opens the possibility to use such electrophysiological measurements, in a clinical, social or ludic context and, in such way improve certain forms of diagnosis, as well as assess the efficiency of visual interaction with a particular individual, while allowing for a more objective way to monitor the emotional effects of said interaction.

Keywords: Electrodermal Activity · Arousal · Valence · Emotional reactivity · Visual emotional stimuli · IAPS

1   Introduction

In our daily lives, we constantly experience events that trigger emotional responses. Both in neuroscientific research and in a clinical context, measuring the emotional effect of an individual exposed to a particular stimulus has become increasingly important.

Emotions play an important role in human communication with the world, so monitoring people's emotional state can be a good indicator of stress or mental illness [1].

Emotional events can be considered as multidimensional phenomena, composed of, at least three principal dimensions: (1) an evaluation of the stimulus, (2) the behavioural response to the emotional event (in the form of autonomic, muscular and/or endocrine activity) and (3) a subjective feeling [2]. In particular, the sympathetic branch of the autonomic nervous system has an important function in providing resources to prepare an individual to react to a given situation. As an example, the sympathetic response is helps prepare the individual to flee a dangerous situation. Thus, an emotional experience generally elicits an activation of the sympathetic nervous system, resulting in changes in heart rate, respiration, adrenaline release, and electrodermal activity, among others. Some studies showed that experienced emotions, such as happiness, sadness, disgust, anger and fear, are correlated with the electrophysiological activity of specific brain regions, including the prefrontal areas, posterior cingulate cortex, ACC, frontal cortex, frontal lobe, medial frontal gyrus, temporal lobe and the amygdala [3]. Those findings confirmed that emotional processing of given stimuli involve multiple psychological processes that recruit a large number of brain areas and networks [4].

As a result, the scientific community has attempted to correlate some electrophysiological signals with the strength of an emotional stimulus. One of the most acceptable measurements, used to classify emotional experiences triggered by stimuli, consists in a two-dimensional scale of valence and arousal. In this model each emotion can be represented by a specific degree of valence and arousal, as illustrated in Fig. 1 [5, 6].

Valence and arousal are continuous scales ranging from 1 to 9. In the case of arousal, 1 means a calming stimulus, while 9 means an exciting stimulus. In the case of valence, 1 means a stimulus of unpleasant content, while a valence of 9 means a pleasant stimulus, in this scale stimuli with a valence level close to 5 are considered neutral. Although this classification scale is widely used in scientific research, the measures are usually assessed by self-reported questionnaires that include a high degree of subjectivity, so it is not yet known how these two dimensions assess an individual's emotional processing.

An objective measurement of one's emotional reactivity to a particular stimulus may be fundamental for the diagnosis of the individual's psychological state and help clinicians to determine the appropriate therapies for some mental disorders. Beyond this application such an objective measure can also be used to improve human-computer communication, in Brain-Computer Interfaces (BCIs), as well as to ascertain the real effect of a proposed product, in a neuromarketing framework.
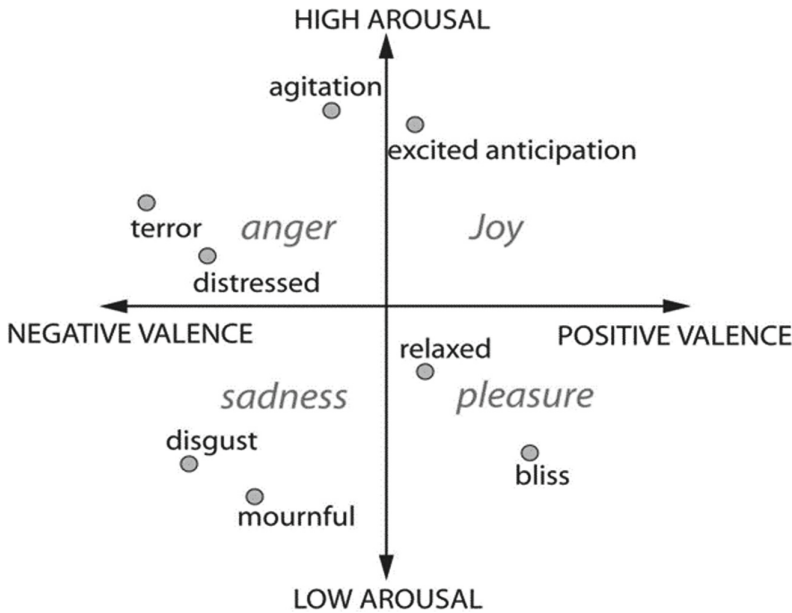
Fig. 1. Overview of the two-dimensional model [6].

In light of the above, the work presented herein aims to evaluate whether there is a correlation between the main parameters of Electrodermal Activity (EDA) and the arousal and valence levels of visual stimuli.

EDA measures changes in electrical properties of the skin, as a response to an externally or internally triggered emotion [7]. On one hand, the changes in skin conductance result from sweat production, by the eccrine sweat glands, which are controlled solely by the Sympathetic Nervous System (SNS) [8]. On the other, the SNS is affected by, at the central nervous system's level, brain regions responsible for emotional processing, such as the basal ganglia, the limbic system, and the premotor cortex [7]. Thus, it is safe to say that EDA can evidence the activity of the Sympathetic Nervous System and, consequently, the emotional impact that a particularly emotional stimulus elicits in a person [9].

2   Methods

The experimental protocol utilized in this work was developed in the context of a Mindfulness Meditation training study [10]. It included the recording of electrophysiological measurements, including an Electroencephalogram (EEG), an Electrocardiogram (ECG), and an EDA signal, as illustrated in Fig. 2. Those were recorded while the subject performed a set of tasks, which included the emotional response to visual stimuli, cognitive tasks, a concentration test, and stress-inducing challenges. All those recordings were performed with 25 subjects [10].
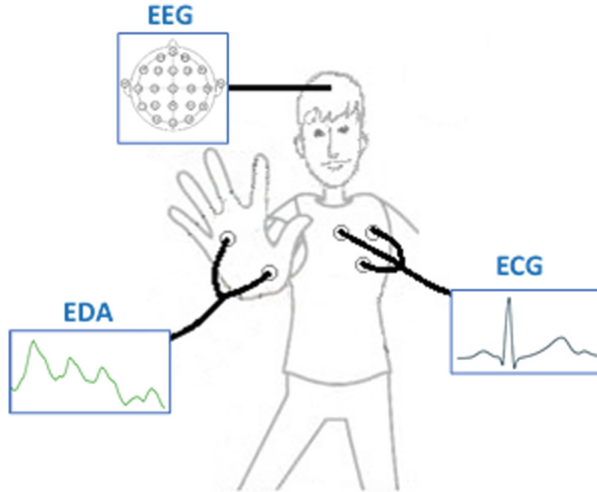
Fig. 2. Illustration of the experimental setup. Adapted from [5].

In the visual stimulation, which we will analyse in this manuscript, each participant viewed a sequence of 75 images, from the International Affective Picture System database (IAPS) [11, 12], developed by the National Institute of Mental Health Centre for Emotion and Attention, at the University of Florida. While observing the sequence of images, the 25 subjects remained comfortably seated, in front of a monitor, for 10 min. Each picture was shown for 6 s, followed by 2 s of an interval, with a black background, between the images. The sequence of 75 images were pooled from 6 different groups, with varying levels of valence and arousal: animals, facial expressions, human body suffering, erotic content, human threats and shock and repulsion. This work will focus on EDA data collected during the presentation of a sequence of emotional response visual stimuli.

2.1   Sample Definition and Characterization

The participation in this study was promoted through voluntary registration. For this purpose, recruitment information was made available through a poster in NOVA School of Science and Technology, and sent by email to all students, teachers, and staff.

The sample used in this study included 25 healthy participants (mean age = 26.0, standard deviation = 7.1), 9 of whom were male [10].

2.2   EDA Data Acquisition

The EDA signal was recorded using a 4-channel BioSignalsPlux wireless system, Fig. 3 [13]. This device collects signals from each sensor and establishes Bluetooth communication with a computer. The EDA signal was recorded with a resolution of 16 bits and a sampling rate of 500 Hz. The EDA data was recorded using the OpenSignals, a proprietary software from BioSignalsPlux.

2.3   Processing and Data Analysis

In this study, we used Ledalab to process and extract EDA parameters from the recorded signals. Ledalab is a powerful software, developed in MATLAB, that is capable of a variety of analyses from EDA recordings. The most important of those being the separation of the rapidly evolving, phasic component, from the slow varying tonic sympathetic autonomic response.

Because we do not need to have such high temporal resolution data, EDA signals were first filtered, using a Gaussian filter and downsampled to 10 Hz (ie., the sampling rate reduced by a factor of 50). Discrete decomposition analysis was then used to separate the tonic and phasic components. This analysis allows for a better temporal differentiation of the skin conductance responses (SCRs), and the identification of the electrodermal response to each specific stimulus, individually [14, 15].

We then extracted, utilizing Ledalab, the amplitude, area, number of SCRs (nSCRs), latency and skin conductance level (SCL) for all stimuli-induced responses. Each one of those parameters was normalized, by participant, to minimize interindividual variability.

Fig. 3.   Representations of the BioSignalsPlux device.

2.4   Statistical Analysis

Since we wanted to be able to confront extreme levels of arousal and valence, we only considered electrodermal responses to stimuli with values of arousal lower than 4.5, which corresponded to observing calming images, or higher than 6.5, associated with exciting images. This process led to 19 analysed stimuli – 12 with high and 7 with low arousal values. In the case of valence, we considered only the responses to stimuli that

had valence values lower than 2.5, i.e., corresponding to unpleasant images, and the ones with valence between 3.5 and 5, associated with neutral images. That resulted in 42 analysed stimuli – 15 neutral and 27 unpleasant.

The relation between the main EDA parameters and the values of arousal and valence was tested through a Linear Mixed Effects Model [16]. In that model, we considered the arousal or valence as fixed effects (i.e. predictor variables), and the interindividual variability as random effects. We applied this statistical analysis using the *fitlme* function, provided by MATLAB [17]. Analyses were conducted separately for each emotional parameter: valence and arousal.

3   Results

Tables 1 and 2 present the results of the statistical analysis, showing how valence and arousal can predict the normalized values of each of the EDA parameters considered in this study. Through the application of the Linear Mixed Effects Model, we can estimate the normalized value of each EDA parameter ($\widehat{P}$) as a function of valence or arousal. This estimation can be calculated by the following equation:

$$\widehat{P} = \beta_0 + \beta_1 \cdot Z \tag{1}$$

In the equation above, β_0 and β_1, represent the coefficients of the linear relation calculated by the model and Z is the predictor variable used in the model, in this study Z corresponds to Valence or Arousal, respectively. The estimator $\widehat{P}$ can assume all the EDA parameters considered in our study ($\widehat{Amp}$, $\widehat{Area}$, $\widehat{nSCRs}$ and $\widehat{SCL}$).

The following tables show the linear dependence verified between each EDA parameter and the values of valence and arousal, respectively. These relations take into account the standard errors for each calculated coefficient, β_0 and β_1. The last column in each table shows the statistical significance of each linear relation.

Table 1. Effects of valence on EDA parameters.

EDA parameter	Linear regression	p-value
Amplitude	$\widehat{Amp} = 0.22 \pm 0.02 + (0.02 \pm 0.01) \cdot Valence$	<0.05
Area	$\widehat{Area} = 0.22 \pm 0.02 + (0.02 \pm 0.01) \cdot Valence$	0.052
nSCRs	$\widehat{nSCRs} = 0.53 \pm 0.02 - (0.01 \pm 0.01) \cdot Valence$	0.43
SCL	$\widehat{SCL} = 0.71 \pm 0.03 + (0.02 \pm 0.01) \cdot Valence$	< 0.001

As shown in Table 1, amplitude and skin conductance levels increase for higher levels of valence. Since in this study images of higher valence correspond to neutral stimuli, we can state that amplitude and skin conductance levels increased as the negative affect of the stimuli decreases, a relation that was statistically significant (p-value < 0.05), while the remaining parameters, area and number of specific skin conductance responses, did not show a statistically significant correlation with the valence of the stimulation.

Table 2 shows that there is a statistically significant correlation between arousal and all EDA parameters studied, expect for number of specific electrodermal responses. The statistical analysis performed showed a significant increase in amplitude, area, and skin conductance level for exciting stimuli.

Table 2. Effects of arousal on EDA parameters.

EDA parameter	Linear regression	p-value
Amplitude	$\hat{Amp} = 0.21 \pm 0.07 + (0.02 \pm 0.01) \cdot Arousal$	< 0.05
Area	$\hat{Area} = 0.21 \pm 0.07 + (0.02 \pm 0.01) \cdot Arousal$	< 0.05
nSCRs	$\hat{nSCRs} = 0.63 \pm 0.07 - (0.01 \pm 0.01) \cdot Arousal$	0.27
SCL	$\hat{SCL} = 0.44 \pm 0.06 + (0.02 \pm 0.01) \cdot Arousal$	< 0.05

4   Discussion

This study examined the changes in electrodermal responses elicited by emotional images of different arousal and valence levels. As presented previously, most of the EDA parameters studied showed a direct relation with arousing pictures, as expected, with higher emotional intensity ones eliciting electrodermal responses with higher amplitude, area under the curve and skin conductance levels.

We also expected unpleasant pictures to elicit stronger electrodermal responses (i.e. greater amplitude, area, number of electrodermal responses and skin conductance levels) than neutral ones. Yet, the opposite relation was shown, for all studied parameters except the number of electrodermal responses. The area under the electrodermal responses, that is considered by some authors as the most important EDA parameter [7], did not show statistically significant relation to negatively charged images.

The overall results are consistent with previous studies that found a stronger relation between EDA and the arousal content of the stimuli used, than to the valence. One of the firsts studies that evaluated physiological and behavioural responses to visual emotional stimuli was conducted by Lang and co-workers [18] and found a stronger arousal to skin conductance association, although not all stimuli sets demonstrated high correlation between valence and skin conductance. However, that study found correlation between valence and other physiological measures, such as heart rate and facial muscles responses [18]. In addition, other studies have found that pleasant and unpleasant stimuli, with the same arousal value, elicit undistinguished electrodermal responses [19]. Our study is in line with those earlier ones, which suggest that electrodermal activity can be used to predict self-reported arousal [20].

Other studies showed also correlations between electrodermal activity and valence [21, 22]. There, it is shown that pleasant and unpleasant stimuli elicit greater electrodermal activity than neutral stimulation [12]. Although that correlation was observed, the

study developed by Lang and Bradley showed also that electrodermal activity is sensitive to habituation, resulting in more engaged electrodermal responses only to highly arousing stimuli. This may explain why the expected correlations were not observed in our study, since it used more unpleasant pictures than neutral ones [12].

Regarding the link between cerebral emotional processing and the electrodermal activity triggered by emotional stimuli, it is known that activity in the amygdalae, thalamus, and the insular and frontomedial cortices are involved in both emotional processing and sympathetic system control. Moreover, some authors point out that different aspects of emotional processing and response are mediated by distinct brain networks [23]. In this respect, Anders and co-workers associated functional measures of brain activity with behavioural and physiological responses such as, eyeblinking and EDA, triggered by emotional stimuli. Therein, they found correlations between valence, amygdalar activity and startle reflex augmentation, while arousal showed a correlation with frontomedial activity and electrodermal responses.

5 Conclusion

The current work shows that EDA is indeed an important physiological measure, which can and should be considered when assessing and monitoring an individual's emotional arousal state. This measure can be used as a good indicator of the emotional interaction that environmental stimuli trigger in a particular individual.

Such results reinforce the pertinence of using EDA signals in a variety of applications and research fields, including to contribute to the diagnosis of some psychological and mental disorders; in neuromarketing or in evaluating the success of brain-computer interfaces. In view of these promising applications of EDA, some researchers have developed wearables and algorithms that can collect electrodermal activity and classify, with good accuracy, the emotional state of a person [1, 22]. If one adds the rather low cost, and easy to collect nature of such signal [19], EDA is becoming an increasingly sought after research tool.

Further research needs to be done to study the electrodermal activity triggered by pleasant pictures, from the IAPS database, which were not considered in our work. It would be interesting also to study whether the relation between arousal and electrodermal activity, which we found in this work, can also be found with different kinds of stimuli, such as auditory and tactile.

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Identifying Government Funds to Help People with Disabilities: An Analytical Process

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Abstract. The development of people living with some type of disability depends on assistive technologies, their families and in some cases government support. Worldwide, 15% of the population lives with some type of disability. In this context, the different degrees of dependency, derived from the different limitations of functional diversity, as a result of disability, cannot in many cases maintain personal development, since their limitations do not allow them to be independent and require permanent care. What happens to these people and their family? The objective of the research is to identify the sectors in Ecuador in which government subsidies are concentrated and in which type of disability. This research is descriptive in nature and public information from authorized sources was used. Obtaining this information will allow to orient what care this vulnerable population requires for its development, since the different degrees of dependency will condition the evolution in the prevalence of disability at any geographical scale.

Keywords: Disability · Government funds · Functional diversity · Family

1 Introduction

At the global level, almost all countries have social protection initiatives, and many are working to expand their content and coverage as well as improve their impact [1]. In some cases, the objective of these systems is to protect only the minimum standards of living. Potentially, there are advances that focus on social protection as a tool to develop stronger livelihoods and address chronic poverty and social inequalities [2].

Target 1.2 of the United Nations Sustainable Development Goals 2015–2030 highlights social protection as a key input to "end poverty in all its forms" [3]. Social protection has social assistance and social insurance as components [4]. Social assistance is

related to the delivery of cash or in kind relief to groups considered vulnerable to poverty or groups who are currently in poverty. Social insurance programs are designed to mitigate the risks that may arise throughout a person's lifetime and generate beneficiaries' contributions.

People with disabilities are considered one of the beneficiaries of social protection strategies at national and international levels [5]. Disability is defined in the United Nations Convention on the Rights of Persons with Disabilities as persons who "have long-term physical, mental, intellectual, or sensory impairments that, in interaction with various barriers, may hinder their full and effective participation in society on an equal basis with others" [6].

Likewise, social protection as a right of persons with disabilities is established in international treaties such as Article 28 of the United Nations Convention on the Rights of Persons with Disabilities and Articles 22 and 25 of the Universal Declaration of Humans Rights [7, 8]. According to the provisions of Article 28 of the United Nations Convention on the Rights of Persons with Disabilities, persons with disabilities have the right to equal access to general social protection programs, such as health insurance, pensions, and other benefits in which eligibility does not depend on disability status [5, 9].

In a study of low- and middle-income countries, 81% of people with disabilities were found to be economically poorer compared to people without disabilities [10]. Likewise, in another study, it was established that they experience high levels of multidimensional poverty, such as malnutrition and lower levels of health, barriers to access to education and health, and exclusion from decent work and social participation [11].

There is very little evidence of the participation of people with disabilities in social protection programs. In a study conducted in Nepal, 31% of people with disabilities had identification of disability, and 13% received social assistance. The form of social assistance that is most frequently accessed is the old-age allowance; social protection rights other than social assistance (e.g., scholarships, discounted transportation, and health services) were generally low. It was established that the factors that influence access are geographic and financial accessibility of the application process, the procedures to determine eligibility, and the compliance of service providers [12].

High levels of poverty, social exclusion, and marginalization are evidence of the importance of developing a study of social protection in Ecuador aimed at people with disabilities. The objective of this research is to identify the sectors in Ecuador in which government subsidies are concentrated and to make the data visible by type of disability.

This article is structured as follows: Sect. 2 presents the methodology used as a key basis in the proposal. Section 3 presents the proposal results and a comparison to some related works. Section 4 presents the conclusions obtained from the results and suggests future lines of research.

2   Methodology

The data on disability bonuses were obtained from the National Council for Disability Equality of Ecuador and can be viewed on its website [13].

In the sample, there was a total of 164,163 valid data; 79,519 (48.4%) were identified as female, and 84,643 were identified as male (51.6%). Table 1 presents the age group distribution of this sample.

Table 1. Age group distribution.

Age group (years)	0 to 3	4 to 6	7 to 12	13 to 18	19 to 29	30–65	>65
Number	386	1,738	10,704	15,916	25,108	66,657	43,653
%	0.2	1.1	6.5	9.7	15.3	40.6	26.6

3   Results

To identify the government bonuses that are given to people with disabilities in Ecuador, the provinces in which there are records were analyzed. The analysis showed that there are seven types of bonuses: Human Development Bonus (HDB), which is $50; HDB variable component, which depends on the number of children; Joaquín Gallegos Lara Bonus, which is $240; Minors with Disabilities, which is $35; Senior Adult Pension, which is $35; My Best Years Pension, which is $100; and Person with Disability Pension, which is $50.

One piece of data that draws attention is that the percentage of women earning the HDB (in its two components) is 3.1%, which is higher than that of men; this allows us to conclude that women are more exposed to the highest levels of poverty; however, globally, women represent 48.4% of beneficiaries, as presented in Table 2.

Table 2. Bonuses by gender (%).

Bonus	Female	Male	Total
HDB	2.4	0.4	2.8
HDB variable component	0.7	0.0	0.7
Joaquín Gallegos Lara Bonus	8.6	9.8	18.3
Minors with Disabilities	4.4	6.0	10.4
Senior Adult Pension	9.9	8.3	18.2
My Best Years Pension	3.4	3.6	7.0
Person with Disability Pension	19.1	23.5	42.5
Total	48.4	51.6	100.0

Comparing the total number of people with disabilities registered in Ecuador (413,089 persons) [14] with the total number of beneficiaries (presented in Table 3) shows that about 39.7% of people with disabilities are beneficiaries of some type of

Table 3. People with disabilities covered by bonuses in Ecuador.

Person with disability	Hearing	Physical	Intellectual	Psycho-social	Visual	Total
Registered	61,605	202,033	75,627	21,142	52,682	413,089
Beneficiaries	21,508	69,407	49,341	7,390	16,516	164,162
%*	34.9	34.4	65.2	35.0	31.4	39.7

*% = Registered/Beneficiaries * 100

bonus. Being the group of people with intellectual disabilities the one who is most covered by bonus (65.2%).

Finally, concerning bonuses, Table 4 shows evidence that people with physical disabilities are the most represented (42.3%), and people with psychosocial disabilities (4.5%) are the least represented. The bonus with the highest participation is the pension for people with disabilities (42.5%).

Table 4. Distribution of bonuses per disability type.

Bonus	Disability					
	Hearing	Physical	Intellectual	Psychosocial	Visual	Total
HDB	0.5	1.3	0.5	0.1	0.4	2.8
HDB variable component	0.1	0.3	0.2	0.0	0.1	0.7
Joaquín Gallegos Lara Bonus	0.0	9.7	7.5	1.1	0.1	18.3
Minors with Disabilities	1.2	2.7	5.6	0.2	0.7	10.4
Senior Adult Pension	3.5	10.0	0.8	0.5	3.4	18.2
My Best Years Pension	1.7	3.3	0.6	0.1	1.3	7.0
Person with Disability Pension	6.0	15.0	15.0	2.4	4.1	42.5
Total	13.1	42.3	30.1	4.5	10.1	100.0

4   Conclusion

According to the available bonus data, women affected by some type of disability in Ecuador are poorer than men. This conclusion is drawn from the fact that the HDB (in its two components) is aimed at people with the highest levels of poverty (3.1% for women).

In future work, the authors plan to develop a more thorough analysis regarding the real contribution of bonuses to the economic development of people with disabilities in Ecuador.

The importance of this study, from a human factors perspective, comes from the fact that poverty is a key factor affecting sustainable development, as recognized by the United Nations. In fact, the United Nations notes: "Ending poverty must go hand-in-hand with strategies that build economic growth and address a range of social needs including education, health, social protection, and job opportunities, while tackling climate change and environmental protection." A clear understanding of the facts will help define adequate strategies and corresponding actions to overcome the factors affecting the goal of reaching adequate population wellbeing conditions in a sustainable world.

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Smart Manufacturing

A Fuzzy Inference Model
for Social-Sustainability Production Planning

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Abstract. Production planning is a scheduling process to acquire, utilize, and allocate production resources to specific production activities in the most efficient way, meeting customer expectations. Due to, e.g., climate crisis, customer expectations are changing shift to be more sustainably produced products. Therefore, decision-makers have to adjust economic production planning goals according to social and environmental aspects. However, driven by financial market expectations, most enterprises still consider the economic dimension more important than the other two. Especially the social dimension has been neglect in previous approaches for sustainable production planning. The paper presents a concept of a fuzzy inference model (FIM) to assess the social-sustainability of production programs using expert knowledge. The concept shows the formulation of the FIM using common methods and fuzzy operators from the fuzzy set theory. The FIM determines the sustainability potential to improve the production program. The concept was applied in a case study. For the case study, the FIM has been implemented in a simulation model of a job shop learning factory.

Keywords: Sustainable development · Human-systems integration · Production planning · Social-sustainability

1 Introduction

Sustainable development is defined as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs [24]."

This definition of "sustainable development" is widely accepted in the scientific literature, while the meaning of sustainable development has remained vague. In general, a system is developed in two steps: First, the potential of a system is determined to a better state, and second, possible actions must be elaborated to reach this better state [6].

For production management, production planning tools exist to determine the future production system state and to identify possible improvements [12]. In general, production planning is a scheduling process to support decision-makers in acquiring, utilizing,

and allocating production resources to specific production activities [7]. Conventional production planning aims to meet customer requirements most efficiently regarding product quantity and quality [7, 12]. Due to crises (e.g., climate crisis) [4], the customer requirements shift to be more sustainable produced products avoiding environmental and social impacts [23]. Therefore, decision-makers have to adjust production planning goals to be more sustainable [9].

Existing sustainable production planning approaches are usually focused on the environmental sustainability aspect. Environmental sustainability production planning is widely studied and considers sustainability aspects, such as energy efficiency, emissions (greenhouse gases, waste, effluent), material reuse and recycling, and product remanufacturing [11, 21]. However, social aspects have been neglected in previous research studies for different reasons [1, 10, 20]. Driven by financial market expectations, most decision-makers in companies still consider the economic aspect as more important than the other two aspects [13]. Moreover, decision-makers in enterprises lack knowledge and awareness of sustainable manufacturing [3]. One reason for this difficulty is the vagueness of the concept and a diverse set of constituents about sustainability visions based on their different needs and aspirations [16].

However, mathematical models can contribute to decrease the complexity of sustainability [27]. These mathematical models require expert knowledge to evaluate sustainability [2, 17]. Therefore, a fuzzy inference model (FIM) has been developed to overcome these problems. The paper presents the concept of the FIM for social-sustainable production planning. Moreover, a case study is presented to prove the concept.

The FIM is developed using common methods and fuzzy operators from the fuzzy set theory [25]. The results of the FIM are used to identify opportunities to improve production programs' social-sustainability. The concept is tested with the aid of a learning factory from the University of Applied Life Sciences Emden/Leer.

Section 2 presents the results of a narrative literature review to further define the paper's context and theoretical background for social-sustainable production planning. Section 3 describes the scope of the case study. Based on such scope, the FIM's general mathematical formulation is described in Sect. 4. The results of the case study are presented in Sect. 5. Finally, Sect. 6 presents the paper's conclusion and future work, followed by the references.

2   Production Planning from a Social-Perspective

Several definitions for sustainable manufacturing exists. Sustainable manufacturing can be defined as: "The creation of manufactured products through economically-sound processes that minimize negative environmental impacts while conserving energy and natural resources. Sustainable manufacturing also enhances employee, community, and product safety [22]." The definition indicates that social-sustainability can be determined for different stakeholders (employees, communities, and consumers). However, this paper is limited to employees' well-being in manual production processes.

For this approach, it is required to understand the needs of the employees related to production systems. Maslow introduces a widely accepted hierarchy of general human needs, which divides the needs into three categories: basic needs (physiological and safety needs), psychological needs (social belongings and self-esteem), and

self-fulfillment needs [15]. Manufacturing environments should be designed to support these needs [19]. The standard "Ergonomic Principles in the Design of Work System" establishes the fundamental principles of ergonomics to support the needs presented by Maslow [8]. The standard divides employees' well-being into three main areas: work task, work environment, and human-machine interaction.

Based on these categories, Cao, Wang, Yi and Zhou constructed a social sustainability assessment framework for manufacturing systems identifying relevant variables to assess the employee's well-being [5]. Moreover, several frameworks exist to describe the social sustainability aspects in different domains [20]. However, the frameworks are applicable for strategic production planning for long-term horizons only, which cannot directly be adapted for operative production planning in short-term horizons. A literature review was performed to overcome this research gap. The literature search has been done in usual databases (e.g., Science Direct, Scopus) for the timeframe 2000 until 2020. Relevant literature must contain at least one social-sustainability aspect, which is used to plan a manufacturing system.

The literature review, which involved the full-text analysis of 19 papers, allowed identifying common objective functions and variables for social-sustainable production planning. Due to lack of space, only the found objective function and variables are presented. The literature review results have been extracted from the previous study for sustainable production planning [28]:

- Threshold for the **required human workforce** for job tasks
- High **learning rate of employees** processing jobs
- Low **forgetting rates of employees** processing jobs
- Maximal **skill level** of the employee
- Minimal **risk of injuries** or health impacts caused by physical stress on employees (e.g., OCRA index).

3   Concept of the Fuzzy Inference Model

The FIM is developed using common methods and fuzzy operators from the fuzzy set theory [25]. In general, fuzzy set theory is one opportunity to use expert knowledge for evaluation processes. The expert knowledge is expressed as mathematical functions, linguistic rules, fuzzy numbers, or linguistic expressions.

Figure 1 presents a general procedure of the FIM evaluating production schedules according to social-sustainability aspects using fuzzy set theory. The formulation of the FIM was adapted from the previous paper for sustainable production planning [28]. The following section is focused on the key features of the FIM for social-sustainable production planning and misses detailed theoretical background information for the fuzzy set theory.

Based on the common objective functions presented in Sect. 2, a sustainability planning goal is set for the case study. The FIM aims to keep workers' physical workload at an acceptable level. For this goal, the accumulated workload peak and the average queue time of the warehouse are evaluated to determine the potential of improving the production program. This potential is quantified through a fuzzy membership degree

(μ_P) that assumes the values $\mu_P = 1$ if there is a high potential, $\mu_P = 0$ if there is a low potential, and between 0 and 1 for medium levels of potential.
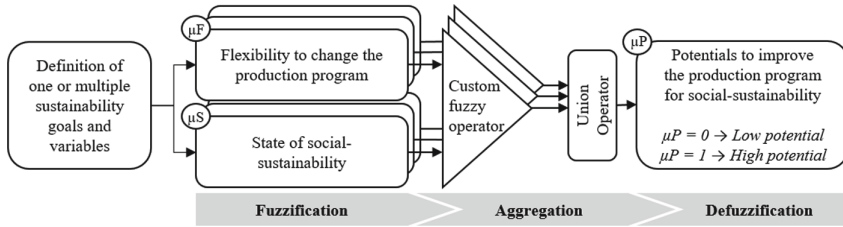
Fig. 1. A general procedure of the FIM evaluating production schedules according to social-sustainability aspects.

Next, the selected variables for the planning goal need to be transformed into fuzzy values. This transformation is named as fuzzification process. The fuzzification process calculates fuzzy values (μ_x) using fuzzy sets (membership functions). A fuzzy set is used to map a variable (x) to a value between zero and one [15]. Table 1 presents the fuzzy sets and membership functions used for the case study. The fuzzy sets' mathematical formulations have been determined based on expert knowledge for acceptable workloads [14] and sensitive analysis evaluating the queue time at different production utilizations.

Table 1. Graphical and mathematical presentation of two fuzzy sets.

Graphical Presentation	Mathematical Formulation
	$\mu_{(X)} \begin{cases} 1, & x \le x_1 \\ \dfrac{x_1 - x}{x_1 - x_2}, & x_1 < x < x_2 \\ 0, & x \ge x_2 \end{cases}$
	$\mu_{(X)} \begin{cases} 0, & x \le x_1 \\ \dfrac{x - x_1}{x_2 - x_1}, & x_1 < x < x_2 \\ 1, & x \ge x_2 \end{cases}$

Next, the fuzzy values are combined. This combination is named as aggregation process. The aggregation process uses fuzzy operators, which combine two or multiple fuzzy values. The FIM for sustainable production planning aggregates the fuzzy values in two steps (see Fig. 2). First, the fuzzy value for the state of sustainability ($\mu_{S,j}$) is combined with the flexibility variable ($\mu_{F,j}$) using a customized fuzzy operator (see Eq. 1). Second, multiple sustainability potential fuzzy values ($\mu_{SP,j}$) are combined using

a union operator to determine the highest sustainability potential (μ_P) for the considered production program (see Eq. 2).

$$\mu_{SP,j} = \frac{1 - \mu_{S,j} + \mu_{F,j} * \left(1 - \mu_{S,j}\right)}{2} \tag{1}$$

$$\mu_P = \max(\mu_{SP,1}; \ldots; \ \mu_{SP,j}) \tag{2}$$

Finally, the aggregated fuzzy value is defuzzified to a linguistic category using the height method [18]. Three sustainability states have been defined for the interpretation of the sustainability potentials: **High sustainability potential** indicates a low or medium state of sustainability. In this case, the production flexibility is sufficient, and the production program can be changed to improve the sustainability state. **Medium sustainability potential** indicates a low or medium production flexibility. In this case, the production program must be changed to increase the production flexibility, e.g., interrupting production processes. Then, the production program can be changed to improve the sustainability state. **Low sustainability potential** indicates a high state of sustainability, and no more action is required to improve the production system.

4   Scope of the Case Study

The FIM has been implemented in an AnyLogic® simulation model of the Learning Factory 4.0 from the University of Applied Life Sciences Emden/Leer. The learning factory demonstrates a job shop production system that is connected to an industrial enterprise resource planning (ERP) system. The ERP system offers several opportunities to collect and analyze production data for different purposes. A detailed description of the physical and digital structure is presented in this reference [26].

Based on the digital data in the ERP system, a simulation model was developed in AnyLogic®. Figure 2 presents the system boundaries of the production system, which contain two relevant processes for the case study: material preparation process and production process.
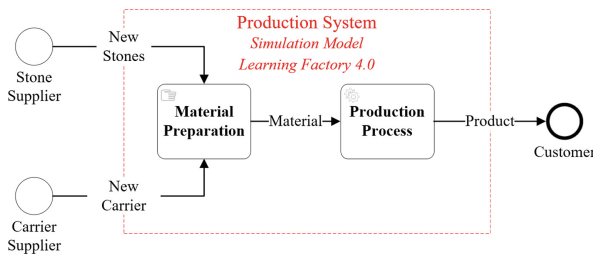
Fig. 2. Presentation of the system boundaries of the case study, illustrating the material's flow between the relevant functional units.

The **material preparation process** adds new materials (carriers and stones) from the suppliers to the production process. The preparation process combines new carriers manually with new stones. This combination process causes physical stress on the worker.

The physical work stress is modeled and evaluated according to data and knowledge from the reference [14]. Second, the **production process** contains several production activities to transforms materials into products. The production activities are fully automated and are controlled by the production manager by, e.g., setting specific production outputs and interrupting production processes if necessary.

5   Results of the Case Study

The FIM concept is tested in two production scenarios, which differ in the utilization of the production system. The simulation results are presented inTable 2.

For the **high utilization production scenario**, the FIM determines a medium sustainability potential to improve the production program's sustainability. In this case, the production flexibility is medium. Therefore, the simulation model gives recommendations to increase the production flexibility, e.g., interrupting production activities at the resource warehouse, which increases the queue time at the resources as well as the production flexibility. Due to this flexibility increase, material preparation activities can be shifted to decrease the worker's workload peak, improving the state of sustainability.

For the **low utilization production scenario**, the FIM determines a low sustainability potential. Therefore, no actions are required to enhance the sustainability state of the production program.

Table 2. Presentation of the case study results.

Production utilization	Variable	Value	Fuzzy value	Aggregated fuzzy value	Defuzzification (model outcome)
32 products/hour	$\mu_{S,High}$	376.7 kJ	0.493	0.442	Medium sustainability potential
	$\mu_{F,High}$	630 s	0.743		
10 products/hour	$\mu_{S,Low}$	124.16 kJ	1	0.003	Low sustainability potentail
	$\mu_{F,Low}$	225 s	0.003		

6   Conclusion and Future Work

The paper presents a concept and case study of a FIM for social-sustainability production planning. The FIM determines the sustainability potential of production programs based on expert knowledge. The FIM was implemented in a simulation model of a job shop learning factory, which uses production data from an industrial ERP System. The simulation model was used for a case study to test the functionality of the FIM in production scenarios, which differ in production utilization. Based on the FIM results, the simulation model gives recommendations on how actions can improve the production program's sustainability state.

The case study results provide several opportunities for future works. The case study is limited to a job shop lab learning factory. Therefore, the case study needs to be extended to other cases considering different production systems (batch, flow production) in real industrial environments to test and validate the FIM for sustainable production planning. Moreover, the FIM uses equal weights of importance for the selected variables to evaluate the production program. A weighting system based on, e.g., user preferences for sustainability should be added to the FIM.

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A First Approach for Implementing a Telepresence Robot in an Industrial Environment

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Abstract. While after months of virtual-only meetings, the benefits of face-to-face meetings have been clearly missed, the alternatives are not only remote and on-site. An interesting path to explore is the usage of telepresence robots (TPR). A TPR is a video conference system with remote control movement capabilities. It allows individuals to work remotely from one place (e.g., home) while at the same time experiencing another place (e.g., production plant). Despite having been used to promote social interaction in office, academic, and medical environments, TPRs have not been implemented in an industrial context. Similarly, formal research for TPR application in industrial environments is amiss. This paper provides an overview of a series of preliminary tests and interviews with technical users and industry experts to determine suitable implementation scenarios and requirements for a TPR in an industrial environment. As a conclusion, an initial set of requirements and four possible application scenarios are presented.

Keywords: Human factors · Human-systems integration · Telepresence robots · Interaction design · Remote work · Interactive video conferencing

1 Introduction

Working remotely for extended periods directly impacts the employees' productivity, engagement, and motivation due to isolation and the lack of informal and spontaneous communication with colleagues within the work environment [1, 2]. Improving the virtual interaction experience during remote working is therefore needed [3]. An option is the broader usage of telepresence robots (TPR). A TPR is essentially a video conference system with movement capabilities that can be operated remotely [4]. It combines the possibility of balancing working remotely while still being able to experience another. The TPR remote user is the user who remotely connects via a computer interface with the TPR and is in a different place (at home) as the TPR. The TPR remote user can move the TPR independently and interact with local users at the other location (at the office). The TPR local users are the users that directly interact with the TPR [5]. The freedom

of movement and the independent point of view given by the TPR are features that can not be achieved with a regular video call [6]. The TPRs have been used to promote social interaction in office, academic, and medical environments [1, 4, 5, 7–10]. The communication is perceived as more natural due to the remote user's physical presence via the TPR and his/her physical and social presence increase [1, 4].

Until this date, there is no known formal research for TPRs applications in industrial environments. The TPR can be applied as a hands-free remote assistance tool as the TPR local user does not need to carry any additional equipment. This opens new research and potential application fields that need to be explored further.

2   Related Work

A TPR system consists of both the physical robot (sensors, actuators, and a screen) and the interface used to control the robot. The most important aspect of using a TPR is merging the real and digital world through the TPR remote user's virtual presence on site. The TPR remote user can move freely (if possible) in the robot's environment and interact with other people [5, 11, 12]. Currently, the usage of a TPR is intended for indoor use only.

Minsky coined the concept of telepresence in 1980 in that work could be done without leaving your home, eliminating, in some cases, chemical and physical hazards and reducing time and energy costs. "One person could do different jobs in different places" [13].

The concept was further developed in 1998 by Paulos and Canny [14] as Personal Roving Presence (PRoP). It provides the fundaments of personal tele-embodiment. PRoP proved in the early stages to be an advantageous and functional apparatus for the communication and cooperation between persons in different locations. It could carry out important work and social tele-activities.

Current use cases for a TPR are limited to virtual mobility in the office, support for medical and nursing staff, teaching, and research. Examples of use in office environments include attending conferences, meeting with colleagues in different locations, saving travel and working time [4, 9]. In healthcare, TPR is used for virtual doctor consultations and nursing and elderly care to facilitate communication between isolated patients or residents of nursing homes [12, 15–17]. For teaching, it is used to bring together teachers and students from different locations and connect sick students with their schools [10, 18]. The positive effect of TPR has been shown for several scenarios, including the offer to people with limited mobility the opportunity to be present at other sites with less effort [7, 8].

3   Requirements and Scenarios for a TPR on the Shopfloor

Bjoernfot et al. [4] state that TPRs could be employed for troubleshooting activities in a production line due to the positive effect of video conferencing. An empirical study on the application of TPR in a production environment using a Double 2 was conducted in 2015 by General Electric. The TPR allowed employees to move freely around the office or workstations in the production and enabled communication between different

locations (offices and production area) and all parties concerned (customers, engineers, technical staff) [19]. Therefore, it is surprising that currently, neither official results nor structured evaluations or standards for TPR in industrial applications are published.

Given the lack of data, we designed and conducted two preliminary tests (n = 26) and one expert workshop (n = 20) with technical users and industry experts to determine possible implementation scenarios and requirements for the TPR. A German car manufacturer was selected as an industrial implementation environment, providing several possible application scenarios. The tests were made using a Double 3 TPR from Double Robotics. The Double 3 was chosen due to its technical specifications (self-driving capabilities, high-resolution cameras, open-source platform) and low purchase cost (5000USD).

Telepresence robots offer an innovative and applicable communication alternative that needs to be explored further. The TPR presents several advantages compared to the use of mobile devices in an industrial environment. The TPR local user does not have to set up or deal with any software before and during the interaction. It also allows the TPR local user to perform hands-free work during the interaction with the TPR remote user.

3.1 Preliminary Test 1 Virtual Tour

The test's main goal was to explain the current and intended implementation of the TPR and showcase its features. 26 participants were selected from different technical backgrounds without any previous experience using a TPR. The participants were located in (Colombia (7), France (2), Germany (13), Lebanon (1), Spain (1), USA (1), and United Kingdom (1)). Each participant acted as a TPR remote user on avg. 70 min and explore a controlled environment. The participants did not face any problems for navigating in an unknown surrounding. All participants show interest in using a TPR daily. They suggested several scenarios and requirements for the implementation of a TPR in an industrial environment. The feedback and implementation requirements from each participant were gathered to be evaluated at the expert workshop.

3.2 Preliminary Test 2 Remote Instructions

The test's main goal was to find if additional artifacts are needed during a remote assistance task. 6 participants who already took part in the Virtual Tour (3 TPR remote users and 3 TPR local users) were selected. The TPR local user had to build a small LEGO set with approx. 90 pieces following the instructions from the TPR remote user. The duration of each test was on avg. 50 min. The task was successfully accomplished and proved that remote assistance could be achieved using only the TPR build in features (e.g., screen sharing). The participants concluded that the TPR is a convenient communication tool that leads to a more natural exchange of ideas than a video conference system using a computer, tablet, or smartphone. Due to the physical presence of the TPR remote user on-site and the TPR local user's ability to perform hands-free work.

The participants list several implementation requirements that could make the remote assistance task (giving and receiving instructions) more comfortable to perform when

employing a TPR. Similar to the first preliminary test, the results were gathered to be evaluated at the expert workshop.

3.3 Expert Workshop

The expert workshop took place at a German car manufacturer's training facility with 20 Participants (5 of them took part in the Preliminary Test 1. Virtual Tour). The participants had the opportunity to act as TPR remote users or local users. The feedback and implementation requirements from the preliminary tests were discussed and summarized (Table 1). The first set of implementation requirements were listed and assessed on a priority basis, including a meta-artifact complexity.

Table 1. Overview of the implementation requirements for a TPR in an industrial environment

Priority	Implementation requirement	Reason	Meta-artifact complexity
1	Headset	Bluetooth Headset for the TPR local user for better communication	Low
2	Laser or light pointer	The TPR remote user could point objects on location	Medium
3	Removable camera	A second camera for explaining details that the camera of the TPR can not see (e.g., inside the car, under/over equipment)	Medium
4	Distance range	The battery percentage indicator should also have a drivable distance range	High
5	Audible alert system	TPR should announce that it is moving for unaware local users	Medium
6	Advertency Light	TPR could have a light ring around the display to be used as a raise hand function	Medium
7	Bird-eye view perspective	Driving through tight spaces and unknown locations could be easier	High
8	Smart building interaction system	TPR could scan QR-Codes and interact with the surroundings, open and close doors, call elevators, and turn lights on and off	Very high
9	Face ID recognition	Digital ID-Tag, while driving in unknown locations, be able to identify the local users	Very high
10	Cover surroundings	For external remote users, fade-out sections of the production line or equipment	Very high

Four suitable implementation scenarios were defined by the need for an expert's physical presence for assistance. 1. *Internal Production Audits/Product development* – experts from different locations can discuss on-site a project/product/equipment without the necessity of traveling, reducing preparation time and costs. The distance between the production sites in Germany can be up to 580 km (360 miles). 2. *Vocational Training* – expansion of the talent pool of trainers from other production sites. 3. *Troubleshooting for dealershi*ps – fewer expenses for technical support from the factory to the dealership. 4. *Logistics* – inventory checks.

4 Conclusion

In summary, we have presented the first approach for implementing the TPR in an industrial environment. Preliminary tests and the expert workshop with technical users and industry experts, nine implementation requirements, and four suitable scenarios were presented. We concluded that the TPR's freedom of movement and perspective is advantageous for the TPR remote user in industrial environments. The TPR could be beneficial in remote assistance scenarios or when control/audit activities need to be performed. The TPR could also be used as a hands-free remote assistance tool.

However, more implementation scenarios, requirements, and limitations should be explored and verified. The benefits of a TPR for remote assistance in a production environment, the interaction design requirements for the TPR, the positive effect on discussion and exchange of information using a TPR, and the importance of being physically present versus telepresence through a TPR (physical robot, digital person), will be examined in subsequent papers.

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How Workers Perceive LAEVO Exoskeleton Use in Non-cyclic Tasks

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Abstract. Exoskeletons are an innovation that have been increasingly explored in various fields. In fact, industries are one sector that have been investing in the studies of this new equipment to answer the unnecessary efforts made by the operators, where technical and organizational measures implemented are not enough to reduce the risk exposure to demanding working conditions. Hence, a study was conducted to understand the operator's perceptions in the workplace regarding the use of a low back passive exoskeleton (Laevo). Ease of performing the different tasks with the use of the exoskeleton, ease of use, discomfort, perceived effort with and without the use of this equipment, acceptance, usability, and intention to use it, were the parameters assessed in this study. The exoskeleton was tested in 3 workstations, by a total of 23 workers during tasks that required trunk flexion, manual material handling or both in an automotive industry. The goal was to develop a pilot test, study the participants' perceptions and opinions, and conclude whether the exoskeletons are ready for the industrial context in non-cyclic processes.

Keywords: Passive exoskeleton · Automotive industry · Non-cyclic tasks

1 Introduction

Throughout the years, not only the number of industries has been increasing but also the technologies used in their environment. Despite the advantages, the workload has increased, along with the number of individuals exposed to work related musculoskeletal disorders (WRMD). WRMD ends up being a problem related not only to the employee's health but also to the prejudice of companies in terms of productivity and economics. Therefore, companies keep continuously trying to improve working conditions through ergonomic approaches [1–3].

However, despite the various efforts of Ergonomics to adapt tasks that initially cause disorders in the human body and avoiding unnecessary efforts through technical and organizational measures, there is still a need to look for new solutions, since it is not always possible to implement them, and when implemented, often the risk of development of WRMD still exists. With the development of technologies, more companies are adapting to robotization and automation, being exoskeletons, an innovation increasingly

explored. Exoskeletons aim to provide support when other preventive measures are not feasible or effective and when automation is not viable due to the constant change of tasks in the workstation [4].

Exoskeletons are mechanisms that support the user's body by assisting demanding postures and movements, which allows a reduction of the metabolic load on the user's body and consequently may reduce the risk of injury and fatigue [5]. Exoskeletons can be active or passive. Active exoskeletons have the ability to increase the strength of the user, in different areas of the body, through an external energy source (for example, electric motors or hydraulic actuators) that contributes mechanically to the joint moment [6, 7], while passive exoskeletons reduce the impact of a movement on the user's body, through the redistribution of the force generated by the movement of the user's body or by the movement of loads, to different regions of the body, having no external energy source but components such as springs and dampers [2, 6]. They can support the entire body, upper limbs, trunk, or specific segments.

With that said, exoskeletons were created to help mostly in the areas of medicine and military, however they are being increasingly explored in industries [8]. The objective is to assist workers during demanding working conditions such as manual material handling, forward bending and overhead work. Hence, for the industrial sector, passive exoskeletons that support mostly the trunk and upper limbs are the most sought. There have been more studies about them over the years, and despite being a mechanism still under development, there are already studies that demonstrate its potential. According to Iranzo and collaborators [2], for example, it is shown that a passive exoskeleton for trunk support can reduce 34% and 18% of the deltoid and the trapezius muscular activities, which can lead to a reduction of discomfort and fatigue, and consequently to the possibility of increasing the worker's performance. Most studies are generally carried out in laboratory; however it is important to conduct tests in an industrial context due to the various characteristics that this environment covers, mainly in terms of versatility and automation.

When analysing an equipment or any technology, it is important to study not only objective measures but also subjective ones. Objective measures allow researchers to prove existing advantages, however, it is also important to study the user's perception since if they don't perceive those effects, their acceptance and motivations to use the equipment might reduce [6]. Therefore, it becomes relevant to study the user's perception regarding acceptance and intention of use. Perceived effort, discomfort and ease of use of the exoskeleton are also factors to study once they might influence the user's acceptance [1].

The aim of this study was to access the subjective evaluation of a passive exoskeleton, through the user's perception, in three different working stations with non-cyclic tasks that require forward bending, trunk rotation and/or manual material handling, in an automotive industry.

2 Methods

2.1 Participant's and Workplace Selection

For the selection of the workplaces where the exoskeleton was tested, the following criteria were used: (i) golden standards reported in the literature; (ii) recommendations given by the manufacturer; (iii) results from the workplaces ergonomics assessments, mainly regarding posture risk factor. Therefore, the workplaces selection was based on the following parameters: trunk bending (20° to 60°) more than 30% of the work cycle, high trunk bending (more than 60°) more than 5% of the work cycle and manual material handling of more than 3 kg.

According to these criteria, three workstations in the Press area were selected:

- workstation 1 (Presses - TAPs 1/3/4: grab pressed parts and place them in the respective containers),
- workstation 2 (Business Unit: construction and manual tooling of molds to make press parts),
- workstation 3 (Maintenance Tool & Die: maintenance and manual tooling of molds to make press parts).

All these workstations are mostly dynamic, complex and have a great variety of cyclic and non-cyclic tasks. However, in the present study only the analysis of non-cyclic tasks were performed.

The participation in this study was voluntary, with a set of requirements to be fulfilled: workers must have more than 3 months of experience in the tasks under study, the medical department must approve the participation of each individual (participants must have no medical restrictions to perform the tasks defined) and their anthropometry must fit the exoskeletons specifications (heights between 164 cm and 196 cm). Thus, the total number of workers who participated in this study was 23, distributed as follows: workstation 1 - 7 participants, workstation 2 - 4 participants and workstation 3 - 12 participants.

2.2 Passive Exoskeleton

For this study, a passive exoskeleton (Laevo V.2.56) was tested. Laevo is designed to support the trunk during repetitive and/or static tasks that require bending. It weighs 2.8 kg and consists of a chest pad, two structures around the thighs, a hip strap to keep the exoskeleton in a steady position, and a smart joint mechanism. The chest pad and the components around the thighs are connected through rigid bars running over a smart joint which allows the user to perform a trunk flexion with less low back effort while creating a resistance in the chest and thighs. Regarding the smart joint, it is possible to adjust the support angle from 0° to 35°. Although this exoskeleton has 5 different rigid bars sizes available, for this study only 4 were obtained, which led to the requirement that heights needed to differ between 164 cm and 196 cm to ensure the right adjustments.

2.3   Testing Procedure and Materials

The test in each workstation lasted approximately 4 weeks and the exoskeleton was only used when the participants were performing tasks adequate for the study, depending on the rotation of the team.

The first step of the testing procedure was to present the pilot test and introduce the exoskeleton to the teams working in the selected workstations. After that, volunteers signed an informed consent, authorizing the participation in the study and the collection of personal data.

Before the start of the pilot test, participants were submitted to an initial medical evaluation which provided the eligibility of each participant to the study. On the first day of testing, there was initially a period of training, so the participants learned how to use and how to don and doff the equipment. The first test lasted no longer than 30 min and in the following days, when possible, there was an increase in the duration of the test, so that there could be an adaptation period. The maximum usage time was established as 2 hours/day per participant.

At the end of each use of the exoskeleton, two different questionnaires based on subjective indexes were applied. One after the usage on the first and last day, and the other on the remaining days (daily questionnaire). In the daily questionnaire, questions related to the perceived ease of performing different tasks with the use of the exoskeleton were applied, to conclude which tasks were more adequate. Its questions were based on Single Use Question (SEQ) [9] and a 7-point Likert scale with "1 - very easy" and "7 - very hard". The initial and final questionnaire collected the participants' perception regarding perceived effort, discomfort, perceived usability, and ease of use (donning and doffing the exoskeleton and angle regulation), and intention to use. Perceived effort was classified for each body region for the conditions with and without the exoskeleton, using the Borg CR-10 scale. Regarding discomfort, its classification might be referring to pressure, heat, perspiration, friction, skin irritation, among others. For its evaluation, a scale based on a 7-point Likert scale was used with "1 - minimum discomfort" and "7 - maximum discomfort". Perceived usability was classified based on the Post-Study System Usability Questionnaire (PSSUQ) [9] evaluating the usefulness, interface quality and satisfaction. In total 10 questions were applied, and a 7-point Likert scale was used with "1 - don't agree" and "7 - totally agree". Regarding ease of use, two questions were added related to the ease of donning and doffing of the exoskeleton and the regulation of the support angle. Lastly, the intention of use was classified through two questions based on the Technology Usage Inventory model [10] concerning wanting to have access to the exoskeleton and intention to use it. The scale used for classification of ease and intention of use was a 7-point Likert scale in terms of agreement "1 - don't agree" and "7 - totally agree". In both questionnaires, participants could also give feedback regarding their opinions and complaints. The analysis was made by grouping the comments into clusters and verifying the frequency that each one was mentioned.

After the conclusion of the test period, all participants were subject to a final medical evaluation by the medical department.

The survey tool used in this study was based on Hensel and Keil's [11] and Ferreira and collaborators' [1] studies, and on methodologies considered relevant derived from the literature review.

3 Results and Discussion

Keeping in mind that the objective of this study was to study non-cyclic tasks that involve trunk flexion, it was possible to conclude how diverse tasks can be while using the exoskeleton and which postures are more favourable. Taking this in account, for all workstations, participants reported that in general, the exoskeleton helped them performing most of the tasks, however they also reported some limitations. In tasks that involved heavy material handling, the participants reported that the exoskeleton made the task easier to perform. Nevertheless, tasks that were most dynamic and involved various postures were classified as harder to perform. Additionally, for tasks that involve slight bending forward, the exoskeleton might sometimes disturb rather than help performing the task. Considering the three workstations, workstation 3 was the one where most participants reported that the use of the exoskeleton made their tasks easier to perform, although their tasks involved various postures, since it also involved static trunk flexion. In workstation 2, for tasks similar to workstation 3 participants reported likewise.

In terms of perceived effort with and without the exoskeleton, in most body regions there was perceived a decreased effort with the exoskeleton in all workstations. Differences were stated on the lower back, chest, and hips in all three workplaces. Besides that, workstation 1 and 3 also reported the upper back and abdominal region as a decrease in effort with the use of the exoskeleton. Additionally, participants in workstation 1 also reported the perceived effort on the neck, shoulders, thighs, and knees as significant. In general, throughout the study the perceived effort maintained or decreased in all body regions. However, in workstation 2, the knees were reported with a slight increase (decimal difference) in the perceived effort since some participants tend not to bend their knees while wearing the exoskeleton causing a bigger effort on this region. Besides, the structure of the exoskeleton that is in contact with the thighs, depending on the length of the workers' legs, can be very close to the knees causing an increased effort on this region. Analysing the results reported regarding the chest for this workstation, we can verify that participants perceived a decreased effort with the exoskeleton on the first day, but on the last day they reported an increase. Its reason is related to the tasks performed since on the last day tasks that required stronger bending were performed causing a bigger pressure in this region. Data also showed that in workstation 2, on the last day of use, participants perceived a slight increase of effort on the abdominal region and thighs. These increments happened due to the tasks that were not 100% suitable for the exoskeleton since they required strong bending of the trunk which leads to a higher pressure and effort in these regions. Angle adjustment from which the exoskeleton will provide the mechanical support is settled initially by the user (often before donning). Whenever dynamic tasks take place and readjustments are needed, workers tend to skip the readjustment step (due to time pressure) and therefore the mechanical support settled will be appropriate for some tasks and disturb while performing others. Analysing the three workplaces, we can conclude that regions where the perception of effort is higher, are also the regions that are exposed to higher physical working demands. In general, the body regions where it is perceived less effort with the use of the exoskeleton, are those mostly reported on the user's trunk (upper back, lower back, abdominal region, chest) and the hips and thighs.

Regarding discomfort, on average in all three workstations the perceived discomfort was low (workstation 1: $\bar{X} = 2,2$; workstation 2: $\bar{X} = 1,7$; workstation 3: $\bar{X} = 2,0$). In general, higher values of discomfort were perceived on the upper back, chest, hips, and thighs. The discomfort in these regions is caused by friction, pressure, and heat. Throughout the study, there was an increased discomfort on the three workstations on the upper back, chest, and shoulders. Meanwhile, for the thighs there was a decrease. Regions such as the lower back and hips were less coherent in the three workstations. In workstation 1, participants perceived a reduction of discomfort in the lower back while in workstation 3 an increase was perceived. Additionally, in workstation 1 a slight decrease in discomfort on the hips was perceived, while in workstations 2 and 3, an increase was perceived. In workstations 2 and 3, workers also reported the thoracic region and arms as discomfort regions caused by the exoskeleton. For certain tasks that involved trunk rotation, the rigid bars of the exoskeleton made pressure on the thoracic region of the participants which caused pain. Due to this, two workers who performed these tasks, reported this region as uncomfortable (2 and 6 on the 7-point Likert scale). The arms were also reported in workstation 2, since for some tasks workers make repetitive movements with the arms close to their bodies, which may limit their movements (classified as 2).

As shown in Table 1, in all three workstations the usability results were quite positive. In all the three workstations, more than 80% of participants agree that the exoskeleton is useful, has a good interface quality and that it is satisfactory. On one hand, in terms of the participants wanting to have access to the exoskeleton, the workers' opinion was similar in the three workstations, tending to agree on the last day of use. Only in workstation 3, 8% of workers do not agree or disagree on this matter. In general, practically all participants would like to have access to the exoskeleton during their work. On the other hand, regarding the intention to use it, there is a bigger disagreement in the three samples. On the last day of use, we can verify that although there is a big percentage of participants who agree that they would use the exoskeleton, there is a small percentage that disagrees in workstation 1 (17%) and workstation 3 (8%). This happened because workers recognize that there are still some necessary improvements to the exoskeleton and that not all tasks or postures are suitable for its use.

Lastly, through the usability questionnaire it was possible to conclude about the ease of use in terms of donning and doffing of the exoskeleton and angle regulation mechanism. In Table 2 we can verify that the participants' opinion regarding the donning and doffing of the equipment maintained and all agree that is easy to use. Considering the angle regulation mechanism, the results were positive although not coherent. Some reported that the angle established was hard to define and verify without external help, especially when wearing gloves.

Through the workers' comments, it was possible to analyze the advantages and disadvantages of this equipment. Most complaints were due to heat, pressure, and limited range of motion, not practicable for all tasks and weight. Most of the advantages reported referred to the decreasing effort required for performing the tasks, the posture improvement and helping with manual material handling and bending forward.

Through the Wilcoxon signed-rank test, the difference between the results of the initial and final questionnaires were compared, however, none of the differences were considered significant. This might have happened due to the small number of usages of

Table 1. Usability and intention of use results.

Participants agreeing with each usability parameter and with the intention to use (%)		Workstation 1	Workstation 2	Workstation 3
1st questionnaire	Usefulness	83	83	97
	Interface quality	92	75	97
	Satisfaction	88	80	98
	Access	71	75	92
	Use	86	75	92
Last questionnaire	Usefulness	96	83	100
	Interface quality	83	75	94
	Satisfaction	90	80	98
	Access	100	100	92
	Use	83	75	84

Table 2. Ease of use results.

Participants agreeing with each ease of use parameter (%)		Workstation 1	Workstation 2	Workstation 3
1st questionnaire	Donning and doffing of the exoskeleton	100	100	92
	Angle regulation mechanism	83	50	92
Last questionnaire	Donning and doffing of the exoskeleton	100	100	92
	Angle regulation mechanism	83	75	84

the exoskeleton per participant (between 1 and 7) and the reduced time of usage for each test (minimum of 15 min). Since it is expected that the participants' opinion changes throughout the study, it is advised to implement a longer study with a longer time of usage per test.

4 Conclusions

In conclusion, the finding results show that although participants perceive the benefit of using the exoskeleton, there are still some aspects that need to be improved so there can be a better adaption to non-cyclic tasks. In fact, they intend to have access to the exoskeleton however they predict that it will not be used as often due to its limitations. Improvements should occur on the contact points with the user's body due to heat, rigid

bars should not limit motion and angle regulation mechanism should be more practicable. With that said, we can conclude that the exoskeleton is eligible for these workstations, but it works better during less dynamic tasks and mostly static positions. Once these changes are made, exoskeletons might become more adequate for these workplaces and their acceptance might increase.

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Human-Centered Design of Digital Assistance Systems in Smart Factories Based on Quality Function Deployment

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Abstract. Digital assistance systems getting more and more relevance for manufacturing and especially in variant-rich manual assembly. Due to increasing product complexity, the information flow during the assembly process are becoming increasingly complex. Therefor digital assistance systems will play an important role in the future by supporting employees and cooperating with them in order to increase productivity, quality, ergonomics and flexibility. Industrial Engineers and IT experts must design digital assistance systems in a joint process. Assistance systems must be designed based on user and process requirements and in such a way that they optimally support the abilities of the employees adaptively. When designing assistance systems today, however, the complexity of the planning task results in many obstacles that companies have to overcome. This paper presents a human-centered approach to the systematic analysis of assembly processes with the focus on user needs and design of digital assistance systems.

Keywords: Human factors · User-centered · Digital assistance systems

1 Introduction

Today, manufacturing is confronted with complex and far-reaching challenges. On the market side, product life cycles are becoming shorter, a growing rate of product customisation is leading to more variants and at the same time to more complex product structures [1, 2]. In addition, the pressure on delivery times and quality requirements is constantly increasing. This is further intensified above all by the volatility of the markets in terms of unit numbers and variant mix. Maintaining the innovative capacity of companies to continuously adapt to growing demands is therefore of crucial importance [3].

As a result of these changes, the information flows accompanying the manual assembly process are becoming increasingly complex and extensive in production [4]. However, this information is indispensable for the error-free and efficient execution of work tasks and making the right decisions: missing, late, incorrect or misleading information

leads to longer throughput times, defective products and dissatisfied customers. Employees must be presented with the right information in a processable form so that cognitive performance is not overtaxed [4].

Digital assistance systems will play an important role in the future by supporting employees and cooperating with them in order to increase productivity, ergonomics and flexibility. Digital assistance systems must be designed in such a way that they optimally support the abilities of the employees in an adaptive manner. Developed assistance systems can offer vast advantages both on technical as well as economical criteria but are not accepted or used by system users due to poor implementation [5]. User centricity and user participation in the design process is therefore an essential, but up to now neglected part in the development of manufacturing assistance systems [6, 7].

2 Basic Work and Terminology

This chapter provides an overview of the current state-of-the-art and advances in industrial applications together with basic terminology relevant for the paper.

2.1 Manual Assembly and Digital Assistance Systems

A manual assembly workstation or a manual workstation requires the continuous cooperation of an operator in order to fulfil its function [8]. Assembly comprises the five different functions: Joining, handling, checking and adjusting as well as various special operations. In addition, characteristic sub-functions can be assigned to each function [9].

The term digital assistance system refers to all systems that support employees in carrying out their work tasks [4]. In assembly, digital assistance systems support the worker by guiding him during his assembly activities with software support and, if necessary, checking the work result. The aim of the assistance is to increase productivity and quality and to make the assembly process transparent, traceable, flexible and safe [10]. Employees are supported in their ability to react, think and draw conclusions when carrying out their work tasks [11–13].

2.2 Design Elements of Digital Assistance Systems

The design of digital assistance systems usually focuses on the human-machine interface and describes how information is entered into the assistance system and how it is output by the assistance system to the user. Beyond that, however, all elementary system components must be taken as the basis of the development task. Main design areas are the following: "Information degree", "Information design" and "Information device" [4], as well as the underlying design principle, the users as such, the place of use and the time of use [14, 15].

2.3 Human-Centered Design and Quality Function Deployment

Human-centered design (HCD) ensures the balance of all stakeholders regarding concerns, values and perceptions [10]. The overall goal is to design desirable, feasible and

viable solutions [16]. The typical human-centered design process consists of five main phases: planning, understanding, defining, prototyping and evaluating. Today, the approach is applied in a wide range of applications such as management frameworks and related adaptations [17, 18].

Quality Function Deployment (QFD) is a methodology for translating customer wishes and customer requirements step by step into concrete services of a company and into functions of a product. In the process, product features and functions are derived from customer requirements [19]. The heart of quality function deployment is the "House of Quality" (HoQ). The basic structure of such a HoQ is shown in Fig. 1.
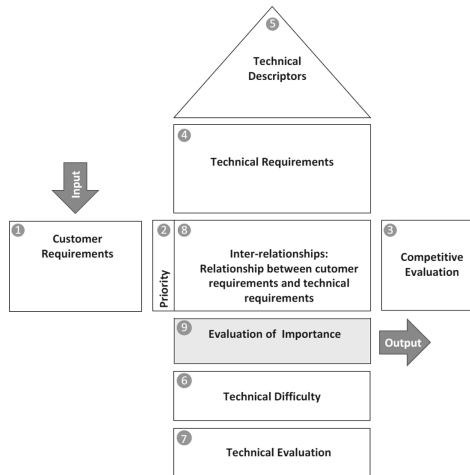
Fig. 1. House of Quality, based on [19]

The HoQ serves to document and create a common understanding of all planning results for all project participants. Above all, however, the HoQ summarises all customer needs and their translation possibilities into concrete design solutions in a transparent overview. The aim of the evaluation with the help of the HoQ is to filter out the most important, critical and purchase-decisive levers of the product to fulfil the customer requirements. The systematic derivation of the components and design elements of the assistance system based on user requirements is a similar task.

2.4 Research Gaps and Approach

The analysis of the relevant literature shows that no methodologies, methods, models, procedures and approaches exist to design a digital assistance system based on human-centered methods.

Classical human-machine planning methodologies tend to consider later design phases and include visual design, output and screen displays as well as the design of meaningful dialogue guidance. However, none of the methodologies allows for the basic design of the assistance system as well as the systematic step-by-step detailing of the functions and components.

3 Approach

For the intended procedure model for human-centered design of digital assistance systems, this work focuses on the first QFD phase with the translation of user requirements into the design elements of a digital assistance system. Human-centricity will be realized by the integration of user-centered development methods and artefacts into the QFD methodology.

4 Human-Centered Design of Digital Assistance Systems

With the help of a seven steps process model, the HoQ for determining the measures for user-centered digital assistance systems is completely filled and thus creates a comprehensible, transparent communication basis for all participants in order to be able to make well-founded decisions together in the project regarding the individual components of an assistance system. Figure 2 shows the corresponding contents in the modified HoQ.
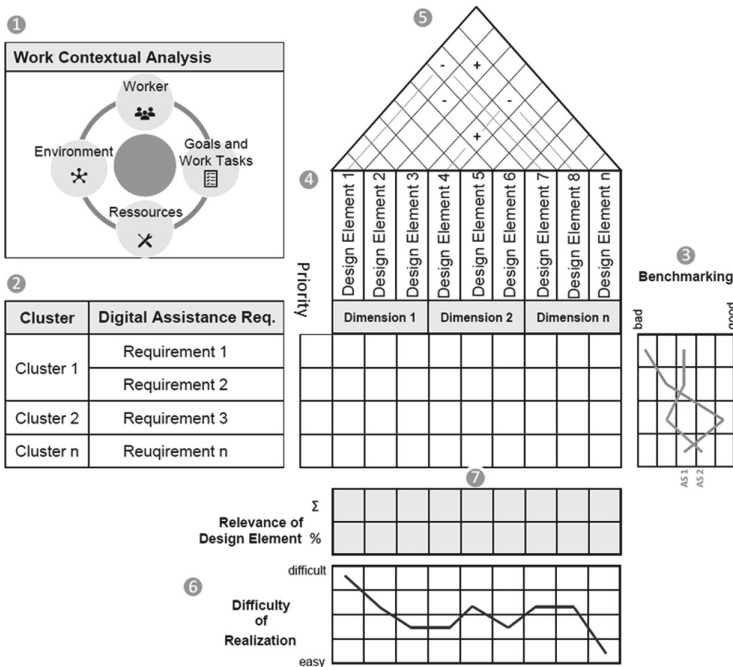

Fig. 2. Modified HoQ

(1) Work Contextual Analysis. In this step the project team observe the user in his work process and to address him specifically about problems and reasons for process deviations. This is possible with the help of the contextual inquiry method. During the preparation phase for such a contextual inquiry, relevant questions with regard to the

context of use of the future assistance system must be developed and defined in the interdisciplinary project team.

The context of use captured with the help of the contextual inquiry now helps the team to jointly derive the assistance needs and potentials as well as the requirements of the users in the next step. In order to support the further refinement and specification of requirements and assistance needs in step 2, user groups derived from the contextual inquiry with their characteristic features can be transferred into personas at this point for better illustration.

(2) Digital Assistance Requirements. With the help of contextual inquiry, the original context of use can be analysed for strengths, weaknesses, problems and needs. Now, in the second step, the results of the contextual analysis must be transferred or specified in user requirements for the future assistance system. In addition to the contextual inquiry method, the method for developing user stories is therefore used here, which has already proven itself in practice in agile projects for the user-oriented specification of requirements. The user requirements specified with contextual inquiry and user stories together form the first part of the HoQ for digital assistance systems.

(3) Benchmarking and User Feedback. On the one hand, a target/actual comparison, for example of the current assembly system with regard to its degree of fulfilment relative to the requirements from step 2, will be requested. On the other hand, already existing digital assistance systems on the market could be examined and evaluated as a benchmark with regard to their degree of fulfilment of the determined requirements in their own context of use from the user's point of view.

(4) Development of Design Elements. The technical view of digital assistance systems is now taken into account in this next step, the development of solution measures. Here, the project team is confronted with the question of how the functional and non-functional requirements can be fulfilled from a technical point of view. Only after the problem-oriented development of the proposed solutions and quality features of the digital assistance system in relation to the given requirements of the users, does the project team decide which technology solutions, design elements come into question. This has the consequence that a technology determinism can be prevented.

Among other things, the hardware, the software, the work content and goals, the physical, cultural, social, legal-organisational environment as well as the interaction and the interfaces between these elements and the user form the designable dimensions of a digital assistance system.

(5) Inter-relationships between Design Elements. Requirements of different user groups as well as solutions to meet the needs and goals of the individual elements of the context of use may interact with each other and may contradict or benefit each other. The fifth step in the HoQ also takes this into account. In order to determine whether there is an interaction and how this is to be evaluated, the individual solution features are compared with each other in pairs and it is discussed whether they would influence each other in the implementation. By creating transparency about possible conflicts of objectives, alternative solutions can be considered at an early stage, or in the case of a positive interaction, the focus can be placed on the corresponding features.

(6) Difficulty of Realization. Field 6 in the HoQ is intended to assess the implementation difficulties of the respective solution proposal. All technical, organisational, economic, financial, social and legal aspects that make the implementation of the respective design element difficult can be included here. The result of this estimation can lead to priorities being assigned differently in the realisation of solution features. As these aspects are relevant for a holistic view of the digital assistance system, they should also be taken into account when interpreting the evaluation results in step 7.

(7) Evaluation of Inter-relationship between User-Requirement and Design elements. The evaluation of the developed solutions and measures in relation to the user's requirements forms the actual implementation step and provides information on the extent to which a proposed solution meets the user requirements. Since user stories with acceptance criteria are proposed in the second step of this process model to specify user requirements, the acceptance criteria can now also be used to assess the degree of fulfilment. This means that each solution approach can now be evaluated step by step in the context of the respective requirement or user story.

   The overall numerical evaluation of the solution features is done in two steps. First, the respective weighting points of the requirements are multiplied by the corresponding matrix points of the solution feature row by row. Then the sum of the resulting multiplication products per column is formed. The result is a ranking, which can be used to make statements about the relevance and suitability of the proposed solutions for fulfilling the most important user requirements.

5   Conclusion and Outlook

The process model developed is based on the conceptual framework of QFD using integrated user experience methods. It has been specially developed for the user-centered development and evaluation of digital assistance systems in production and is intended to serve as a guideline for this.

   With regard to the sensitivity of the results from the HoQ in the preliminary model, it can be said that the evaluated correlations are only based on discussions and estimates of the interdisciplinary project team. The quality of the results from this exchange is again dependent on the expertise of the participants. The limits of this process model are influenced on the one hand by the limits of the selected conceptual framework and the selected UX methods. On the other hand, the success of a project using the process model depends on the prerequisites that are defined in the first step of the model. This also includes the availability of the end users and target groups of the system for the implementation of the proposed UX methods as well as for the evaluations of the HoQ, which deliberately demand constant dialogue between users and developers.

   From this critical evaluation, there is potential for further development with regard to additional variants of the process model for the derivation of component, design and process sequences.

   Overall, however, the developed process model provides a new, concrete approach for the stronger involvement of users in the development process of digital assistance systems for smart factories, which can create user acceptance for assistance solutions from the outset.

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Human Functions in Organizational Systems

Women's Operational Vulnerability and Risk in Ghanaian Business Systems: A Case Study of "Kayayei" in Accra, Ghana

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Abstract. The 'Kayayei' business presents several risks to the young women although there are some economic benefits. Over the years, there have been some studies in this area, but to the best of our knowledge, none of these studies has examined extensively the vulnerability (emotional and physical) of these porters. This study, therefore, assesses women's vulnerability and risk in Kayayei business in Accra Central District. Specifically, this study examines the extent of harassment by patrons on the female head porters and the effect it has on their productivity. It further investigates the reproductive health challenges faced by these female head porters. Using a qualitative approach, interviews were conducted with fourteen purposively selected head porters. This study found that the Kayayei become victims of verbal and sexual harassment and exploitation by their patrons and the general public and face some reproductive health challenges due to the very nature of their jobs.

Keywords: Vulnerability · Internal migration · Porter · Porterage · Job quality · Ghana

1 Introduction/Background

Ghana, like most developing countries, faces many developmental challenges. Among the list of problems is the issue of migration that manifests itself in several forms. While professionals usually seek greener pastures by migrating to developed countries, unskilled youths from rural areas and the hinterlands move from the underdeveloped areas predominantly farming communities to the cities to do menial jobs [2]. Specifically, many migrate from the northern part of Ghana to the south. This pattern of internal migration has particularly been influenced by the stark differences in the levels of poverty between the Northern and the Southern regions of the country, as well as their respective capacities to respond to new economic opportunities. A majority of these low skilled migrants end up working in the informal sector in occupations requiring very little or no education and skills such as porters, petty traders and seasonal laborers [3].

Porters (aka Kayayei) are individuals who carry goods for shoppers or traders in and around commercial areas for a negotiated fee. They provide a useful service to their patrons who are usually traders, travelers, business owners, food sellers and home managers who shop in bulk [4]. Kayayei is a noun that is used to represent female head porters in Ghana. The term Kayayie is made up of two words; 'kaya', a Hausa word meaning load or goods and 'yei', a Ga word meaning females [5]. Although there are no records of Kayayie in Southern Ghana, it is estimated that, there are about 160,000 in Accra [6]. The history of the Kayayie in Ghana can be blamed on the withdrawal of government subsidies on health care, social services and agricultural input in Northern Ghana as early as in the 1980s. It resulted in an increase in the cost of agricultural production and general cost of living and consequently, led to increased migration from northern regions of the country to urban centres perceived to offer better opportunities that will help enhance their livelihood [5]. Porterage has been an ancient traditional mode of transporting goods in the world [7]. Traditionally, porterage in Ghana is a means of transporting goods in the absence of modern means of transport. For instance, congestion in and around markets in Ghana caused by unplanned buildings and structures, human traffic, and motorised traffic make it difficult for the effective use of trucks and vehicles hence the services of porters "are used to offset the difficulty of vehicles accessing the center of the markets to load or discharge goods" [4, p. 1].

Porterage activity is a means to economic prosperity for these unskilled women. According to Opare [8], women porters in southern Ghana use the activity as a means to accumulate capital to engage in other economic ventures such as skills training, marriage or trading. However, there exist several risks in the continuous carrying of the goods from one place to the other and the risk and vulnerability of their living environment. For instance, the daily graphic in January 2007 in a report described the plight of the female head porters in the two major cities in Ghana. The report described how many porters sleep and wash down in the open, defecate in open gutters, cook, engage in sexual activities and deliver their babies at major lorry parks. These can pose as a threat to the health of the general public as a result of the activities of these Kayayei [10]. Since they mostly migrate from rural areas to urban areas, and practically do not know anyone, they usually have no place of abode and sleep in kiosks and corners of the market. This directly exposes them to armed robbers and rapists [9] which also leads them having sexually transmitted infections and the consequential complications.

Also, the Kayayei are exploited in many ways by their leaders and supervisors and this sometimes make them so vulnerable and lures them into having force relationship with other males as a surviving strategy. These head porters are seen as one of the marginalised group in society, so they become subjects of multiple abuses including their rights, freedoms and access to basic life necessities [9]. Additionally, Yeboah and Appiah-Yeboah [4, p. 3] observe that it is 'common that kayayei are exploited by their patrons and hassled by police and city authorities. Also, patrons harass the porters so much that Opare [8, p. 44] characterized it as "an exploitation of women by women". For instance, some patrons insult and ridicule them while some family members and people who act as chaperons take advantage and exploit them. As an example, some chaperons are unable to account for monies saved with them by these porters [8].

Despite the urgency of this topic, there is a significant gap in studies conducted on the risk female porters' face in Ghana. Among the few available studies, the focus has been on the reasons for migration [8] and an analysis of porters as street children [1]. Hence, it is then prudent for more studies to be carried out focusing on firsthand account of the associated risks and its subsequent impact on the socio-economic growth of Ghana as a country. Our study fills the lacuna in this field by elaborating on women vulnerabilities and risks in the Kayayei business and how these risks transcend to a national economic hindrance towards the full realization of the Sustainable Development Goals by 2030.

2 Methodology

The aim of this study is to investigate the risks associated with females who are into the Kayayei business in Ghana. To achieve this purpose, the following objectives were set:

i.   To examine the extent of harassment faced by the Kayayei from patrons
ii. To examine the effect of harassment on their work productivity
iii. To investigate the reproductive health challenges faced by the Kayayei

To achieve these objectives, this study adopted the qualitative research approach which according to Bryman (2004) looks at the relationship between theories and research findings by focusing on generation of theories to establish its consistency and deviations. Responses were collected with the use of semi-structured interview which allowed the interviewer to deduce fundamental relationships that exists between variables (Saunders et al. 2009). Employing the purposive sampling technique, 14 participants were interviewed for this study. These respondents were recruited from Accra central business market. Employing the snowballing technique, an initial contact was established with a kayayo who also referred the interviewer to others with similar experiences. Due to their level of education and language barriers, the interviewer had to explain the study variables to respondents in its basic form and sometimes to the extent of getting interpreters. Averagely, interviews span between 30 to 45 min with each respondent. The ethical protocols of informed consent, anonymity and confidentiality were strictly adhered. These respondents were not coerced but encouraged and even provided with lunch for their time in responding to the interview. Due to the manageable sample size, data collected was manually analyzed thematically. Inductively, themes were developed after the data were audio recorded and transcribed.

3 Findings and Discussion

This subsection presents demographic information about the respondents, the nature of harassment, the effect on their productivity and reproductive health challenges faced by these head porters.

3.1   Demographic Characteristics of Female Head Porters

The demographic information about the respondents included information on their ages, their current marital status, number of children, level of formal education, their religious affiliation, their hometown, their ethnicity, the type of house they dwell, whether they have any family relation in Accra and where they sleep after work (Fig. 1).
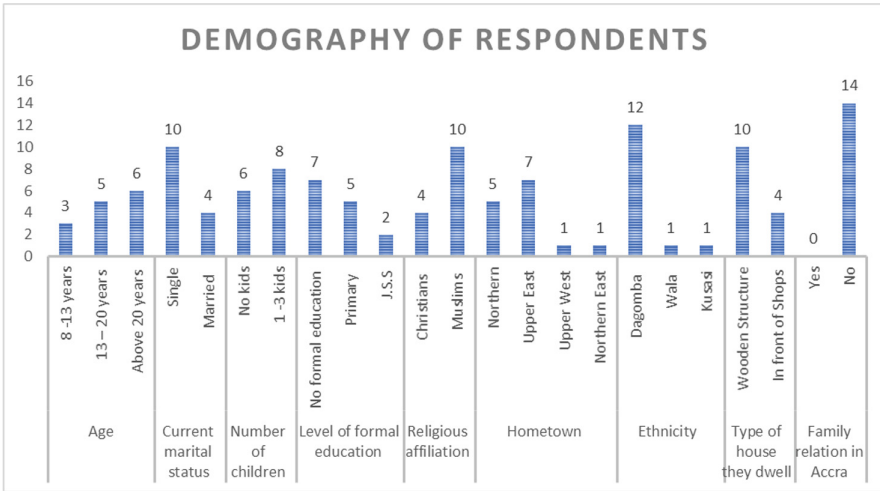

Fig. 1. Respondents demographic details

As shown in the figure above, the respondents were relatively young. The ages of these porters ranged from 8 years to 45 years. Majority of the participants of the study were identified to be Muslims and only four of the Kayayei were Christians. Also, the percentage of the respondents who were single exceeded those who are married. Most of the porters have little or no formal education. However, those who have formal education were either primary school graduates or have reached junior high school level. Although not married, many have between one and three children. The Kayayei originated mainly from the Northern sector in Ghana namely, Northern region, Savannah region, North - East region, Upper East region and the Upper West regions of Ghana, a finding similar to Boakye-Yiadom & MacKay's [2] study which found kayayei to have migrated predominantly from the northern regions of the country. The living places of the Kayayei as described by the respondents are rooms in the slums and some wooden structures that are shared by numerous Kayayei. The porters inferred that they either sleep in the open in front of people's stores or in the slums in the city as they have no relatives in Accra.

3.2   Objective 1: Harassment Faced by Female Head Porters

The literature on Kayayei indicated some instances, whereby the patrons of the Kayayei in some ways harass the Kayayei to get their advances honoured. The Kayayei due to

their desire to make ends meet become victims to their patrons at times. For our study, we asked the respondents if they experience any form of harassment. A majority of the respondents admit to being harassed by their patrons. While, physical pain is at times inflicted on these Kayayei by the patrons, sexual abuse and actions such as abusive comments and insults that emotionally disorient the Kayayei were also acknowledged. Below are comments by respondents on how they are being abused due to the nature of their trade as kayayei:

There are patrons who will insult you for charging a certain amount. As for the harassment, we encounter that on a daily basis (**Interviewee 1**)

Physically, some of the patrons molest these kayayei over negotiation of prices.

*"When I quote my price, some do pay, some do not pay. Sometimes if we quote the prices, it can turn into a fight between me and the patron" (***Interviewee 2***)*

Also, there are instances where some of the male patrons want to have sexual affair with these female porters and according to a respondent, she has encountered several issues of such nature.

*On countless occasions, some clients have tried to forcefully harass me sexually when I carry the load to their destination (***interviewee 3***).*

The harassments are not limited to patrons, because the Kayayei also face harassments from the general public making their vulnerability widespread. Here are some comments that reflect the various forms of harassments:

*Sometimes as we go about our duties, people push us away with their elbows and abuse us in the process. It's a very difficult situation and there is nothing we can do. Sometimes you get insulted in the process. It's a pathetic situation. For instance, I have seen times where some of my colleagues fall with the language on their head in an attempt to safeguard the clients' load as a result of a push which consequentially led to injury***" (***Interview 4***).*

In the course of their work, they endure emotional torture due to the very nature of their jobs. Some kayayei are subjected to emotional abuses and many forms of emotionally abusive comments and behaviours that affect them negatively.

This work that we do, sometimes you meet people who look at you in a way that makes it look like you are a nobody. Some people just see and then proceed to disrespect you out of nothing. It usually comes in the form insults and disrespect. Sometimes too when you get a direction wrong, they insult you as well. (**Interviewee 5**).

3.3   Objective 2: The Effect of Harassment on Productivity

The respondents posited that these harassments by their patrons and the general public affect their rates of productivity in many respects. Some of the Kayayei leave the profession and return to their places of origin. For instance, according to a respondent:

> *Oh yes, it affects us a lot. You know that if you were to be in your hometown, you won't be subjected to some of these issues. It's a painful thing. But there is very little you can do in that regard, so we tend to brush it off and focus on our work* **[Interviewee 9].**

Unfortunately, it appears there is no room for redress for these kayayei as expressed by one of them.

> *Oh usually, we do not do anything. We have no place to lodge our grievances. We are not known, so it makes it difficult for us to take any action. Because if we make an attempt to say something, they will say it's a Kayayei matter, and since we are a nobody, we do not get the assistance we want.* **[Interviewee 10].**

It is worth mentioning that there are no written laws and legal frameworks in existence that protect the Kayayei other than the general laws of the country that binds everyone in the borders of the country. That said, the respondents noted some strategies devised to limit the incidence of harassment by their patrons. These strategies include forming a resistant group that are used to oppress any form of harassment that are inflicted on any of their members. Sometimes, they boycott the meetings with their patrons as an attempt to register their disdain to the patrons for the harassment and abuses that have been meted out to them. Also, there exists informal conventions that have been accepted by the members of the Kayayei as to their area of operation. These conventions guide the Kayayei as to how to conduct themselves in the area of work and within their group. The rules ensure that there is harmony between themselves and their supervisors and that they live and work peacefully with one another in a professional manner.

3.4   Objective 3: The Reproductive Health Challenges Faced by the Head Porters

It appears the freedom to control reproduction does not really exist. It was revealed that the Kayayei become vulnerable to their male counterparts (truck pushers) and as a result only live to satisfy and admit their abuse. Many therefore become pregnant at an early age unwillingly. Those who get the opportunity to determine when they conceive also narrated that the very nature of the job puts pressure on them to have children early before they start experiencing the negative impact of carrying heavy loads on their reproductive health. While they engage in the trade during pregnancy, many experience health challenges. For instance, miscarriages are rampant among these girls as they hardly also go for antenatal care. Some of the Kayayei said during pregnancy, their ability to carry loads are reduced, hence their earnings. It therefore affects their ability to have healthy meals that would help protect the unborn baby. This lack of good meals and medication coupled with the carrying of the loads therefore result in reproductive

issues during pregnancy. Those who are lucky to have the babies without miscarrying sometimes have challenged ones. Below is how an interviewee puts it:

*Some of us give birth to children with some physical deformities or psychological challenges" (***Interviewee, 9).***

Others were of the view that it had no effect on their reproductive health. Their main concerns were in relation to health conditions they generally face due to the heavy load. An account by another was that:

*Yes, it does affect us, but am not too sure about my reproductive health, but it has affected other parts of my body. The last time, I carried a heavy load and I felt so much pain in my chest and joints to the extent that I vomited blood (***Interviewee 11).***

It was refreshing to note that the economic gain they make from this occupation in the south is much more than they would have ever gotten if they were in their hometowns. According to some of the kayayei, the daily income made is saved on their mobile wallets, a safer and better mode than the 'susu' which hitherto was the only form of safekeeping their proceeds.

4 Discussion

The business of kayayei is the result of an increasing disparity in the distribution of the national resources among the regions in the country which leads to the northern movement of young and growing girls into the Kayayei business in the southern parts of the country. Based on the regional location of the female porters, it is also identified that all respondents originated from the northern regions of the country paralleling Whitehead and Hashim's [3] finding. The economic hardship within the regions and the villages in the Northern regions where the Kayayei come from, and the quest to find better living conditions in the cities are the reasons why these females are engaged as kayayei, a finding concurring with Streifel's [6]. The study identified a similar finding with Streifel's, [6] research when we found that the no/low level of academic qualification of these porters and the lower requirement to embark in the porterage business are the reasons for the increasing number of female head porters. Objective 1 was achieved as our study found several instances of harassment of the Kayayei by their patrons, chaperons and the general public, a finding similar to Awumbila and Ardayfio-Schandorf's [9] report of several abuses on these girls hence seen as a marginalised group in the Ghanaian society. It is worth noting that although Opare [8] found that they are usually harassed by women, we found otherwise as they were abused by patrons of both genders (i.e. male patrons who sexually abuse them and female patrons who insult and fight them over fees charged), street boys who impregnate them against their wishes and the general public who push and disregard them because of their occupation. Regarding Objective 2, the porters noted the harassments affect their productivity since their jobs are not formalized, they have no formal protection from the authorities against the harassment they face. They however have conditioned their minds to work irrespective of the abuses.

We found that regarding their reproductive health, some believed their occupation has no impact, however, majority thought otherwise. The negative impact is not surprising because Streifel [6] indicates that the nature of one's profession may have negative consequences on the person's reproductive health and the Kayayei business is not an exception. On a positive note however, we find that abuses from the chaperons who hither to acted as their bankers are no more, a result contrary to Opare [8]. After about two decades, we see positive change as they have embraced mobile technology to their advantage thereby limiting/prohibiting the inability of their chaperons to account for monies deposited in their care.

5   Conclusion

The study adds knowledge to the existing literature on the phenomenon and bridges the gaps on the issues of risk and vulnerability of Kayayei. In line with the findings, the Ghanaian government and other relevant stakeholders must adopt and implement relevant policies which will reduce the rate of internal migration of female porters from the Northern regions of the country. The development gap should be bridged between the northern and southern sectors by channeling resources so as to reduce the inequality. Again, policies to protect and shape the porterage business could also be created based on the findings of the study. With less than a decade to the deadline of meeting the SDG's goals, we suggest that since education is an important divider between 'good' and 'bad' jobs predicting earnings, autonomy, security and many job characteristics, these girls should be encouraged to take advantage of the free Senior High School (SHS) policy and get educated. Theoretically, the study extends the debate on the need for the improvement of employees' job quality. In fact, more emphasis should be put on adult education of the 'women child' as late education is better than no education. Furthermore, for a high labour intensive job like this kayayei business, measures must be put in place to enhance employees' wellbeing by redesigning this porterage profession.

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A Post-mortem Analysis of a Merger and a Rightsizing Exercise: The Case of Ecobank Ghana Limited and the Trust Bank Limited

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Abstract. The study examined the after effect of a merger and rightsizing strategy employed by Ecobank Ghana Limited and the Trust Bank Limited when they merged in the year 2012. The aim of the study was to gather data to be able to create a practice guide for future corporate restructurings. As a qualitative study, data was collected from twenty (20) survivors using a semi-structured interview and secondary information for the period 2012–2019. The study found that while the merger had a significant effect on role and workload, it had little effect on productivity and job security. Although the merger had to an extent brought on certain efficiencies for EGH in terms of its share of operating assets and its asset quality, it had not achieved efficiency regarding its cost-to-income ratio and liquidity.

Keywords: Merger · Rightsizing · Survivors · Role change · Productivity · Efficiency

1 Introduction

In the year 2012, Ecobank Ghana (EGH) underwent a merger with The Trust Bank with its resultant rightsizing exercise. At the 2012 extra-ordinary general meeting therefore held on 20th January 2012, shareholders of EGH were asked to consider the benefits of the merger and so began the marriage of EGH and TTB. The anticipated benefits to be gained among others were being number one in terms of assets and profitability out of 26 banks operating in Ghana as at June 30, 2011; enhanced treasury base, wider geographical presence and enhanced shareholder value through improved financial performance. Sometimes, companies use mergers as strategic positioning tools to perform their rightsizing activities and stay competitive despite the internal and external challenges they face in the markets they operate in Osei-Bonsu [14]. A merger is therefore 'a corporate event in which two companies consolidate to form a new company' [2, p. 6]. The merging process can result in some form of rightsizing due to the duplication of functions. Rightsizing is not something that can be done overnight or rushed hence involves carefully structured actions or processes to readjust the organisation or parts of it in order to increase efficiency [11].

Thus, rightsizing could involve a reduction in employees, a reduction of the divisions or units in a firm or even reductions in the hierarchical structure [8]. Anytime a rightsizing activity is done, there are two groups of people; i.e. victims and survivors. The term survivors originate from the idea of the survivor syndrome which reflects the physical and psychological effects that affects workers that are not laid off during a downsizing activity [20]. Essentially these are employees who remain with the organisation after rightsizing and are the ones responsible for new business performance and the successful implementation of the organisation's restructuring [21]. The factors accounting for rightsizing can be both internal and external and usually involves the reduction in employees to improve productivity and efficiency and also gain competitive advantage in the market [6]. Apart from some negative consequences of rightsizing such as producing an undesired culture, there are some positives including cost cutting, financial benefits and overall organisational performance [12]. Rightsizing could even be considered now as a standard management practice or a corporate strategy [13].

Literature on the effects of mergers and rightsizing on the role change, the productivity, the workload of survivors and the efficiency of the organization abound. For instance, roles do change thereby leading to role ambiguity, lower commitment, feelings of insecurity and increase turnover decisions [17]. A relevant explanation for these role changes in mergers and their resultant rightsizing is that the different processes and policies of the firm need to be harmonised [16]. It is therefore important that management of companies provide some coping mechanisms such as rigorous debriefing processes for survivors since these could improve survivors' attitudes to their work roles [21]. Poor communication could lead to mistrust between management and survivors which could affect the productivity of the survivors [10]. Therefore, a healthy organisational climate is key to determining whether a survivor would be productive or not [14]. Applying the equity theory, "during times of organisational change, perceptions of injustice may not only lead to dissatisfaction, but also to decreased job performance, poor quality of work, decreased job involvement, increased intentions to leave and less co-operation with co-workers" [21 p. 23]. Following the distributive justice theory, when employees "develop negative perceptions about merger-induced organizational changes and also distrust those managing the changes, their job satisfactions and commitments will also be negatively affected" [16, p. 30]. An increased workload would not be viewed as a negative outcome if the increased workload resulted in an increase in income [19]. According to the Social Identity Theory, employees may experience a change or "break in their comfort zones" pertaining to their colleagues and work [17]. The Threat-Rigidity theory also suggests that people respond when they feel threatened whether it is at the individual, group or even organisational level [18]. In order to improve efficiency of the organisation, some organisations consider merging and rightsizing as a strategic option [19]. For instance, Aidoo and Mensah [3] found that an organisation's share of industry operating assets can increase after a merging exercise.

The paper examines the effect that the merger had on the survivors regarding (a) their role changes; (b) productivity; (c) workload; and (d) the efficiency of the merged bank. Interestingly, while earlier studies had discussed mergers, there always seemed to be a focus on the financials and a neglect on the effect of the mergers/rightsizing on the survivors and what became of them after the merger. These earlier studies had

confirmed that "when a decision is taken to merge or acquire, a company analyses its feasibility on the business' financial and legal fronts, but fails to recognise the importance attached to the human resources of the organizations involved" [17, p. 4]. Thus, there is a need to review the case of the neglect of the survivors and also prove the case of efficiency through merging and resultant rightsizing in order to develop a practice guide on survivors and also bridge the knowledge gap in merging and rightsizing activities.

2 Methodology

This study employed a qualitative approach and the case analysis technique using a semi-structured interview with twenty survivors of the merged EGH and TTB. This was most appropriate because it provided the opportunity to have in-depth understanding of the participants' experiences and was "particularly helpful in the generation of an intensive, detailed examination of a case" [5, p. 49]. A purposive sampling technique was used to select the participants of the study who were survivors from the erstwhile EGH and TTB, now the merged bank and experienced the merger and resultant rightsizing over the period of the study (2012–2019). These survivors were identified with the help of the snowballing technique, where an initial contact was made and further recommendations of others who shared similar experiences. This technique was most appropriate because this study excluded workers who were not involved in the merging process. An online mode was used in collecting data due to the Covid-19 pandemic which prevented an ideal face to face interview. A semi-structured interview guide was designed comprising 26 questions with data collected between October 2019 to July 2020. There were equal numbers of males against females in the participants, 95% of them were married, and 80% of them had worked between 5–10 years and 0–5 years at EGH or TTB before the merger. The remaining 20% of the survivors had been with the company for between 15–20 years and 95% of the participants were full-timers. Secondary information was sourced from the annual reports and financial information of EGH. The primary data collected was processed with Microsoft Excel for the demographic details and a thematic analysis done where themes that flowed from common threads in the responses of the participants were utilized. Using Braun and Clarke's (2006) thematic analysis, the study identified, analysed and reported patterns within the data. The secondary information from the annual reports of Ecobank Ghana Limited and the PricewaterhouseCoopers (PWC)'s Annual Banking Surveys reports for the period 2012–2019 were analysed by way of document analysis to show whether the efficiency of the merged bank had increased and if the goal of the merged bank to achieve efficiency through the merger had been successful.

3 Findings and Discussion

The effect of the merging and resultant rightsizing strategy employed by Ecobank Ghana Limited and The Trust Bank are summarised hereunder.

3.1   The Effect of Merger on Role Changes of Survivors

The study showed movement of survivors from one department to another. Ten out of 20 different departments existing before the merger experienced this movement of survivors. In the study, 30% of the participants experienced role changes and others (70%) remained in their roles but experienced different business processes confirming that roles could be affected because of the "harmonization of the different business processes and policies of the old firms that merged to form the new firm" [16, p. 32]. Although there had been role changes, some survivors did not have the adequate support or funding to perform their roles properly and this made closing deals quite difficult. The changes in roles at the new Ecobank required that the company have some coping mechanisms in place for survivors so training was common place at the new Ecobank confirming Tetteh's [21] suggestion that training was important for survivors after a rightsizing exercise. Role ambiguity came up during the study because some survivors claimed that their managers were not very competent in the roles they had been assigned so this has the tendency of affecting commitment negatively and increasing turnover decisions of survivors as advanced by Sassah [17]. Others believed that their colleagues did not understand their roles and even their management information system (MIS) was inadequate for management decision making. The study found that job security was not threatened at the new Ecobank although earlier studies had found that survivors faced job insecurities in such cases [19]. Job security could however be threatened because more technology was being employed at the new Ecobank through the outsourcing of banking processes and also because there is no clear understanding by survivors of their career progression.

3.2   The Effect of Merging and Rightsizing on the Productivity of Survivors

Some survivors (40%) at the new Ecobank found the organisational climate quite pleasing. However, some survivors found the environment rigid and initially unfriendly resonating with earlier studies that found that survivors could have negative perceptions of merging and rightsizing [21]. These negative perceptions must be managed because according to the distributive justice theory, these could affect commitment and productivity of survivors. Also, if survivors felt that there was injustice, this could lead to decreased job performance and lower productivity based on the equity theory [21]. The Social Identity Theory also came to light as the new environment had brought a change in the bonds that employees had before the merger and the disruption in their comfort zones could affect their commitment too. A good corporate environment is however necessary for survivors to be productive. Also, a small cohort of 30% survivors had issues with trust and 55% of the participants indicated that the merger had not affected their trust of management. Rather, the merger had helped to improve the relationship between management and employees. On the whole however, the trust situation at the new Ecobank was improving and survivors did not let it affect their productivity at all.

Participants (25%) indicated that management did not share information with staff, communication was generally poor, and relationships were not cordial at all especially among EGH and TTB staff because of the unfriendly environment. Organisational Justice had a key role to play here as the concern was not just on the communication

of the decision of management to employees but also how management implemented these decisions. 25% of survivors blamed the communication problems on the merger but further confirmed that communication had become better over time. The issue of communication was important because it was essential in making employees know what management expected from them and helped to prevent rumours and speculations among employees. Furthermore, the study showed that 60% of participants perceived that office politics was rife at the new Ecobank. 30% of the participants also indicated that office politics featured prominently in top positions and some employees were placed in positions they were not competent enough to handle. There was also the case that not many TTB staff were in key management positions. Thus, some survivors instead of working did a lot of bootlicking which wasted time and resources and affected not just the productivity of the survivors but also impacted the performance of the merged bank. Issues of unfairness and inequity therefore came up confirming the distributive justice theory which could lead to a reduction in effort and a decrease in productivity. A key driver of productivity at the new Ecobank was self-motivation but not extrinsic motivation from management. Survivors were self-motivated and neither the motivation by management nor the lack thereof could drive their motivation nor affect their productivity. Survivors however were acting in order to conform to expected behaviour at the new Ecobank.

3.3 Effect of Rightsizing on Workload of Survivors

Mergers have been associated with increased workload [21]. The merger at the new Ecobank had caused an increase in the workload of some of the survivors with some even experiencing a doubling of their workload. The changes in responsibility made some participants (50%) to have a change from their previous departments but some participants did not experience any change in their responsibilities/or workload since technology reduced their workload and made them more efficient. The concern though was that the increased workload for some survivors could lead to stress and a decrease in productivity. The responses of a minority of participants (5%) indicated that some survivors experienced loss of prestige, recognition, and tangible benefits after the merger. Benefits at the merged bank were different for non-full-time employees. Also, the merger had negatively impacted work life/family balance as it brought with it increased workload, working more hours including weekends, stress and less time spent with family. Family-life based interaction among staff could be rejuvenated and this would improve the work-life balance. There were elements of unfairness and inequity regarding responsibility and the sharing of work at the new Ecobank. These elements stemmed from differences in the workforce and then survivor's commitment to work such that hardworking people were given more work to do. Also, there was an inherent problem in the distribution of work because of the structure of roles at the new Ecobank. This created a situation where some survivors had little to do whiles other were inundated with work confirming the distributive justice theory of perceptions of survivors regarding unfairness to them. The bigger problem was that survivors were not being compensated or rewarded for the additional workload and the no-reward could lead to underperformance and a reduction in productivity over time.

3.4   Effect of Merger on the Efficiency of the Merged Bank

Before the merger, that is in 2011, EGH held 10.2% of the 33% share of industry assets held by the four largest banks in Ghana. This increased to 12.4% after the merger in the year 2012. The new Ecobank held its position as having significant share of industry operating assets over the period 2012 to 2019 and was only second to Ghana Commercial Bank (GCB) after it rebranded in 2014. The efficiency of the merged bank had therefore increased based on this measurement and this confirmed that merging could cause an increase in an organisation's share of industry operating assets [3]. Also, EGH's cost-to-income ratio before the merger was 52% in 2011 but this fell to 50% in 2012 and was attributed to the merger. The cost-to-income ratio of the merged bank experienced several fluctuations over the period 2012–2019 with greater efficiency experienced in some years. On the score of cost-to-income ratio therefore, the efficiency of the merged bank had increased. The asset quality of the merged bank faced a few challenges. Though its loan profitability improved to 1.7% in 2012 because of its expansion into the small-medium enterprise (SME) sector, it had to make provision for credit losses to cater for the expansion. A decline in specific term loans also led to a decline in its profitability in 2014. By 2018, the new Ecobank had addressed its impairment losses including its legacy Bulk Oil Distributor Company (BDC) loan book and thus encouraging a new phase in the merged bank's asset quality. In terms of liquid funds/total deposits, the new Ecobank did not achieve the efficiency intended by the merger. Its liquidity fell over the period 2012–2015 to an all-time low of 57% in 2015 from 68% in 2011. Even though the new Ecobank increased its loans and advances in 2018, its liquidity still fell from 76% in 2017 to 71% in 2018. The liquid funds/total assets of EGH was 0.55 in 2011. After the merger, this continued to fall for the period between 2012–2019. It was at an all-time low of 0.43 in 2015 and increased to 0.47 in 2016. The liquid funds/total interest-bearing liabilities of the merged bank fell generally over the period 2012–2019 even to a low of 0.53 from 0.64 in 2011 before the merger. The merged bank however saw an increase to 0.74 in 2017 but again fell to 0.70 in 2018. The low values of the three liquidity ratios show a bank that is less than efficient than its counterparts, a finding consistent with Amoako-Boateng [4]. Thus, regarding liquidity, the efficiency of the merged bank did not increase with the merger.

4   Conclusion

The case of Ecobank Ghana Limited and The Trust Bank showed that mergers when used by organisations could affect not just the survivors in the organisation but also have an effect on how effective the bank could be. Particularly in this case, the mergers had changed the roles of some survivors and increased others workload. Their productivity had however not been impacted as they were self-motivated. The fear though was that having merged for just under a decade, it would be possible that if the corporate environment was not improved and compensation made fair, employees would leave the organisation especially since the increased workload did not come with increased compensation but rather promotions were biased. The efficiencies of the merger included a bigger market share and a more favourable asset quality. However, the cost-to-income ratio and liquidity over the decade were below expectations considering the benefits that

were to be derived from the merger. Consequently, the study brought to light certain critical points which needed further attention for future corporate restructurings. To begin, mergers would come with role changes but it was important for management to ensure that survivors did not lose prestige and recognition in the organisation with the role changes. Productivity of survivors was a lifeline to the performance of the organisation. In order for survivors to stay productive after a merger strategy with role changes, there was the need to ensure that survivors remained self-motivated, are well compensated for their workload, had a conducive work environment and there was opportunity for career progression in the organisation. If these are absent, in the long run, survivors would re-adjust their attitude to work and this would affect their productivity and the performance of the organisation. A merging/rightsizing activity could bring on board technological change and advancement which would cause the organisation to outsource some of its processes or practices and this could displace survivors, make them underutilized or ultimately, render them redundant. Considering that with a merger, there would be a scramble for positions, it is possible that unhealthy feelings would be created especially for upper management at the helm of affairs. There was therefore the need to resolve any differences generated as differences unresolved could fuel bad internal politics not just for management but also trickle down to all nooks and crannies of the organisation. An organisation that intended to improve its efficiency could look to other means aside a merger because it was not a guarantee that it would lead to efficiency of the organisation as the conditions for efficiency including liquidity and cost-to-income ratio were determined by the market which was ever competitive and dynamic.

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Client's Quality Assessment of Digital Transaction Platforms Interactivenesses in a Covid-19 E-Commerce Business Environment

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Abstract. This paper explored online shoppers perspectives of the quality of their systemic interactions with digital transaction platforms provided by e-commerce firms to excite their shopping experiences, especially during this period of Covid-19 pandemic, with a corresponding significant impact on consumer behaviour. Guided by a survey research design, quantitative data was collected from 304 online shoppers and analyzed descriptively and inferentially. The results showed that digital platform factors that excite clients shopping experiences include senses of care, flexibility, community, customization, character, and interactivity. Female clients were found to found relate more to such enablers than male clients, even though, the differences in their premium ratings the factors were not insignificant. It is concluded that the increase in clients usage of digital platforms for shopping and subsequent excitement is influenced by the quality of the platforms' interactivenesses derived from feelings of care, customization, community, character and flexibilities provided by its design.

Keywords: Gender · E-commerce · Online shopping · Online shopping excitement · Digital transaction platform · Consumer behaviour

1 Introduction

It is an established fact from [1] that a large diversity of online platforms and other online services exist in Europe, with almost 10,000 high-growth SMEs trying to scale up in the EU Single Market. According to [1], most of these SMEs are start-ups accounting for only 2% of total value. Though such statistics is unavailable for the sub-Saharan economies, there is no denying the fact that E-commerce is a growing enterprise in sub-Saharan countries, including Ghana, with firms, mostly start-up SMEs, mirroring the structure of those in the European Union and developed economies. The advent of

the Covid-19 pandemic has resulted in significant shift of consumer behaviour towards e-commerce. According to [2], despite the COVID-19 pandemic increasing the level of online buying globally, a slump in sales was found among several e-commerce firms in least developed countries. Findings by [2] in a study of e-commerce firms in 23 countries, mainly in Asia and Africa showed a stark difference on how the Covid-19 pandemic impacted firms in these countries. According to [2], a five-month operational assessment of over 250 firms with less than ten employees in these countries in the year 2020, showed that 58% of these firms who sell their own services and/products online experienced a slump in their monthly revenues. On the contrary, [2] reported that about 64% of the firms who operated as third-party experienced increases in their sales. As it is highlighted by [2], most firms in Asia and Africa found it difficult to adapt and enhance their online operations, despite the rise in e-commerce necessitated by the Covid-19 pandemic. According to [2], despite the introduction of new digital business models and other opportunities induced by the coronavirus pandemic, the challenges faced by firms in these countries to adapt or adopt such models are quite profound.

There are studies that show that clients' derivation of entertainment and satisfaction is a source of motivation for online consumption. By implication, the acceptance of e-shopping by consumers is deemed to reflect such enjoyment which is encapsulated by the trust the have on the virtual technology that interface their e-shopping transactions. The e-shopping structural system design, as a virtual technology system, is expected to cater for some key human-interactive components, which includes consumer service provision interface enabled by secure and trustful website design, while taking into cognizance the relative importance of competition and level-playing field in this sector. As highlighted by [1], an on-going reflection on competition law challenges in this digital age has led to the evolution of competition policy to help continue to promote pro-consumer innovation, and to ensure complementarity between ex ante regulation and ex post competition law. Yet, in most sub-Saharan countries business environments, there prevail the notion among consumers that digital platforms provided by firms are engulfed by risk and trust issues which constrain their transactional interactivenesses for online shopping decisions. One of such firms was established in Ghana in the year 2014 with the vision of becoming the one-stop shop for retail in Ghana. The firm has grown to become the largest online retail store in Ghana hosting over 10,000 vendors with over 5 million products available online for sale to shoppers, and it is its intention to enable exciting shopping experiences to its clients. Yet, aside a conceptual attempt by [3], the issue as to whether the clients of firms providing online services derive excitement in their shopping experience remains unexplored. The purpose of this study is to understand whether the digital platform provided by the firm to excite the shopping experience of its clients meets their expectation or otherwise. The paper explored online shoppers perspectives of the quality of their systemic interactions with digital transaction platforms provided by e-commerce firms to excite their shopping experiences, especially during this period of Covid-19 pandemic, with a corresponding significant impact on consumer behaviour.

2   Literature Review

Digital transformation is forcing companies to change their business models and adapt to the new market reality. This reality is driven by customers' expectations of what they deem as relevant content to their activities relative to time, space and the characteristics of their chosen technological tools and supporting digital medium. According to [4], the behaviour of consumers towards e-commerce has been affected significantly. This is due to the provision of enhanced shopping opportunities entailing more transactional options that are convenient to consumers [4]. Consequentially, online purchases have increased due to consumers preferences of patronizing goods and/or services on digital platforms. Arguing from the perspective of [4], such shift in consumer behaviour could be aligned to the consumer's admiration of online purchases and its associated benefits, despite the inherent perceptions of risks, privacy concerns and trust issues. According to [5], some consumers are apprehensive of online shopping. This is because, they feel unsafe to transact business on digital platforms [5]. Such a consumer behaviour, as argued by [5], is influenced by several environmental factors that are both external and internal. The external influences as outlined by [5], include technological factors, marketing factors, socioeconomics, cultural factors, and demographics factors. The internal influences, which are cognitive-oriented, include the consumer's learning capability, attitude, his/her perception, his/her self-image, his/her motivation, and his/her semiotics orientation [5]. Relatively, a study by [6] established that business transaction on digital platforms is a goal-oriented activity [7, 8] for clients. According to [6], intrinsic elements, such as entertainment derivation, is a strong influencing factor in making a digital platform become an acceptable medium for clients online shopping transactions.

The intrinsic elements are associated with the importance assigned and cognitive amalgamation derived from clients' experiences with digital platforms [6]. As it was intimated by [6], consumers utilization of digital platforms for shopping activities is reflective of the enjoyment characteristics of the activity, and the trust shown in the technology to excite shopping satisfaction. Thus, the following are deemed important factors in exciting consumers digital shopping behaviour; consumer service, digital platform design and digital platform security. These factors contribute in determining clients perceptions of the quality, trustfulness and usefulness of digital platforms, and its derivative enjoyment for online shopping. Therefore, arguing from the perspective of [9], consumer behaviour towards transactional activity on a digital platform is primarily influenced by the consumer's perceptions of its usefulness, complimented by its trustworthiness and its enabling of enjoyment. In addition to these factors is the notion that consumers might use a digital platform as an experimental tool to fulfil their needs of good service [10]. Additionally, [11] has identified other consumer behaviour indices that influence clients shopping excitement on digital platforms. These include characteristics such as the comfortability derived from its design customization, character and the interactivity of contact, choice, community, care, and cultivation it provides.

3   Methodology

The online survey design method was used for the study. The study populations were clients who use digital platforms provided by an organization in the conduct of their shopping activities. The sample size was three hundred and four (304) respondents, all of whom are clients and who use the online platforms provided by the organization to shopping activities. The data was collected using a self-administered questionnaire. The questionnaire was divided into two sections. The first section collected data on the respondents' demography. The second section collected data relative to the respondents' experiences in using the digital platforms provided them in the conducting of their shopping activities. The responses were designed using the Likert's five-point scale, which ranged from 1 (strongly agree) to 5 (strongly disagree). The questionnaires were mailed to each of the 304 study participants on continuous basis to complete. The participants were encouraged to read the synopsis provided in the questionnaire for them to understand the rationale behind the issue being studied and for them to be truthful in their responses. The duration for data collection period was 21 days and was collected in the month of June 2020. All the completed questionnaires retrieved were checked for completeness. The data was analyzed both descriptively and inferentially. In the descriptive analysis, the job values scale was factor analyzed from the perspectives of principal component analysis to identify factors that are predictive of job values. Mean ratings of job values were also analyzed to establish the premium levels of job values factors for both gender and employment preferences among the study participants. In the inferential analysis, one-sample test was performed to establish the levels of significances of the job values factors identified as premium. Independent sample tests were conducted, firstly to establish the level of variation in the job values factors identified as premium by males and females. Secondly it was used to establish the level of variation in individual job value factors determination of job preference. The SPSS software was used as the analytic tool.

4   Results and Analysis

The gender distribution of the respondents is showed that 124 (41%) were males and 180 (59%) were females. Forty-one (13%) respondents have been clients of the organization for less than one year while the remaining 263 (87%) respondents have been clients for more than one year. For the organization, clients who have patronized it services for one year and above are considered to have a good understanding of the ability of digital platforms to excite shopping experience. The implication is that majority of the respondents have been clients of organization for a longer period and thus have a good understanding of digital platforms experience covered in this study.

4.1   Analysis of Factors Predictive of Clients' Excitement of Digital Platforms

To assess whether the measured factors in the digital platforms scale are predictive of the students' job values, principal component analysis was conducted. The estimated

Kaiser-Meyer-Olkin (KMO) value for personal social capital is 0.840 which exceeded the recommended 0.6 value [12, 13]. The estimated chi-square (χ^2) value from the Bartlett's test is 711.136 (p = 0.000, df = 15), which is highly significant (p < 0.001). These values indicate that the correlation pattern of the digital platforms factors are good and is therefore appropriate to factor analyze the digital platforms indicators tested. Thus, factors analysis was performed to identify and segregate the factors perceived by the study participants as predictive of those that enable clients' excitement shopping experiences on digital platforms. Principal component analysis was conducted as an extraction method to characterize the various predictive factors of job values. Varimax with Kaiser Normalization was used as the method of rotation, but which converged in only one (1) iteration. The component (C) matrix with the factor loadings/regression values (r) is shown in Table 1 below. It is observable that all the six (6) items have factor loadings greater than 0.50 [13, 14]. This implies that each factor has a predictive strength to enable clients excitement of shopping using digital platforms.

Table 1. Regression estimates for component matrix of digital platforms factors

Digital platforms factors	Component regression values (r)
My loyalty to online business is influenced by the care I receive from its digital platforms	0.753
My loyalty in online business is influenced by the customization of the digital platforms	0.780
My loyalty in online business is influenced by the community created by the digital platforms	0.744
My loyalty in online business is influenced by the character of the digital platforms	0.750
My loyalty in online business is influenced by the flexibilities of choice provided by the digital platforms	0.761
My loyalty in online business is influenced by the interactivity of the digital platforms	0.765

4.2   Analysis of Excitement Premium Levels of Digital Platforms Factors

To answer the first question relative to which digital platforms factors have the ability to excite clients' interactive shopping experience, the mean ratings of the response scores were analyzed using the one sample t-test. The mean (M), standard deviation (SD), standard error mean (SEM), t-values, degree of freedom (df), and probability level (p) estimates of excitement premium level ratings of digital platforms factors are shown in Table 2 below.

Table 2. One-sample test statistics for respondents' premium level ratings of digital platforms' ability to excite clients' interactive shopping experience

Digital platform factors	M	SD	SEM	Test value = 3		
				t	df	p
My online shopping excitement is influenced by the care I receive from its digital platforms	4.23	0.828	0.048	25.897	303	0.000***
My online shopping excitement is influenced by the customization of the digital platforms	4.19	0.744	0.043	27.998	303	0.000***
My online shopping excitement is influenced by the community created by the digital platforms	4.18	0.819	0.047	25.152	303	0.000***
My online shopping excitement is influenced by the character of the digital platforms	4.10	0.801	0.046	23.854	303	0.000***
My online shopping excitement is influenced by the flexibilities of choice in the digital platforms	4.18	0.709	0.041	28.951	303	0.000***
My online shopping excitement is influenced by the interactivity of the digital platforms	4.09	0.856	0.049	22.123	303	0.000***

N = 304; *** $p \leq 0.001$ significance level (2-tailed)

From Table 2 above, the excitement premium ratings for the digital platforms factors are as follows; Digital platforms that invoke in clients a sense of flexibility of choice (SEM = 0.041) has the highest premium. This implies that for clients, platform's ease of use is deemed to be of very great importance. This is followed by the digital platforms provision of a sense of customization (SEM = 0.043), character (SEM = 0.046), community (SEM = 0.047), care (SEM = 0.048), and interactivity (SEM = 0.049) of the digital platforms. This implies that for the clients, incorporation of special characteristics to the platform job designs that enables client derive a feeling of self, attention, collaboration and cooperation are also deemed to be of importance.

4.3 Analysis of Excitement Premium of Digital Platforms Based on Gender

To answer the second question as to which digital platforms factors male and female clients perceive as having the premium ability to excite interactive shopping experience, their ratings was analyzed. The mean (M), standard deviation (SD) and standard error mean (SEM) estimates, and also the independent sample tests of the clients' premium level ratings are shown in Table 3 below.

Table 3. Statistics for male and female respondents' comparative ratings of digital platforms' ability to excite clients' interactive shopping experience.

Digital Platform Factors	Males				Females				Levene's Test for Equality of Variances			t-test for Mean Equality	
	N	M	SD	SEM	N	M	SD	SEM	F	P	T	Df	P
My online shopping excitement is influenced by the care I receive from its digital platforms.	124	4.13	0.855	0.077	180	4.30	0.804	0.060	0.019	0.889	-1.775	302	0.077
My online shopping excitement is influenced by the customization of the digital platforms.	124	4.09	0.744	0.067	180	4.27	0.737	0.055	3.433	0.065	-2.062	302	0.040*
My online shopping excitement is influenced by the community created by the digital platforms	124	4.11	0.767	0.069	180	4.23	0.851	0.063	5.774	0.017*	-1.203	302	0.230
My online shopping excitement is influenced by the character of the digital platforms.	124	4.05	0.795	0.071	180	4.13	0.805	0.060	0.132	0.716	-0.849	302	0.396
My online shopping excitement is influenced by the flexibilities of choice in the digital platforms.	124	4.10	0.748	0.067	180	4.23	0.678	0.051	0.029	0.864	-1.655	302	0.099
My online shopping excitement is influenced by the interactivity of the digital platforms.	124	4.07	0.903	0.081	180	4.09	0.824	0.061	0.243	0.623	-0.219	302	0.827

N = 304; * $p \leq 0.05$ significance level (2-tailed)

From Table 3 above, the male and female premium ratings for the digital platforms factors, are as follows;

The female clients perceived digital platforms that provides a sense of community to be of higher premium than male clients. Though the results from the Levene's test for equality of variances indicated that equal variances can be assumed (F = 5.774; $p = 0.017$), the t-test showed that the difference in the premium ratings between the males and females on this digital platform factor is not significant (t = −1.203; $p = 0.230$). This implies that female clients do not perceive digital platforms entailing a sense of community to be of greater premium than their male colleagues. The female clients also perceived digital platforms that provides a sense of customization to be of higher premium than male clients. Though the results from the Levene's test for equality of variances indicated that equal variances cannot be assumed (F = 3.433; $p = 0.065$), the t-test showed that the difference in the premium ratings between the males and females on this job value factor is significant (t = −2.062; $p = 0.040$). This implies that female clients perceive digital platforms that are customized to be of greater premium than their male colleagues. Similarly, the female clients perceived digital platforms that provides a sense of care to be of higher premium than male clients. But, the results from the Levene's test for equality of variances indicated that equal variances cannot be assumed (F = 0.019; $p = 0.889$), and the t-test showed that the difference in the premium ratings between the males and females on this digital platforms factor is not significant (t = −1.775; $p = 0.077$). This implies that female clients do not perceive digital platforms

entailing a sense of care to be of greater premium than their male colleagues. The same observations are made for digital platforms factors that provide clients a sense of character, flexibility, and interactivity, with female clients perceiving them of higher premium than their male colleagues.

For digital platforms factors that invoke in clients a sense of character, (F = 0.132, $p = 0.716$), the t-test showed that the difference in the premium ratings between the males and females on this job value factor is not significant (t = -0.849; $p = 0.396$). This implies that female clients do not perceive digital platforms providing a sense of character to be of greater premium than their male colleagues. Similarly, for digital platforms factors that invoke in clients a sense of flexibility (F = 0.029, $p = 0.864$), the t-test showed that the difference in the premium ratings between the males and females on this job value factor is not significant (t = -1.655; $p = 0.099$). This implies that female clients do not perceive digital platforms entailing flexibility to be of greater premium than their male colleagues. For digital platforms factors that invoke in clients a sense of interactivity (F = 0.243, $p = 0.623$), the t-test showed that the difference in the premium ratings between the males and females on this job value factor is not significant (t = -0.219; $p = 0.827$). This implies that female clients do not perceive digital platforms entailing flexibility to be of greater premium than their male colleagues.

5 Conclusion

The findings show that digital platforms that for clients, ease of use of digital platforms complimented by the incorporation of special characteristics to the platform job designs that enables client derive a feeling of self-attention, collaboration and cooperation are of great importance. Both genders tend to cherish the prevalence of communal atmosphere and a characteristic sense of care during their interactive activity with the digital platforms. It is concluded that a significant number of the firm's clients believe that their excitement as online shoppers is induced by the flexibility of choice, customization, character, care, and sense of community, provided by digital platforms. Thus, to generate a large network of future online shoppers, digital platforms must continually improve on the choices available to clients on digital platforms. This requires that firms should design their digital platforms to enable user care since this resonates with online shoppers as they feel loved on a personal level. Undoubtedly, digital customization is very relevant in today's e-commerce. It makes clients feel a sense of acceptance and recognition, and also being in charge of the digital transaction themselves. Firms should incorporate such perspectives in the design of their digital platforms to create conducive digital transactional environments that will excite their clients' shopping experience.

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Human Systems and Transportation Applications

Exploring Pilot Workload During Professional Pilot Primary Training and Development: A Feasibility Study

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Abstract. Workload is an effective analytical attribute that helps to evaluate a pilot's performance while operating an aircraft yet is an under-researched construct in aviation. In the foundational study, we sought to utilize electroencephalogram (EEG) and flight simulator performance data to explore the relationship between mental and physical workload of pilots as they completed routine flight activities. The study focused on two specific metrics- the EEG response (sensory inhibition, and attention) and a physical workload metric derived from flight control activity and the deviation from reference pitch and bank attitudes. Five pilots participated in the study, each completing five sessions in an Advanced Aviation Training Device (AATD). The results were inconclusive but seemed to indicate trends that were reasonably linked to pilot's skill profile. A more complete and nuanced understanding of how mental and physical workloads relate to pilot activity may be determined from additional research with a larger sample size and broader range of performance metrics and assessment strategies.

Keywords: Pilot workload · Mental workload · Flight training · Attention · EEG · Frontomedial theta

1 Introduction

Mental workload is one of the vital metrics to evaluate pilots' decision-making skills during critical phases of flight. The definition of mental workload is multifaceted, considering various aspects like characteristics of the task, operator, and environment of task performance [11]. The evaluation and measurement of mental workload often presents challenges in understanding cognition and brain activity [11]. Dahlstrom and Nahlinder [5] conducted a study to investigate mental workload in basic civil aviation training. This study included a mixture of psychophysiological measures like heart rate, eye movement, blinks, and subjective measurements of pilots' ratings of mental workload. The recorded

time of individual maneuvers was reported, and a statistical significance was observed during three flight segments - takeoff brake release, engine failure, and cruise. For both aircraft and simulator flights, participants noted higher mental workload ratings during engine failure and lower ratings for rejected takeoff, climb, and descent segments. Measuring mental workload, along with psychophysiological measures, would provide valuable insights into the workload demands of distinct flight segments in civilian aviation training [5].

Wilson [10] conducted a study to explore the effects of cognitive workload demands of the pilots. Several psychophysiological measures like heart rate, heart rate variability, eye blinks, electrodermal activity, electrical brain activity, and subjective data of mental workload were reported in the study. Due to the multitude of cognitive processes, a single measure was not enough to reveal the depth of the problems associated with flying. To ensure the reliability of psychophysiological measures, participants flew two trials in both IFR and VFR conditions. Data between two trials were compared and no statistical significance was observed among psychophysiological measures across all the workload segments. But there were significant Electroencephalography (EEG) signal comparisons between varied flight scenarios administered from many days to weeks. The alpha band power among EEG signals attenuated during flight segments like landings, VFR touch and go, IFR missed approach, IFR climb-out, HS ILS tracking, and the final landing. Takeoffs and landings were the predominant phases of flight, which requires considerable cognitive demand among the pilots [10].

The rise in automation can result in a reduction in operator mental workload, which raises the debate of mental underload as it impacts the performance of human operators. According to Young and Stanton [12], malleable attentional resource theory (MART) posits that "if the maximum capacity of an operator has been limited as a consequence of the task… they cannot cope when a critical situation arises" (p. 186). This theory supports that low mental workload could lead to the mitigation of several attentional resources available to the operator, which further limits performance in their tasks. For evading mental overload and underload situations, task demands should be increased consistently to improve the performance of operators. According to MART, operators who are accustomed to higher demands will perform better than the underloaded operators if an emergency arises. Underloaded operators cannot manage a situation of scarce resources and unexpected workload demand, even though the tasks are carried out within their capacity. For gaining additional insight into MART, Young and Stanton [12] conducted a driving simulator experiment, where levels of automation were manipulated to observe the changes in mental workload, attention, and performance. The reduction in attention ratio score was found with the increase in mental workload task demands.

Aircraft dynamics provide a more objective assessment as the measurement of aircraft dynamics variables occurs without any pilot intervention and thus presents itself as an information source for effective evaluation of pilot physical workload. In a recent study [1], a parameter reflecting a traditional definition of "work" from Newtonian mechanics (work = force × displacement) was used as a measure of pilot workload experienced during nominal General Aviation or Primary Flight training flights. This was based on an earlier approach that was applied for quantifying the work expended by a pilot while evaluating the performance of different Neural Network augmentations of an adaptive

flight controller [9]. The current study compared the differences and their relationships were explored between physical workload and mental workload of the participants using Pearson's r. Most of the existing literature posited the use of biometric sensors (heart rate measurements, eye tracking, electrodermal response, EEG, facial thermography, etc.) and fundamental subjective measurements (NASA-TLX scale, Modified Cooper-Harper (MCH) scale, Bedford Workload Scale, Subjective Workload Assessment Technique (SWAT), etc.) to measure and evaluate mental workload. For measuring physical workload, many existing studies in literature utilized various flight trials, which either estimated time to complete the trial or participants' success on finishing the flight trial. There is a significant research gap in the literature, utilizing the deflections of flight controls as an objective measurement of physical workload. The present study sought to use deflections of aileron and elevator as measures of physical workload to better understand the mental workload of pilots. An advantage of this approach was that it facilitated conducting the experimental study without any pilot intervention.

2 Materials and Methods

Five participants (n = 5) were recruited from a four-year undergraduate professional pilot degree program. Participants A and B each held a commercial certificate with a multi-engine rating. Participants C and D were private pilots while participant E was a student pilot. All participants completed five flight sessions; however, the EEG of Participant D failed to be recorded in the first session, and the workload of Participant A failed to be recorded in the last session. Therefore, a total of 23 sessions were analyzed. All the participants except Participant E held an instrument rating and all participants had at least 25 h experience in an AATD. Participant E had zero actual instrument time and less than 25 h of simulated instrument time. All research was conducted with the approval of the University Institutional Review Board.

Pilots completed a predefined flight pattern in a Precision Flight Controls Modular Flight Deck Advanced Aviation Training Device. They completed five sessions to capture potential variations in performance and attributes from the perspective of their mental mechanisms. Participants were asked to perform the designated circuit twice in each session, the first transitioning into a missed approach and the second transitioning to a landing. Thus, each session contained seven segments including takeoff, enroute, arrival, approach/missed approach, enroute-2, arrival-2 and approach-2/landing (Fig. 1). The flight and EEG data were synchronized by correlating starting times of the respective data sets and the time stamps of the individual segments. EEG data was collected using a EPOC+ 14-channel headset (Emotiv Inc.). The electrode sensor pads were pre-soaked in saline. Figure 2 shows the electrode positions [3]. The sampling rate of the EEG signals was 128 Hz. The EEG signal was pre-filtered between $0.16-43$ Hz and analysis began with the synchronization of the flight data with the EEG data. EEG signals were first filtered through the following frequency bands: theta ($4-8$ Hz) and alpha ($8-13$ Hz). In each frequency band, the power was normalized by the overall-frequency power in $0.1-50$ Hz with a 100th-order FIR filter [13]. This normalization ensured that the fluctuations of the power in any frequency band were not due to a particularly larger-scaled EEG waveform (determined by the electrode conductivity) on that day.
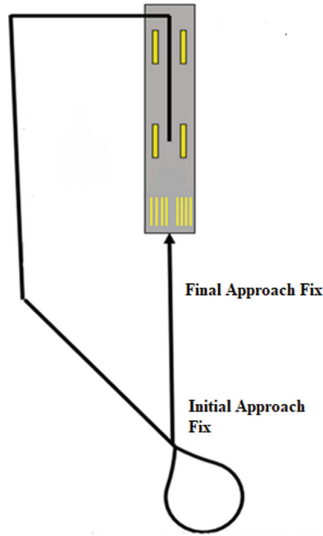
Fig. 1. Flight pattern.

Two types of EEG features were then computed based on the above brain waves. First, the power of the alpha wave was computed for the auditory and visual cortices. The left auditory-cortex response was obtained with Electrode T7; the right auditory-cortex response was obtained with Electrode T8; the left visual-cortex response was obtained with Electrode O1; the right visual-cortex response was obtained with Electrode O2.

To measure the attention or effort, the power of frontomedial theta wave was computed as an average using Electrodes AF3 and AF4 (Fig. 2). We computed the posterior alpha wave by averaging Electrodes P7 and P8.

There was no active electrode at the posterior region; therefore, the occipital alpha wave was obtained again from the average of O1 and O2. Nevertheless, as the two reference electrodes, P3 and P4, were located at the posterior region, the obtained signals were interpreted as differences between the occipital and the posterior electrodes. We then derived the ratio F_th/O_al as an indicator of the amount of attention or effort (Clayton et al. 2015). A higher F_th/O_al indicates that the human is either paying more attention or trying to pay more attention; therefore, we consider it as an indication of "engagement" in this study. Physical workload was analyzed in two ways for each participant: aileron workload and elevator workload. The flight simulation software recorded pilot control inputs and the corresponding flight dynamics variables. As each session had seven segments, and all but two subjects had five sessions, a total of 35 (28 for Pilots A and D) means/standard-deviations of workload values were obtained from each subject to be correlated to the EEG data.

Kruskal-Wallis tests were conducted to determine if there were differences in physical and mental workload parameters between the individual pilots [7]. Where the test revealed significance, a Dunn [6] pairwise comparison procedure with a Bonferroni correction for multiple comparisons with statistical significance accepted at the $p < .005$ level was presented where appropriate. The relationships between mental and physical

workload parameters for each participant were then assessed using Pearson's product-moment correlation. Both the average value of the physical workload and its dispersion are relevant factors when exploring the nature of a pilot's physical workload. As such, the means and standard deviations of the aileron and elevator workloads were each correlated to the EEG metrics.
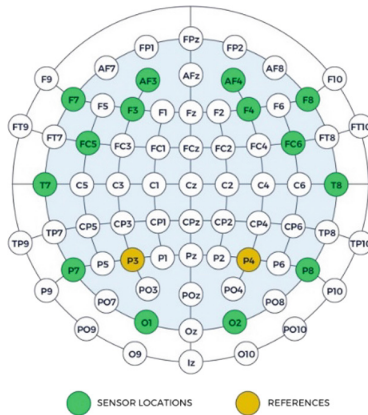
Fig. 2. EEG electrode placements with the EPOC+ 14 channel headset mapped onto a standard 10–20 system. Green electrodes were the 14 channels used in this study; P3 and P4 were the reference electrodes.

3   Results

Kruskal-Wallis test results returned significant differences between the pilots for three of the five EEG parameters (Table 1). Median and mean ranks for the EEG parameters are listed in Tables 2 and 3. In each of these three cases, a visual inspection of the test boxplot indicated that the distributions of the values were not similar for all the pilots.

Table 1. Kruskal-Wallis EEG parameter test statistics.

	Left visual cortex	Right visual cortex	Left auditory cortex	Right auditory cortex	FM ratio
Kruskal-Wallis H test	23.385	22.829	8.973	21.638	5.173
df	4	4	4	4	4
Sig.	<.001	<.001	.062	<.001	.270

Table 2. EEG parameter medians.

Pilot	Left visual cortex	Right visual cortex	Left auditory cortex	Right auditory cortex	FM ratio
A	0.9107	0.9145	0.8904	0.9273	1.0171
B	0.9631	0.9812	0.9697	0.9679	0.9779
C	0.9525	0.9812	0.9290	0.9814	1.0055
D	0.8246	0.8255	0.8837	0.7742	1.0072
E	0.9023	0.9079	0.8784	0.8906	0.9573

Table 3. EEG parameter mean ranks.

Pilot	Left visual cortex	Right visual cortex	Left auditory cortex	Right auditory cortex	FM ratio
A	75.89	75.71	82.60	80.51	102.80
B	107.74	109.57	105.34	97.51	76.37
C	110.31	109.11	96.91	115.86	89.69
D	62.26	64.14	73.63	62.63	83.29
E	83.80	81.46	81.51	83.49	87.86

However, the boxplots did appear to cluster, as the distributions for pilots A, B, and C were similar as were the distributions for pilots D and E (Fig. 3). For left visual cortex, the distributions were statistically significant $\chi^2(4) = 23.385$, $p < .001$. Pairwise comparisons revealed significance between the mean ranks of pilots A (75.89) & C (110.31), $p = .045$, B (107.74) & D (62.26), $p = .002$, and C (110.31) & D (62.26), $p = .001$. The right visual cortex mean ranks were statistically significant, $\chi^2(4) = 22.829$, $p < .001$, and pairwise comparisons between pilots B (109.57) & D (64.14) $p = .002$, and C (109.11) and D (64.14), $p = .002$. For the right auditory cortex, mean ranks were statistically significant, $\chi^2(4) = 21.638$, $p < .001$, and pairwise comparisons found this significance between pilots A (80.51) & C (115.86) $p = .035$, B (97.51) & D (62.63) $p = .040$, and C (115.86) & D (62.63) $p < .001$.

The remaining two parameters, left auditory cortex and engagement, were not found to have statistically significant differences. For the left auditory cortex, the boxplots once again indicated that the distributions of the values were not similar for all of the pilots and the distribution differences were not statistically significant $\chi^2(4) = 8.973$, $p = .062$. Finally, regarding the engagement parameter, the boxplots for engagement appeared to present similar distributions for all pilots. The differences were not statistically significant, $\chi^2(4) = 5.173$, $p = .270$. When combining all the subjects, sessions, and segments, the mean and the standard deviation were strongly correlated ($r = 0.52$ and 0.60 for aileron and elevator, respectively) and statistically significant ($df = 159$, $p < 0.001$). Although there were cross-subject and cross-session variations, a general
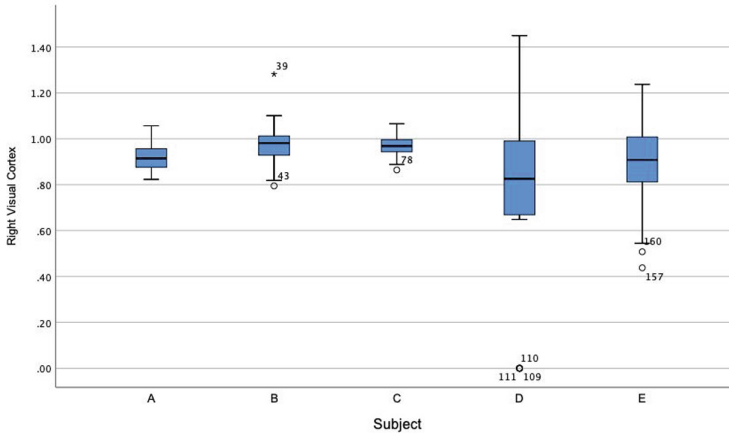
Fig. 3. Kruskal-Wallis boxplot of right visual cortex EEG power.

trend was that the largest means and standard deviations of physical workload were observed with Segments 1 (takeoff), 4 (first approach), and 7 (second approach). This was expected, as these segments represented the greatest demand in terms of changes in altitude and heading. For elevator workload a visual inspection of the Kruskal-Wallis test boxplot found that the distributions of the values were not similar for all pilots. The distributions of elevator workload scores were statistically significantly different between pilots, χ^2 (4) = 11.703, p = .02. Pairwise comparisons revealed statistically significant differences the mean ranks of elevator workload between pilot D (24.71) and pilot E (9.00) (Adj. p = .005), but not between any other pilot combination.

For aileron workload, visual inspection of the Kruskal-Wallis test boxplot found the distributions of the values were not similar for all pilots. The distributions were not statistically significantly different between pilots, χ^2 (4) = 3.442, p = .487. The mean ranks of aileron workload are contained in Table 4.

Table 4. EEG parameter mean ranks.

Pilot	Aileron workload
A	15.57
B	20.29
C	20.43
D	20.86
E	12.86

Less experienced pilots tended to show negative correlations for both auditory and visual feedback and workload indicating that when the workload increased, these pilots relied more on auditory and/or visual feedback. Pilot C showed consistent attention

for both visual and auditory, while pilots D and E intensified both auditory and visual feedback as workload increased. The second metric to be correlated to pilot workload was the ratio of the frontomedial theta wave to the posterior alpha wave, F_th/O_al. In this case, a positive correlation indicated that a higher demand of attention and effort occurred as the workload increased. Although the means and standard deviations of workload yielded somewhat different results, overall, Participants B, D and E consistently had moderate to strong correlations with either elevator or aileron workload, or both. In other words, inexperienced pilots underwent an increased demand of attention and effort with increased workload. In contrast, Participants A and C consistently showed a weak to moderate negative correlation. It seems that the activity was not as demanding even as the workload increased for these pilots.

4   Conclusion

An effort was initiated to explore the relationship between a pilot's mental and physical workloads while executing a flight maneuver in an Advanced Aviation Training Device. A total of 5 pilots with varying levels of experience, including commercial multi-engine, private and student, participated in the study. The pilots were instructed to fly a pre-designed flight pattern while EEG activity and flight performance were recorded and analyzed for differences between pilots using Kruskal-Wallis tests. The trends in the results indicated potential correlations between mental and physical workload in relation to pilot experience; however, the small sample size limits the generalization of these results to a broader population. The findings support additional inquiry with a larger sample and additional performance parameters to pursue a more complete and nuanced understanding of how mental and physical workloads relate to pilot activity and experience.

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Digitalization of Railway Maintenance: A Situation Awareness Perspective

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Abstract. Digitalization in railway maintenance opens new avenues for decision-making and maintenance actions. Advanced sensors and support systems help in automating railway maintenance operations, but this also brings new challenges. Dealing with huge amount of data, transparency and observability are becoming critical aspects in the digitalized word. Successively influence the human ability to gain Situation Awareness, which is considered as important human cognitive aspect for decision-making. The study elaborates the opportunities and challenges of digitalization, in a Situation Awareness perspective. Review of present studies shows that although digitalization is meant to increase: Situation Awareness is often challenged and, sometimes even hindered. Therefore, the major focus is on making recommendations using proper Situation Awareness interventions for meeting the emerging challenges of digitalization on the railway maintenance, so as to provide a better awareness about the railway systems they are dealing with.

Keywords: Digitalization · Railway maintenance · Situation Awareness

1 Introduction

Fast growing digitalization enables a new level of "awareness" in the railway maintenance. Following the global trend as at 2019, the railway freight activities will be more than doubled by 2050 [1]. Therefore, many demands rise for more efficient railway operations; casting both opportunities and challenges for maintenance of railways; safety, quality, and reliability of the service remains as key challenges [2]. As a result, railway maintenance sector drives for increased need for digitalization [3], which brings many opportunities such as enabling the access to huge amount of data. On the contrary, other challenges emerge, for example the demand of increased digital literacy to make sense of those huge amount of data.

Situation Awareness (SA), in general, refers to how operators in complex and dynamic systems develop and maintain awareness of "what is going on" [4]. It is the "perception of the elements in the environment within a volume of time and space, the

comprehension of their meaning and the projection of their status in the near future" [5]. Effective railway maintenance requires current and predicted knowledge about many dynamic elements [6]: development of anomalies, progress of maintenance work, traffic status, weather conditions, and availability of resources, just to name a few. Railways have become an integral part of a nation's economy and the future growth of a nation relies increasingly upon a safe and efficient railway network.

Digitalization is expected to improve the knowledge about these dynamic elements, but new challenges are anticipated such as designing of effective human-machine interfaces. Implementation of proper SA interventions have been found successful in dealing with digitalization challenges in other fields, such as making sense of huge amount of piloting data in modern aircraft [7]. The key is that, proper SA interventions promote naturalistic interactions [8] between human and technology, for example by considering training, and design of interfaces.

We hypothesize that proper SA interventions can assist to overcome the digitalization challenges in the railway maintenance. We first examine what digitalization expects to bring for railway maintenance. Then we analyses what challenges have hindered this transformation. Relating to the theoretical background of SA, we illustrate how proper SA interventions can help overcome these challenges. We also reflect on how SA can relate to potential future digitalization. Understanding the nature of SA may have an impact on how digitalization in railway maintenance should consider training, technology design and assessment. The associated theoretical model of SA is influenced by information processing theories, but SA more specifically describe how human utilize information processing in complex and dynamic environments.

2 Why Digitalization?

Railway maintenance often demands high physically and cognitive effort, making it difficult for human to cope successfully. Therefore, digitalization can be attributed to two main motivations: to accommodate the rising needs for better information management, and as a substitute for the inherent physical challenges in railway maintenance. Two decades ago, the causes related to maintenance contributed to about 30% of railway related incidents in Sweden [9]. More recent study finds 36% of the railway accidents were due to failures in infrastructure [10]. These accidents connect with the inherent nature of railway maintained work: monotonous inspection tasks, exposer to severe weather conditions, encountering risks on active railway tracks, working with uncomfortable postures for prolonged periods, under time pressure etc. Moreover, there are often differences in the physical and cognitive abilities between operators, considerably affecting the maintenance performance [11, 12]. Efficient maintenance decisions require access to quality information [13]. Over the last decades, paper based maintenance job cards were dominating [14]; technicians still follow task card and maintain technical logs regarding the maintenance work [15]. However, those studies find that technicians spend a significant portion of the time on finding and reading instructional procedures for job tasks. These factors contribute in human failures and maintenance errors [16, 17]. Digitalization brings new hopes on the railway maintenance.

Classical digitalization involves obtaining discrete information for processing it on a computer and storing it in a database [18], implying a gradual move towards paperless

maintenance works. Digital transformation is a changes in ways of working, roles, and business offering caused by adoption of digital technologies in an organization, or in the operation environment of the organization [19]. Digitalization in railway maintenance is realized at different levels of complexities (i.e. organizational, operational, technical) [20], and brings new technologies such as predictive analytics, autonomous inspection, augmented reality, virtual reality and digital twins, etc. [18]. For example, data collection from various sensors and their analysis can identify the critical states on railways and provide a forecast of deterioration [21]. Moreover, robotic and autonomous systems take over monotonous inspection tasks on rail tack, crossings, bridges, tunnel and power transmission lines; and reduces the technicians' exposure to risk [22].

The importance of human performance and human error in ensuring the safety of railway operations has been increasingly recognized [23]. In fact, SA is been used to describe the cause of human-automation errors, those can occur at any level of SA: the perception of what is happening (Level 1), the understanding of what has been perceived (Level 2) and, what is understood to think ahead (Level 3). SA is influenced by many individual and task related factors. For example, failures to perceive information often occur due to lack of discriminability in data; and failures to comprehend the significance of events causes by overreliance on some default understating. SA is affected by 8 "demons" [24]: "Attentional tunneling", "Requisite memory traps", "Workload-Anxiety-Fatigue-Stressors", "Data overload", "Misplaced salience", "Complexity creep", "Errant mental models" and "Out-of-the-loop syndrome".

There are serious factors related to loss of SA that are important from the perspective of development of digitalized railway maintenance. SA related affairs on the railway maintenance have been studied, in the context of safety and teamwork [25]. Why SA is so important in safety is that, most of the maintenance takes place while traffic is in operation, therefore, SA related to signaling has been a key focus [26]. Maintaining SA among railway maintenance teams is largely challenged by the scattered nature of the assets [25], for example, rail track seen as a linear asset.

3   Making Sense of Large Amounts of Data

Information is often viewed as beneficial, but if that information is not collated properly, processing it can become overwhelming. Digitalization enables the collection, storage and analysis of the large amounts of data, rising hopes for potentially improved decision-making. However, the barrage of dynamic data have the tendency to be complex and overwhelm the user, threatening their ability to effectively use them. This makes SA a predominant concern in digitalized systems, increasing the likelihood of reaching incorrect decisions. Enormous amount real-time data collected by actuators, sensors, GPS devices, and other wireless and mobile devices along the railway components produces large flows; these need to be processed and analyzed to be useful. Furthermore, the sensors used to collect data are not always co-located, and those can be sending information in different intervals. Therefore integrating as well as interpreting information needs to be done effectively. In this respect, effective visualization of information to provide the view of system dynamics will become a key concern. Information overload is a key problem that needs to be overcome, possibly by only presenting information

that is critical. However, filtering of critical information under dynamic environments becomes a challenge itself.

3.1 Working with Uncertain Data

Maintenance decisions require information of sufficient quality, quantity and validity. In order to ensure the usefulness of the digitalization support, the decision maker should able to maintain sufficient level of context-awareness, with respect to the maintenance location, identity, time and environment or activity [27]. However, studies often find issues with missing data, heterogeneous data types, calibration problems, or non-standard distributions in maintenance data [28]. For example in the collection of railway track geometry data, the sampling positions are often uncertain, because sensors on the measurement car are moving along the track. Another issue is the different seasons that can prohibit regular sampling. With these uncertainties, the sensor data may not detect failure or they can produce false alarms, which can develop deep rooted mistrust in the monitoring system [29]. An emerging challenge is that the large variety of sensory items installed in a railway, require proper maintenance, making maintenance management a more complex task.

3.2 Limitations Inherent to Technologies

Although digitalization can overcome most of the limitations of paper base maintenance materials (such as job cards), the emerging digital technologies are not without their inherent technical limitations. For example, VR will able to better train technicians, by visualize how railway components fit together, and VR can serve as a research tool for understanding technicians interactions. VR fails to recognize the elementary perceptual and cognitive tasks, when technicians deal with real contexts. In contrast, AR is in the real context. But, interacting with both real and digital spaces could become confusing and bring visual fatigue; many factors contribute: discontinuing interactions [30], imprecise positioning of virtual objects [31], and the need for continuously switching the focus between real and virtual objects [32]. There is need for structured approach for better implementation of AR in industrial applications (including railway sector) in terms of cognitive workload assessment and technology readiness [33]. Digital Twins those use Post-WIMP interaction techniques can be seen an attempt to largely overcome the technical limitations inherent to AR and VR [31].

3.3 Human-Technology Collaboration

Digitization can make maintenance situations more complex, as human and robots enter the situations. Robots do not only have to operate efficiently in the maintenance environments, but also be able to achieve higher levels of cooperation with human technicians. In this respect, the element of trust in human-robot collaboration becomes an extremely important factor [35]. In fact, beyond the question of physical collaboration, there is a more challenging question: cognitive collaboration. Human cognitive aspects, such as thinking, sensing, understanding and predicting, and using experience have to be considered.

The question centers on the role of technicians expertise knowledge, in a digitalized maintenance environment. The expertise knowledge personal to technicians spreads in a wide spectrum [36]; this knowledge is often not verbalized in realized only in the action commitments. This needs a new generation of digitalized human knowledge [37–39]. With such approach, digitalized maintenance solutions can also become more adaptive. On the other hand, digitalized solutions can also be used to provide opportunities for technicians to develop their expertise.

Advancements in SA research offer a variety of interventions in job and workplace design addressing a wide range of issues related to digitalization and automation [40]. The major focus has been on the user interfaces. Only a carefully designed user interface will allow the technicians and maintenance decision makers to effectively manage the information to gain a high level of understanding of what is currently happening and what will happen next. Focusing on the what decision makers really wants to know, the SA interventions address the issues related to huge amounts of low-level data, and disorganized information. With our insights to the current challenges with railway maintenance digitalization.

3.4   Remaining Challenges and the Way Forward

A number of aspects about the digitalization in railway maintenance and the challenges that would hinder a high level of development were examined. Proper SA interventions can help overcome those challenges. An interesting research topic is how maintenance technicians can be facilitated to collaborate with the digitalized system, both physically and cognitively. Physical collaboration of automating and human has been frequently addressed. How to collaborate with the knowledge that can be verbalized has also been subjected to research. However, an existing challenge is about the collaboration of the expert's knowledge that is not verbalized. The question is how to digitalize the expert knowledge.

Moreover, on the arena of intuitive engagement, digitalized technologies can go further. Humans are equipped with intuitive learning skills that enhance their implicit knowledge. Both implicit learning and implicit memory require little amount of cognitive resources, in comparison to what is needed by analytical thinking [41, 42]. Technicians with their physical access to railway maintenance work, gather enormous amount of knowledge implicitly. This is supported by their access to railway behavior through multimodal perceptions such as hearing, touch, feeling vibrations etc. This knowledge often stays personal to those technicians, since it is hard to verbalize.

Thus far, the focus has been to maintain an intuitive engagement with the interfaces, for example by using Post-WIMP interaction techniques used with Digital Twins. Opportunities lie for enhancing the technicians' knowledge about the railway behavior itself, through implicit learning. That being the case, future digitalization may not only focus intuitive engagement with the interfaces, but also should able to facilitate the development of users' implicit knowledge about the behavior of the engineering system (i.e. railways). To sum up, future digitalization attempts need to facilitate two-way cognition: digitalizing existing implicit knowledge, and to enable enhancement of implicit knowledge about the behavior of the railway itself.

4   Conclusions

This study discussed the challenges in railway maintenance and emphasized the factors critical in the digitalization. Our discussion on the state of the art revels how well these challenges can be accommodated by the emerging digital technologies. We argued that SA interventions could provide a sound platform for these advancements, as well as to overcome digitalization challenges. Explaining the connections between the digitalization challenges, the potential SA interventions, and how the emerging digital tools can accommodate those interventions.

We conclude by making recommendations for unresolved and emerging challenge: more research should focus on the directions of digitalizing human experts' knowledge, as well as to provide opportunities for retaining implicit learning in a collaborative manner. In long term, this will bring about an environment that is able to support a sustainable development; the sustainability of human expertise in a digitalized world.

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Updating Parameters of Fitts' Law Based on Multi Monitor Command and Control System

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Abstract. At present, the previous studies on the parameters of Fitts' law in the command and control system interface are mostly carried out in a single monitor system. However, with the increase of the complexity of the command system, the amount of information that needs to be displayed becomes more and more large, so the system needs to display information with the help of multi monitor, and cross-screen operation is also needed for the operation of the system. In the multi-monitor command and control system, aiming at the mouse click behavior, this study uses Fitts' law to model. Through the analysis of the collected data, the functional relationship between the movement time, the motion amplitude and the width of the target area is updated under the multi monitor command and control system, and the time of predicting the human-computer interaction of the multi monitor command and control system is quantified. The new fitting function can provide strong support for man-machine interface design and human factor engineering research of multi-monitor command and control system.

Keywords: Fitts' law · Command and control system · Function fitting

1 Introduction

In 1954, Paul M. Fitts studied the motion characteristics, motion time, motion range and motion accuracy of operators in the process of operation, and put forward the famous Fitts' Law [1]. Fitts' law is not only an important guiding theory in human-computer interface design, but also an important quantitative prediction model in the field of human-computer interaction. Fitts' law established the functional relationship between the motion time and the motion amplitude and the width of the target area, and it has been widely used as a few quantifiable human-computer interaction models. Fitts' law can be applied to the evaluation of computer input equipment, the optimization of system interface and the modeling of other complex human-computer interaction tasks. At present, the research is mainly focused on modeling and evaluating the graphical user

interface, comparing and evaluating the effectiveness of input devices [2]. As shown in Eq. 1, Fitts' law states that the interaction time T required for any point to move to the center of the target is related to the distance A from the point to the target and the size W of the target. The longer the distance, the longer the time it takes to move to the target, the larger the target, the shorter the time it takes to move to the target.

$$T \; = \; a \; + \; b\log_2(A/W + 1). \tag{1}$$

Where T is the average motion time, A is the amplitude of movement, W is the width of the target, a and b are constants, which can be obtained by data regression analysis.

For the placement task whose motion amplitude is A and the width of the target area is W, Fitts' law gives the prediction formula of the average motion time T, where A represents the amplitude of movement, W represents the width of the target, and T represents the moving time. a and b are parameters related to equipment and users, which need to be tested in combination with specific people and equipment. Fitts' law has a good theoretical basis and is widely used, such as calculating the target size through torque in the process of grasping the task [3], and calculating the touch screen touch size of the blind [4]. Many scholars at home and abroad have carried out research based on the original Fitts formula, for example: Murata et al. [5] studied the influence of motion direction on Fitts formula under different target shapes, and proposed an extended model; Drews et al. [6] believed that the shape and size of equipment will affect the efficiency of task execution; Hatfield et al. [7] studied the effect of auditory feedback on interaction time in task execution. Heath et al. [8] found that when the moving distance and the target size are different, the ratio of difficulty coefficient to interaction time is also different. In terms of the influence on the interaction time, reducing the moving distance may not be more effective than increasing the target size. In general, Fitts' law has excellent prediction performance, but using the same formula in different devices will lead to a decline in the prediction performance of Fitts' law. This is because the interaction time T required in this law depends not only on the value of A/W, but also on the values of constants a and b. At present, scholars at home and abroad mostly focus on the single-screen graphical user interface. There are less graphical user interfaces for multi monitor command and control systems. Therefore, it is necessary to update the existing Fitts' law parameters and fit a more targeted model to predict the time of human-computer interaction in the multi monitor command and control system.

2 Experimentation

In this experiment, the experimental task is set, and the multi monitor command and control system is used as the experimental platform to determine the parameters a and b of the Fitts' law formula of the operator's mouse interaction behavior.

2.1 Subjects

The subjects were 20 command and control system operators, including 12 male and 8 female. These users had professional knowledge background, the average age was 25 years old, the average working life was 2 years, the corrected visual acuity was more than 1.0, and they were right-handed. All the subjects signed the informed consent form for the experiment and carried out the experiment after passing the training.

2.2 Apparatus

Experimental equipment includes: multi monitor command and control system, two monitors, simulation software, mouse, keyboard. The display resolution of the interface was 1600×1200, the original screen size is 29.65×52.71 cm, and the display area size is 29.65×44.50 cm. The distance from the screen was 0.65 m.

2.3 Procedure

The known Fitts' Law is shown in Eq. 1, where A represents the moving distance, W represents the target width, and T represents the moving time. a and b are determined by the experimental equipment. Therefore, in this experiment, to determine the a and b of the multi monitor system, the subjects need to complete the two tasks of crossing the screen. First, the target width W is unchanged and the target distance is changed. Second, the target distance A is unchanged, and the target width is changed. The subjects were required to use the mouse to complete the "click" operation on the display interface of the main experiment. An example is shown in Fig. 1:

Fig. 1. An example of task display interface, *G* and *D* are two rectangular icons that have been set in size and distance. "Click" means "Click on the red rectangle icon."

Before the beginning of the experiment, researcher need to briefly explain the content of the experiment to the subjects. Each subject conducted three exercises on the experiment with given parameters in order to make the subjects familiar with the content of the experiment. The interval between the two experiments is 5 min, and the subjects can rest in their seats. After issuing the experimental command, the subjects completed the

experiment at a comfortable speed. In the experiment, the subjects were 0.65 m away from the display screen. After starting the experiment, the subjects need to click on two rectangular icons back and forth in the course of the experiment until the dialog box pops up. The number of subjects is 20, and each of them needs to complete at least 11 kinds of experiments. The experimental variables are the distance between the current position of the device and the target position, and the size of the target, which is the size of the target, and the experimental variables are the distance between the current position of the device and the target position. In the experiment, the subjects need to complete the experiment of intersection of 4 target distances: 1000, 1200, 1200, 1400, 2000, pixels, 10, 30, 50, 70, pixels, and get a total of 11 independent variables, that is, moving time T.

2.4   Data Processing

By using the analysis software to analyze and fit the experimental results, the Fitts' Law parameters a and b of the interface can be obtained. The experimental results are shown in Table 1, A is the distance between the current position of the equipment and the target position, W is the target size, and T is the average time for 20 people to complete the task under different experimental conditions.

Table 1. Summary of mouse movement time measurement results of subjects (unit: ms)

A (pixels)	W (pixels)	ID (bits)	T (ms)
1000	30	5.08	1178.53
1000	70	3.89	984.39
1200	10	6.91	1512.83
1200	30	5.34	1185.35
1200	50	4.61	1042.21
1200	70	4.14	996.71
1400	30	5.56	1229.56
1400	70	4.36	1046.02
2000	10	7.65	1761.69
2000	30	6.07	1376.64
2000	70	4.86	1192.96

The formula of Fitts' law is fitted by analysis software, the result is shown in Fig. 2:

The fitting line on the chart shows $y = 201.5x + 156.8$ and $R^2 = 0.9699$. The y-axis is labeled T(ms) and the x-axis is labeled ID(bits)=log2(A/W+1).
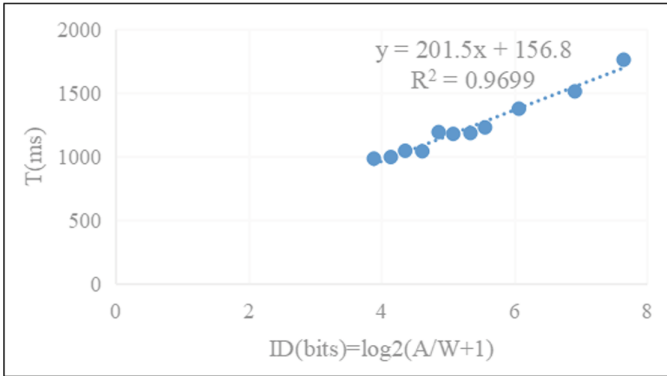
Fig. 2. Experimental fitting results

The fitting function is: $T = 156.8 + 201.5 \log_2(A/W + 1)$, time unit is millisecond (ms). The parameters a and b of Fitts' law under the human-computer interface of complex command and control system are measured by experiments, and the parameters a and b are (a = 156.8 and b = 201.5). In addition, the error analysis of function fitting is shown in Table 2.

Table 2. The result of fitting degree analysis of function

	Values
Correlation coefficient (Multiple-R)	0.984828
Coefficient of determination (R-Square)	0.969886
Standard deviation (SD)	43.82511

As shown in Table 2, the coefficient of determination of the fitting function in this experiment is 0.9699, which is close to 1. It can be seen that the fitting degree of this fitting function is high. For the standard deviation, the fitting is 43.83, which is within the acceptable range. Therefore, the fitting function value is more consistent with the actual value.

3   Results

In this experiment, Fitts' law is used to measure and model the motion behavior based on mouse operation. According to the experimental measurement, the Fitts' law formula parameters of the operator's mouse interaction behavior are (a = 156.8 and b = 201.5), and the Fitts' law is described as: $T = 156.8 + 201.5 \log_2(A/W + 1)$, the unit is millisecond (ms). the coefficient of determination of the fitting function in this experiment is 0.9699, the standard deviation of the fitting function is 43.83.

4   Conclusion

In this paper, aiming at the problem of mouse moving across screen in multi monitor command and control system, based on the original Fitts formula, through experimental data analysis and modeling, the functional relationship between mouse movement time, motion amplitude and target area width in multi monitor command and control system is updated, which lays a foundation for predicting the operation time of human-computer interaction in multi monitor command and control system in the next stage. The reliability of the fitted model is verified by the analysis of the fitting degree of the fitting function. The results show that the fitting degree of the fitting function is high, in addition, more experiments are needed to study the reliability and robustness of the model in the future. The new fitting function can provide strong support for man-machine interface design and human factor engineering research of multi monitor command and control system.

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Accessible and Inclusive Technology

Digital Resources and Children's Learning: Parental Perception During the Pandemic

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Abstract. The coronavirus disease (COVID-19) pandemic has disrupted family life around the world. Families had to adapt to teleworking and online learning to maintain young children's learning at home. During quarantine and nationwide school closures, parents of young children and children with disabilities had to act as teachers, therapists and caregivers. The role of parents gained relevance and it was needed to be able to guide their children to use technology during online learning. Digital resources provided an opportunity for children to keep learning, take part in games and keep in touch with their friends and teachers. But it increased access online brings heightened risks for children's safety, protection and privacy, so it is necessary that parents observe their children and support them. In this context, this paper presents the perception from parents about on the use of digital resources and techno-logical tools that teachers applied before and during pandemic. This study surveyed 773 Peruvian parents to know which of the resources used by teachers helped their children to understand the content of the course and which of tools allowed a better interaction with their classmates and teachers. According to the results of the survey, the most used resource before pandemic has been WhatsApp (32.1%), followed by office tools (Word or Excel 20.3%) and email (8.7%). However, for carrying out online activities during the pandemic the most digital used resource by the teachers has been WhatsApp (29.9%), then YouTube (17.6%), Google Drive (16.7%) and Google Docs. (7.9%). Regarding to a good interaction to increase a better interaction between their classmates and teacher were Zoom (61.7%), Google Meet (25.1%) and WhatsApp (11.6%). These results suggested that the use of digital resources and technological tools during the pandemic has been problematic and challenging for families.

Keywords: Training · Education · Learning Sciences · Parental perception · Covid-19

1   Introduction

At the global level, an abysmal change has been generated from various perspectives due to the COVID-19 pandemic, which has influenced radical changes to be made in the economic, social, business and cultural spheres [1] and in education with the aim of continuing education, leaving behind face-to-face education to make way for virtual education [2, 3], in which Information and Communication Technologies (ICT) have omnipotence [4] by providing active methodologies in the ways of teaching and learning [5], as well as breaking the boundaries of space and time, which are now crucial to prevent further increase in contagion.

This new rethinking of education has meant that the school is transferred to the home and that parents assume an active role as academic guardians, unlike in previous years where the school had the preponderant role as a training agent for their children [6].

As parents are directly responsible for the education of their children [7], especially if they are children at the preschool or primary level whom they have to guide, control and supervise [8], they should be alert to the risks cyberspace, due to the large amount of information that exists and that is available to them without restrictions of any kind, in addition to this, parents have had to adapt to the new ways of learning of their children and train themselves in the use and appropriation of the technologies [7], which are a priority in this context of a pandemic due to the change in virtual and distance education, so this study aimed to find out what resources used by teachers have helped their children understand the content of the course before and during the pandemic and what tools have allowed better interaction with peers and teachers.

1.1   Education, Parents and Technologies

One of the roles of parents is to provide their children with an education that will serve them for life [9] and to provide them with constant accompaniment in their formation, even more so if they are minors and children with special educational needs and if to this is added the fact that they are confined by the worldwide pandemic, having been forced to receive their classes on a virtual basis, parental support has therefore become more relevant through parental mediation [10] that should be provided to parents in their educational development involving ICT, being their most active participation and being aware of all the resources and digital tools that the teacher provides them and that they have selected to situate the learning of the students to the different learning styles [11].

In this context where ICTs have become part of our routine and where minors are more likely to be victims or deceived in virtual environments, parents need to observe their children and guide them with this new teaching modality, in which the use of technologies takes precedence because they are digital means of communication and interaction at a globalized level and are part of the family and social reality [12]. In this twenty-first century, human life can no longer be disconnected from ICTs because it makes it easier to know and to do in the different spheres of the development of human life [13] and even more so in the educational sphere.

From the moment that education was virtualized and home became school, the triad of education-parents-technologies began, relegating the priority role that the teacher had before the pandemic, since this was the guide and guidance in the education of his students, but this has changed, he is now a facilitator of learning, because he has had to acquire the right digital skills to be able to provide the technological resources and tools in addition to the contents that allow his students to acquire the skills, [14] skills and abilities required by the curriculum with the appropriation of ICT and the mediation of parents, who must have all the knowledge about ICT and the relationship that their children have with ICT [15].

1.2   Digital Tools and Resources for Education in Times of Pandemic

Reinventing oneself has been a constant for all human beings in this time of health crisis, where resilience has played an important role, and also in which many have been forced to unlearn in order to relearn in a context of uncertainty that has had to be faced [8], in which ICT became essential, since it has allowed to continue with some of the routines necessary for the development of the human being such as education, as well as innovating to continue training future professionals [16].

The immersion that has been had in ICT education by providing a diversity of resources and digital tools to improve learning and enable the student to learn to know, learn to be, learn to do and learn to live in community, has led to greater use of ICT [13], and having all the knowledge within one click provides greater versatility for teaching [17].

Technologies are increasingly integrated as part of curriculum content at all levels of the education system, through digital resources and tools (WhatsApp, YouTube, Google Drive, Google Docs., Zoom, Google Meet, among others), as students can participate, express themselves and access information [18].

The use of the above-mentioned digital resources and tools date from before the pandemic, but during the pandemic they have had a greater preponderance and frequency in their use. In the case of videoconferences (Zoom, Google Meet, Microsoft Teams) have been a means for interaction [19] between parent-teachers and student-teachers, students and their peers, which, being synchronous, allow real-time interaction.

Another tool that has served as a resource in the learning teaching process is the WhatsApp is a messaging application, which sends and receives messages, photos, videos, documents, voice messages, make calls, as well as contributing to the development of teaching-learning strategies by enabling asynchronous, synchronous activities, group formation for collaborative work, discussions, user-friendly and interacting [20, 21]. Being the second social network with 2,000 million users until February 2020 [22] and handles 60 billion daily messages [23].

The predisposition of parents for their children to use ICTs has increased, as they are now involved in this new form of technology-mediated teaching, being the YouTube channel one of the learning tools that parents use to provide multimedia teaching that is motivating and didactic for their children, facilitating documentary research, in addition, its user-friendliness and accessibility have also allowed teachers to use it as a complement to their virtual classes [24, 25].

The enormous amount of information that through the use of ICT students can carry out in off-site teaching, has led teachers to use secure tools for the storage of activities carried out and also for collaborative tasks, being the Google drive one of these useful tools for the management of information and encouraging collaborative work favoring socio-affective development and thinking, being a web service in which it can be stored, modify, share and access files and documents regardless of where they are via the internet at any time desired [26].

2   Material and Methods

The sample was census type, not probabilistic, because it was not necessary to design a type of sampling [27], and was made up of 773 primary-level parents who voluntarily agreed to be part of the research of three educational institutions in Peru during the quarantine of 2020.

Data collection was carried out using Google Forms, through a questionnaire that addressed the following aspects: (1) The use of resources and tools used by the teacher before the pandemic, (2) Resources used by the teacher in their sessions of learning, and (3) Videoconferencing tools used by the teacher for better interaction with their classmates and the teacher. The information obtained in an indirect way from the facts will allow to represent, in many cases, the reality of a population and its subsequent analysis [28].

The study is of the Basic type and aims to increase theoretical information in support of the advancement of science [29]. The design is nonexperimental and descriptive, because what is sought is to describe the frequency of a variable in one or more study groups [27], in addition to characterizing a specific phenomenon or situation indicating its most peculiar or differentiating features [30].

3   Results

After the application of the instruments, WhatsApp is the tool most used by teachers before the pandemic (32.1%), followed by Office (20.3%) and other tools (22.6%), with social networks being the least used according to parents family (1.3%). On the other hand, WhatsApp is the tool that helps students the most in understanding class content (29.9%), followed by YouTube (17.6%), Google Drive (16.7%) and Google doc. (7.9%), as presented in Figs. 1 and 2 respectively.

BEFORE THE COVID-19 PANDEMIC, THE TEACHER USED IN HER CLASSES:

WhatsApp (audio, imagen, video)
35%
30%
25%
20%
15%
10%
5%
0%

other
Email
Web page, Blog
Videoconferences (zoom, Google Meet, Microsoft Teams)
Youtube o Vimeo
Social networks (Facebook, Twitter, Instagram)
Image and video editors (Photoshop, Paint, illustrator
Ofimática (Word, Excel, power point)
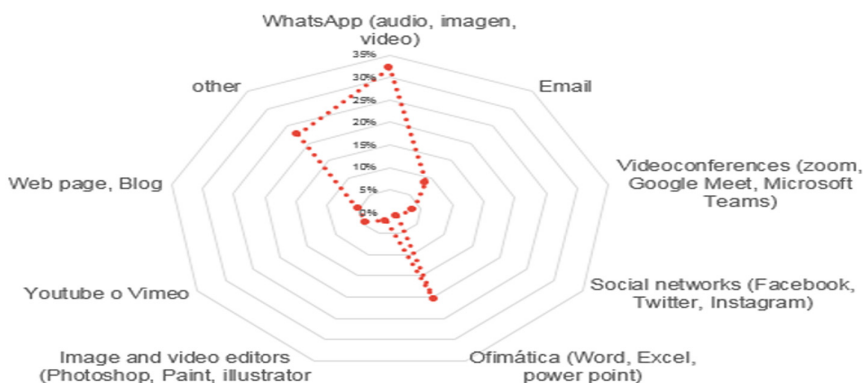
Fig. 1. The use of resources and tools used by the teacher before the pandemic.

WHAT ARE THE RESOURCES TO USE IN THE LEARNING SESSION TO HELP YOUR STUDENT TO UNDERSTAND OF THE CONTENT OF THE CLASS?

Mentimenter
30%
25%
20%
15%
10%
5%
0%

Others
Google doc
Adobe
Google drive
Google Jamboard
Quizziz
Blog
Kahoot
Facebook
Genially
Wiki
Neapord
Youtube
Whatsapp
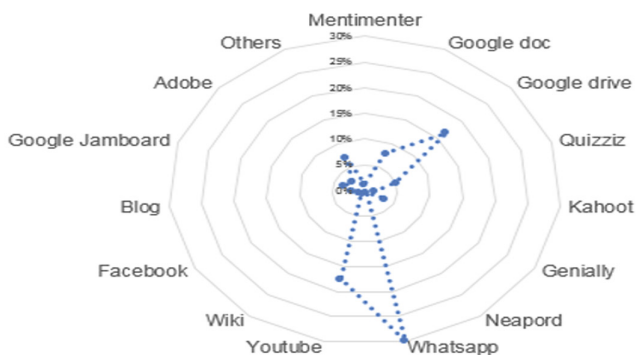
Fig. 2. Resources used by the teacher in her learning sessions.

In Fig. 3, we see the video conferencing tool that allows better interaction between the teacher and his students according to the parents, is the Zoom with a big difference (61.7%), followed by Google Meet (25.1%) and in smaller percentage WhatsApp (11.6%).
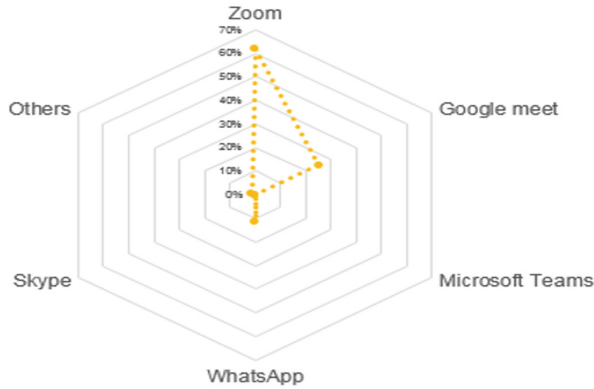
Fig. 3. Video conferencing tools used in the classroom.

4   Conclusions

The increase in the use of ICTs worldwide has been exponential in various areas of society, and with greater emphasis on all levels of education, because classes are now online because of the pandemic, both teachers and parents have had to change paradigms and innovate [31], since they are the calls to guide and guide students, for their part parents having moved from school to home and teachers because they must apply active methodologies mediated by technologies.

Innovation is an elementary element in education, since it allows us to recreate new forms of education mediated by technologies, appropriating the digital resources and tools that exist in the network [32].

The use of messaging resources has been increasing during the time of the pandemic, before it was used to a lesser extent, but in the course of the health crisis it has had a high level of use, as is the case with WhatsApp, which has been most widely used by teachers as a means of communication as indicated by parents in this study, and which is considered a collaborative tool [21, 23].

From the perspective of the surveyed parents, a good interaction between teachers and students has been carried out through the videoconference in Zoom [32, 33] and in a smaller proportion when using the Google Meet.

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Towards the Development of Serious Games Accessible for Users with Cognitive Disabilities

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Abstract. Nowadays, checking the ease of interaction with a serious game is a tremendous challenge for universal design and accessibility experts. Therefore, accessibility in this context means that people with intellectual disabilities can easily navigate and interact in a web application. Accessibility is an essential parameter to consider in each software development phase with the Web Content Accessibility Guidelines (WCAG) 2.1. As a case study, it was applied to the Ludominga platform. Accessibility experts defined 18 guidelines to evaluate ten serious games with a manual method. This research can serve as a reference for future work related to accessibility in serious web-based games.

Keywords: Accessibility · Assessment · Cognitive disability · Manual method · Serious games · WCAG 2.1

1 Introduction

Nowadays, checking the ease of interaction with a serious game is a significant challenge for experts in Universal design and accessibility. According to Article 2 of the United Nations Convention in 2006, universal design is defined as [1] "the design of products, environments, programs, and services that can be used by all people, to the greatest extent possible, without the need for adaptation or specialized design". It also specifies that specific designs are not excluded when personal circumstances so require. Therefore, accessibility in this context means that persons with intellectual disabilities [2] can easily use a computer application.

To generate user-friendly software, the W3C has established guidelines [3] used in the development of software. In this context, accessibility is an essential parameter to be considered in each phase of software development with the guidelines based on the Web Content Accessibility Guidelines (WCAG) 2.1 [3].

This study presents an evaluation of serious games to achieve a level of accessibility "AA." To solve this problem, we applied the accessibility guidelines based on the WCAG 2.1 with the principles: perceptible, operable, understandable, and robust [3] that allow us to design serious accessible games, especially for people with intellectual disabilities, as tools for the development of socio-cognitive skills for full inclusion. We consider that the policies and regulations for web accessibility should be teamwork between governments, academia, and the company to achieve more inclusive applications [4].

There are no automatic methods to evaluate serious games, so a combined method is proposed, using an automatic tool and manual evaluation. Its application allowed to measure the accessibility of the serious games of the LudoMinga platform. In the manual evaluation, the accessibility experts defined 18 guidelines based on WCAG 2.1 [3]. The manual method was applied to ten serious games. Two accessibility experts participated in the evaluation, who have several publications indexed in the area; a third expert was invited to solve disagreements between experts.

The method to be applied consists of seven phases: 1) select the serious games, 2) explore each serious game, 3) list the WCAG 2.1 guidelines, 4) define the types of users, 5) apply the combined method, 6) record the results, and 7) analyze the results.

When applying the combined method, we found that the "AA" level guidelines are met at an acceptable level. By applying the four accessibility principles of WCAG 2.1, it was possible to design more accessible and inclusive serious games. The combined method applied in this project can be applied to any serious game considering the guidelines for each disability. This research can serve as a reference for future work related to easy access in serious gaming.

The rest of the document is structured in the following way: in section two, we show the antecedents and previous works; in section three, we describe the methodology and the case study; in section four, we show the results and discussion, and finally, in section five, we incorporate our conclusions and future work.

2   Background and Related Work

The LudoMinga application is a web platform that includes serious games for mobile applications. The games are designed to develop social-cognitive skills and support learning and job training for people with intellectual disabilities.

We applied 18 guidelines based on the Web Content Accessibility Guidelines (WCAG) 2.1 to evaluate serious games. Besides, access levels of type: "A," "AA," and "AAA" were considered. Category "A" indicates a lack of compliance in terms of access, "AA" shows a satisfactory level and "AAA" shows a high level of accessibility. This study observes that the more criteria are met in serious games, the easier access to the application.

The WCAG 2.1 guidelines [3, 5] are composed of 4 principles, 13 guidelines, and 78 conformity criteria. The four principles consist of:

Principle 1: Perceptible - The user interface's information and components must be presented to users in a distinguishable manner. Principle 2: Operable - User interface components and navigation must be manageable. Principle 3: Understandable - Information and user interface handling must be clear. Principle 4: Robust - Content must

be strong enough to be trusted in its interpretation by a wide variety of user agents, including assistive technologies.

The 13 guidelines [3] consist of Guideline 1.1: Alternative Text: Provide alternative text for non-text content to be transformed into other formats that people need, such as large print, Braille, spoken language, symbols, or more straightforward language. Guideline 1.2: Time-Dependent Media Content: Provide synchronized alternatives for synchronized time-dependent media content. Guideline 1.3: Adaptive: Create content presented in different ways without losing information or structure. Guideline 1.4: Distinguishable: Make it easy for users to see and hear content, including distinction.

Guideline 2.1: Accessible Keyboard: Be able to control all functions from the keyboard. Guideline 2.2 Sufficient time: Provide sufficient time for users to read and use the content. Guideline 2.3: Epileptic seizures: Do not design content that can cause epileptic seizures. Guideline 2.4: Navigation: Provide ways to help users navigate, search for content, and determine where it is. Guideline 2.5: Input Modes: Facilitate users to operate functionality through various input methods in addition to the keyboard.

Guideline 3.1: Readability. Make text content readable and understandable. Guideline 3.2 Predictable: Make the appearance and use of web pages predictable. Guideline 3.3 Data entry assistance: Help users will avoid and correct errors.

Guideline 4.1 Compatible: Maximize compatibility with current and future user agents, including assistive technologies.

3   Method and Case Study

The evaluation of the accessibility in the serious games was made in the platform LudoMinga located in https://ludominga-aff09.firebaseapp.com/. A combined method [6, 7] was applied, described in Fig. 1(a), which consists of seven phases.

An accessibility evaluation template using the 18 guidelines based on WCAG 2.1 is used. The WAVE accessibility evaluation tool was also applied to evaluate the guidelines related to the contrast of serious games.
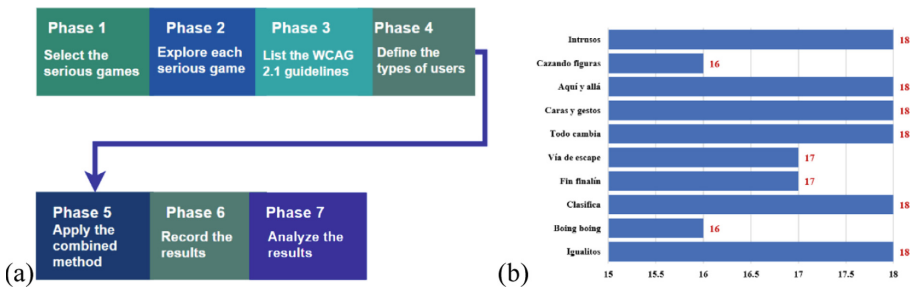
Fig. 1.   (a) Combined method to assess accessibility in serious games. (b) Results of the evaluation of the games evaluated.

Phase 1: Select the serious games; in this phase, the ten serious games to evaluate were selected. Table 1 presents a list of the games to evaluate, contains the serious game's name, and the 18 accessibility guidelines based on WCAG 2.1.

Phase 2: Explore each serious game; in this phase, each option on the serious game screens related to socio-cognitive skills was explored.

Table 1. Assessing the accessibility of serious games and manual evaluation

Serious games	G01	G02	G03	G04	G05	G06	G07	G08	G09	G10	G11	G12	G13	G14	G15	G16	G17	G18
Igualitos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Boing boing	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Clasifica	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Fin finalín	1	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Vía de escape	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Todo cambia	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Caras y gestos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Aquí y allá	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Cazando figuras	1	0	1	1	1	1	1	1	1	1	1	0	1	1	1	1	1	1
Intrusos	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1

Figure 2 presents the primary interfaces associated with serious gaming.

(a)   (b)
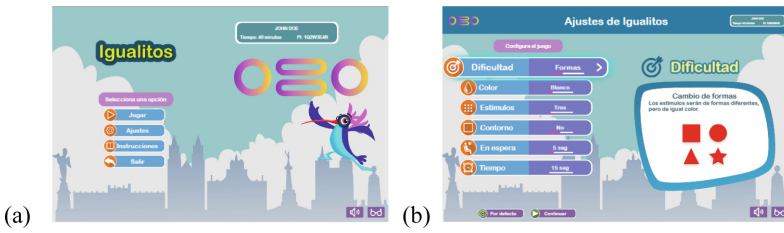
Fig. 2. Interfaces (a) Main screen. (b) Settings interface.

Phase 3: List the WCAG 2.1 guidelines; the 18 parameters based on WCAG 2.1 applied in evaluating serious games were defined. Table 2 contains the code, the guideline's name, the accessibility principles, according to WCAG 2.1, the success criteria, and the level.

Phase 4: Define the types of users; previous studies [2] of the population with intellectual disabilities associated with one or more disabilities (hearing, physical, psychosocial, and visual) were considered. Besides, health problems and the combined presence of some conditions and syndromes are observed in FINE users, including language restrictions, cerebral palsy, epilepsy, scoliosis, autism spectrum disorder, positional back pain, behavior disorders, transient hypotension, muscular dystrophy, Robinow syndrome, and Apert syndrome.

Phase 5: Apply the combined method; In this phase, the two accessibility experts evaluated the serious games' interfaces in Table 1; when there were discrepancies between them, the collaboration of an invited expert was requested. The applied method was a combination of an automated tool and manual review [8, 9].

In the evaluation, the categories that met one (1) and those that did not meet the parameters with zero (0). The data is available in the Mendeley repository[1] for review and replication of the experiment.

Phase 6: Record the results; in this phase, the evaluation values are recorded in a spreadsheet. Table 1 presents the data record of the evaluation of accessibility in serious games. It contains the serious game's name and the 18 guidelines related to intellectual disability characterized by FINE users.

Phase 7: Analyze the results; Fig. 1(b) shows the total results of the evaluated games; in this phase, it was observed that all the games comply with 60% of the guidelines.

4   Results and Discussion

Table 2 shows the accumulated results of all the serious games evaluated according to the fulfillment of the guidelines defined in WCAG 2.1. Table 2 contains the code assigned to the guideline, the guideline's name, the WCAG 2.1 accessibility principles, success criteria, the level of accessibility, and the total accumulated value.

Table 2. Accessibility guidelines based on WCAG 2.1

ID	Guidelines	WCAG 2.1 principles	Success criteria	Level	Total
G01	Accessible keyboard	Operable	2.1.1	A	10
G02	Luminance flare faults	Operable	2.3.1	A	7
G03	Animation of interactions	Operable	2.3.3	AAA	10
G04	Easy to read font	Perceptible	1.1.1	A	10
G05	Text alternatives	Perceptible	1.1.1	A	10
G06	Subtitled	Perceptible	1.2.4	AA	10
G07	Information and relationships	Perceptible	1.3.1	A	10
G08	Sensory characteristics	Perceptible	1.3.1	A	10
G09	Adjust display settings	Perceptible	1.3.4	AA	10
G10	Use of color	Perceptible	1.4.1	A	10
G11	Well-spaced elements	Perceptible	1.4.12	A	10
G12	Good audio techniques	Perceptible	1.4.2	A	7
G13	Images as sharp as possible	Perceptible	1.4.5	AA	10
G14	Visual presentation	Perceptible	1.4.8	AAA	10
G15	Pause, stop, hide	Perceptible	2.2.2	A	10
G16	Consistent navigation	Robust	4.1.3	AA	10
G17	Labels or instructions	Understandable	3.3.2	A	10
G18	Help	Understandable	3.3.5	AAA	10

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[1] http://dx.doi.org/10.17632/sd8zppdtdj.1.

Figure 3(a) shows the accessibility principles of serious games, where 67.2% correspond to perceptible, 15.5% to operable, 11.5% to understandable, and 5.7% to robust. We can conclude that serious games have much force concerning the perceptible principle. Figure 3(b) shows the accessibility levels of LudoMinga, where 59.8% correspond to level A, 23.0% to AA, and 17.2 to AAA. We can conclude that serious games have much strength with level A.
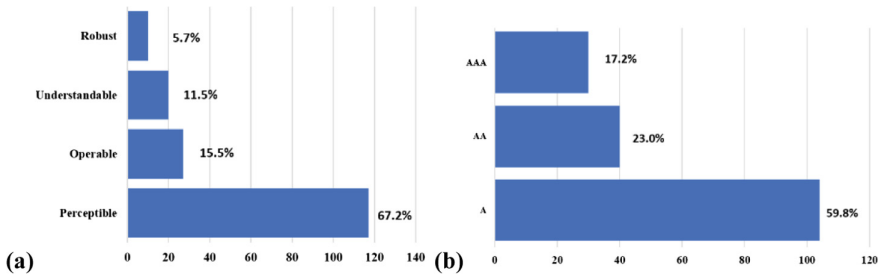
Fig. 3. (a) Accessibility principles applied in LudoMinga. (b) Accessibility levels applied in LudoMinga.

5   Conclusions and Future Works

In this research, the 18 guidelines related to intellectual disability were applied. It was observed that the guidelines related to the "AA" level comply with 23% reaching an acceptable level. By applying the four accessibility principles of WCAG 2.1, it was possible to design more accessible and inclusive serious games. The combined method applied in this project can be applied to any serious game considering the guidelines for each disability. This research can serve as a reference for future work related to easy access in serious games. Finally, we suggest including two options to improve accessibility levels for users with different types of disabilities: 1) Language; this option will allow access to a more significant number of users regardless of language, in such a way that the serious game is multilanguage. 2) Sign Language; this option will help people with disabilities to communicate effectively while learning to perfect spoken sounds.

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Towards Accessibility Assessment with a Combined Approach for Native Mobile Applications

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Abstract. According to the Global Digital Report of 2020, mobile applications have increased significantly in recent years; more than 5.19 billion people use cell phones, with many users up to 124 million compared to 2019. There are thousands of mobile apps for education, health, business, economy, banking, each with its style and form. However, not all applications meet the standardization requirements proposed by the World Wide Web Consortium, which sets standards for applications or products to have an acceptable level of access and structure. This investigation got as a case study the accessibility problems of six mobile applications most used in 2020. In the accessibility assessment, we apply a combined method that performs automatic review with Accessibility Scanner and manual accessibility review. This research can contribute to future studies related to accessibility in native mobile applications.

Keywords: Accessibility · Assessment · Combined approach · Mobile application · WCAG 2.1

1 Introduction

Accessibility is identified as the ease of access to a product or service. We recommend applying the Web Content Accessibility Guidelines 2.1 [1] and 2.2 [2] to achieve adequate access. To make accessible, the content of mobile applications, in this research, the four principles of accessibility were applied 1) Perceptible to identify information

and user interface components. 2) Operable related to the user's interface and application to interact and navigate easily 3) Understandable related to the information and operations users perform with the mobile application. 4) Robust so that it can support the technologies that users use, including assistive technologies.

In the accessibility evaluation, we apply a combined method consisting of seven phases to achieve a greater accessibility level: 1) Select the applications. According to Google Play Store, we selected the six most used applications in 2020. 2) Explore each application; in this stage, we interact with each of the selected applications. 3) Define the test scenario; we define the activities to be performed in each of the selected applications in this stage. 4) Establish the barriers based on WCAG 2.1; in this stage, we list several accessibility issues and relate them to the WCAG 2.1 guidelines. 5) Define the users according to the barriers; we define the users' accessibility barriers in this stage. 6) Apply the combined method; in this phase, we apply an automatic method with Accessibility Scanner and a manual to review each selected application. 7) Register and analyze the data; finally, in this stage, we register the data in an open-access dataset to analyze the results and suggest improvements.

This research can contribute to 1) Future studies related to accessibility in mobile applications. 2) Design a software application that helps experts evaluate accessibility in mobile applications with WCAG 2.1. 3) Disseminate the guidelines with the combined method so that developers of mobile applications can apply them to all products to make them more inclusive and accessible.

The rest of the article is structured as follows: in Sect. 2, we show the background; in Sect. 3, we define the methodology and the case study; in Sect. 4, we show the results and the discussion; and finally, in Sect. 5, we tend to incorporate our conclusions and propose future analyzes.

2   Background and Related Work

Nowadays, there are several mobile applications; in our daily lives, they are valuable for ordering a cab, knowing the traffic conditions in any city in real-time, ordering food delivery, taking and editing photographs. We also enjoy playing games, and we can check and write our emails while looking up the dictionary to clarify our grammatical doubts.

In this research, we consider the evaluation of accessibility in six mobile applications most used in 2020 according to the PCWorld site[1]. The Web Accessibility Initiative [3] states that "mobile accessibility" refers to making applications more accessible to people with disabilities when using cell phones and other devices.

Jabangwe et al. [4] indicate that a mobile application is software depending on the technologies involved: native, web, or hybrid. Mobile applications are created for use on smart mobile devices or tablets.

The study [5] on the development of accessible mobile applications applied to the "Crossfit Coyote Fitness" sports center argues that accessibility in mobile applications was evaluated with WCAG 2.1 during the entire development cycle in which accessibility

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[1] https://www.pcworld.es/.

barriers for users with low vision were corrected. The study contributes to future studies related to accessibility methods for more inclusive mobile applications.

The study [6] applied the accessibility assessment to ten mobile applications according to PCMAG, used WCAG 2.1 all through manual review and automatic review. Concludes that applications are not very accessible, the research proposes suggestions to improve and raise awareness among mobile application designers.

Besides, Acosta-Vargas et al. [7] evaluated the accessibility of mobile apps for air quality with the Accessibility Scanner tool. Undoubtedly, mobile devices have many free applications, but not all of those mobile applications are accessible. The study proposes to use the Google Accessibility Scanner, applying the Web Content Accessibility Guidelines 2.1.

The studies [8, 9] point to the evaluation of serious educational games that can be applied in any software application, including mobile applications; the study suggests applying a combined method based on WCAG 2.1 that relates the accessibility barriers with the characterization of the disability of users in such a way that more inclusive and accessible applications are achieved.

3   Method and Case Study

As a case study, we evaluated six mobile apps of the best Android apps of 2020 taken from the PCWorld site, summarized in Table 1 contains the assigned identifier, the name of the mobile application, the logo, the updated date, the company that offers the application, the number of downloads and the type of application.

Table 1. Summary of evaluated mobile applications.

Id	App	Logo	Updated	Offered by	Download	Application type
A	WhatsApp		December 4, 2020	WhatsApp Inc.	5.000.000.000+	Messenger service
B	Telegram		January 1, 2021	Telegram FZ-LLC	500.000.000+	Messenger service
C	Facebook		January 15, 2021	Facebook	5.000.000.000+	Social networks
D	Teams		January 15, 2021	Microsoft Corporation	100.000.000+	Communication and collaboration
E	Snapseed		April 14, 2020	Google LLC	100.000.000+	Photos
F	Instagram		January 14, 2021	Instagram	1.000.000.000+	Photos

In this study, we applied a combined automatic review method with Accessibility Scanner and a manual review based on the WCAG 2.1 guidelines that apply the four principles of accessibility. The applied method includes seven phases and is summarized in Fig. 1.

Phase 1: Randomly select mobile apps; in this phase, we randomly select six mobile applications described in Table 1. The applications were selected from the PCWorld site. They were installed from the Google Play Store; as a reference, we took the number of downloads and the most current version.
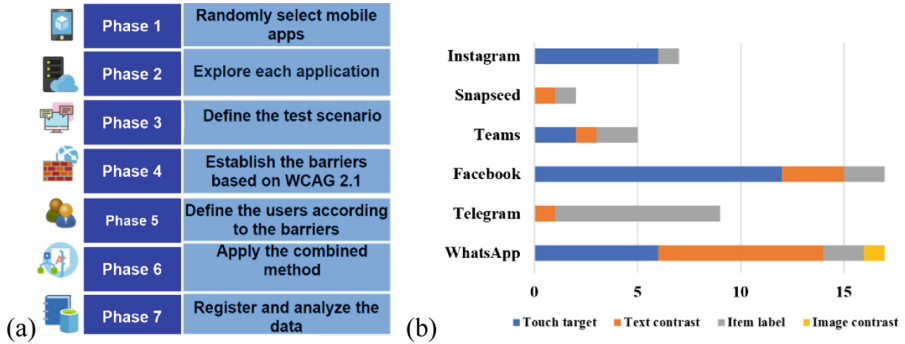
Fig. 1. (a) Combined method to evaluate accessibility in a mobile application. (b) Evaluation of mobile applications with Accessibility Scanner.

Phase 2: Explore each application; in this phase, we explore, navigate and interact with each of the randomly selected mobile applications.

Phase 3: Define the test scenario; in this phase, we define the activities and tasks that users must carry out in each of the evaluated mobile applications.

Phase 4: Establish the barriers based on WCAG 2.1; define the list of accessibility barriers based on the four accessibility principles of WCAG 2.1, which contains 14 guidelines detailed in Table 2.

Table 2. List accessibility barriers.

Barrier	Principle	Level
1.4.3 Contrast (Minimum)	Perceivable	AA
1.4.4 Resize text	Perceivable	AA
1.4.6 Contrast (Enhanced)	Perceivable	AAA
2.1.1 Keyboard	Operable	A
2.1.2 No Keyboard Trap	Operable	A
2.4.3 Focus Order	Operable	A
2.4.4 Link Purpose (In Context)	Operable	A
2.4.7 Focus Visible	Operable	AA
2.4.9 Link Purpose (Link Only)	Operable	AA
3.2.3 Consistent Navigation	Understandable	AA

(*continued*)

Table 2. (*continued*)

Barrier	Principle	Level
3.2.4 Consistent Identification	Understandable	AA
3.3.2 Labels or Instructions	Understandable	A
3.3.5 Help	Understandable	AAA
4.1.3 Status Messages	Robust	AA

Phase 5: Define the users according to the barriers; in this phase, we select users with visual impairment, the principle that is most related to this type of disability is the perceptible one.

Phase 6: Apply the combined method; this is the essential phase of the method; we apply for the automatic review with Google Accessibility Scanner, and then we review each guideline manually in such a way that each screen of the mobile application is more accessible and inclusive.

Phase 7: Register and analyze the data; in this phase, we record the evaluation data with the Google Accessibility Scanner tool and the manual evaluation. The data set for the replication of the experiment and the analysis are available in the Mendeley repository[2].

4   Results and Discussion

Table 3 contains the data of the mobile applications' evaluation with Accessibility Scanner presents the application with the evaluated parameters such as # Elements, Touch target, Text contrast, Item label, and Image contrast.

Table 3. Evaluation with accessibility scanner.

Application	# Elements	Touch target	Text contrast	Item label	Image contrast
WhatsApp	17	6	8	2	1
Telegram	9	0	1	8	0
Facebook	17	12	3	2	0
Teams	5	2	1	2	0
Snapseed	2	0	1	1	0
Instagram	7	6	0	1	0

Table 4 contains the applications' manual evaluation data; it shows the criteria, the guideline, and the level of the evaluated applications.

Table 4. Manual evaluation.

Criterion	Guideline	Level	WhatsApp	Telegram	Facebook	Teams	Snapseed	Instagram
1.4.4	Resize text	AA	0	0	1	1	0	0
1.4.3	Contrast (Minimum)	AA	1	1	1	1	1	1
1.4.6	Contrast (Enhanced)	AAA	0	0	0	1	0	0
2.1.1	Keyboard	A	0	0	1	1	0	0
2.1.2	No Keyboard Trap	A	0	0	1	1	0	0
2.4.3	Focus Order	A	1	1	1	1	1	1
2.4.4	Link Purpose (In Context)	A	1	1	1	1	1	1
2.4.7	Focus Visible	AA	0	0	1	1	0	0
2.4.9	Link Purpose (Link Only)	AA	0	0	1	1	0	0
3.2.3	Consistent Navigation	AA	1	1	1	1	1	1
3.2.4	Consistent Identification	AA	1	1	1	1	0	0
3.3.2	Labels or Instructions	A	1	1	1	1	1	1
3.3.5	Help	AAA	1	1	1	1	1	1
4.1.3	Status Messages	AA	1	1	1	1	0	0

Figure 1(b) shows that the applications evaluated with Accessibility Scanner present 26 touch target errors, representing 45.6%, followed by text contrast with 14 errors, corresponding to 24.6%. Item label with 16, representing 28.1%, and finally, one image contrast error, representing 1.8% of the total errors found.

Figure 2(a) the understandable principle presents 22 errors, representing 40.0%, followed by operable with 20, corresponding to 7.3%, then perceivable with nine, corresponding to 16.4%, and finally, robust with four errors, representing 36.4% of the total.

Figure 2(b) the level with the most errors corresponds to AA with 26, representing 47.3% followed by A with 22, corresponding to 40.0%, finally, AAA with seven errors, representing 12.7% of the total, according to the data the evaluated mobile applications do not comply with an adequate level of accessibility which must comply with at least level AA.
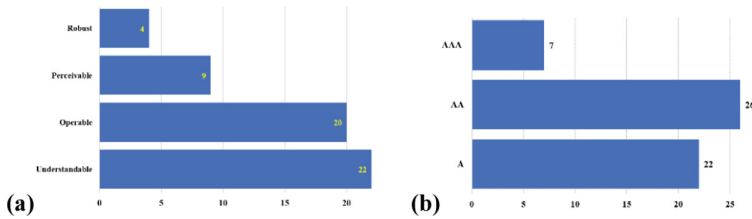
Fig. 2. (a) Accessibility principles. (b) Accessibility levels.

5   Conclusions and Future Works

One of the advantages of Android is that it presents multiple hardware options so that the user can choose the most accessible device. Android allows solving vision and hearing needs with the accessibility option. Among the accessibility configuration options in Android, you can 1) control people's brightness level with photosensitivity issues. 2) The font size and contrast. 3) With the TalkBack tool, the accessibility service allows blind or visually impaired users to interact with devices more easily. The combined method applied in this study has its limitations; it depends on the experience of accessibility experts. This research can serve as a reference for future studies related to combined methods of accessibility in mobile applications to achieve more inclusive applications. The method can be improved through heuristic methods that allow replicating the process with different users, taking into account the various accessibility barriers. We believe that in the future, browsers are essential before mobile applications, so browsers should include WCAG 2.1 in their options so that all applications are accessible and inclusive.

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Challenges of Web Accessibility in a Health Application to Predict Neonatal Mortality – The Score Bebe ®

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Abstract. We are currently experiencing the first global pandemic in the digital age due to the COVID-19 disease, caused by the SARS-CoV-2 virus. As we try to protect ourselves with isolation and social distancing measures, the digital tools for connecting with the world become more critical. Newborn health care, a critical public health problem everywhere, has been severely affected by the pandemic. Therefore, web-based tools could be an alternative to improve newborn care. For these reasons, we believe that web applications should have accessibility standards. To predict neonatal mortality, we have designed the web application - The Score Bebe ® - considering the Web Content Accessibility Guidelines (WCAG) 2.1. These accessibility studies will make it possible to contribute to more inclusive access for all people, including people with disabilities. It will also improve the web's visibility in search engines and reuse the content in multiple formats or devices.

Keywords: Accessibility · Assessment · Health · Neonatal mortality · The Score Bebe · Web · WCAG 2.1

1 Introduction

The COVID-19 pandemic is revolutionizing society and our life, getting us to apply social distancing to avoid contagion, but for this, we force ourselves to be confined. This crisis teaches us to live online through the web, whether to work, buy, or access the most basic services such as education and health. This shift towards digital is here to stay, as this crisis is making us change our lifestyle habits.

It is difficult for many people - or even impossible - to interact with the website or a mobile application. The prevalence of different disabilities increases in older adults and impacts the use of a computer or mobile device, so a new urgency is growing: accessibility on the web. Without a doubt, this situation is further proof of the importance of the accessibility of technology. Nevertheless, most of the existing platforms do not have accessibility tools incorporated. Thousands of people will be isolated due to Internet barriers, as they do not have access to or adapted websites.

Health care requires emerging technologies to cope with the pandemic and health care for the risk of infection, especially for those vulnerable groups. Newborn health care, an essential public health problem everywhere, has been severely affected by the pandemic. Therefore, web-based tools could be an alternative for improving newborn care.

According to the UNICEF [1], it indicates that under-five mortality rates have decreased by almost 60% since 1990; however, the impact of the COVID-19 pandemic threatens years of improvement in children's survival through the interruption of health services. Although mortality rates have continued to decline, more than 5 million children died before their fifth birthday, and almost half of those deaths occurred in newborns up to about 28 days of age, which is a problem of public health. Specifically in Ecuador, the newborn mortality rate has been raised from 4.6 to 6.0 per 1000 live births in the last six years [2]; therefore, new policies and clinical guidelines towards significant improvement in newborn care are urgently needed. The Score Bebe ® was developed and validated as a tool to facilitate nurses and physicians in assessing newborn risk [3].

Accessibility aims to make applications usable by the most significant number of people, regardless of their knowledge or personal abilities and regardless of the technical characteristics of the equipment used to access the web.

To evaluate the web application's accessibility, we used the [4] Web Accessibility Evaluation Tool (WAVE) evaluation tool, version 3.1.2, updated October 16, 2020, which applies the four WCAG 2.1 accessibility principles.

In evaluating the application's web accessibility, we used the following review method, which consists of six phases: 1) Select a random sample of five screens from the application. 2) Define the test scenario. 3) Run the web evaluation tool. 4) Record the results. 5) Analyze the results. 6) Propose improvements for the accessible web application. The results of this web accessibility evaluation will help to refine the accessible and inclusive design of the Score Bebé ® and, potentially, any health-related web application. These accessibility studies allow improving access to the contents Web to all the people, including people with disabilities. On the other hand, it will improve search engine results and reuse content through multiple formats or devices.

The rest of the document is structured in the following way: in section two, we show the antecedents and previous works; In section three, we describe the methodology and the case study the Score Bebé ®; in section four, we show the results and discussion, and finally, in section five, we incorporate our conclusions and future work.

2 Background and Related Work

According to Google Trends, Fig. 1 shows that in the last five years when comparing the terms of "Web applications", "Newborn health" and "WCAG 2.1" it tends to grow as of

2019, specifically in November 2019 the term that tends to grow is "Newborn health" followed by "WCAG 2.1" and "WCAG 2.1". The growing use of the web [5] and mobile applications for doctors and patients in health care causes a real revolution in the sector.

The development of applications for doctors and hospitals has transformed and improved many aspects of clinical practice. From viewing a patient's lab results to monitoring vital signs, these tools support the medical field in diagnosing, monitoring, and treating disease.
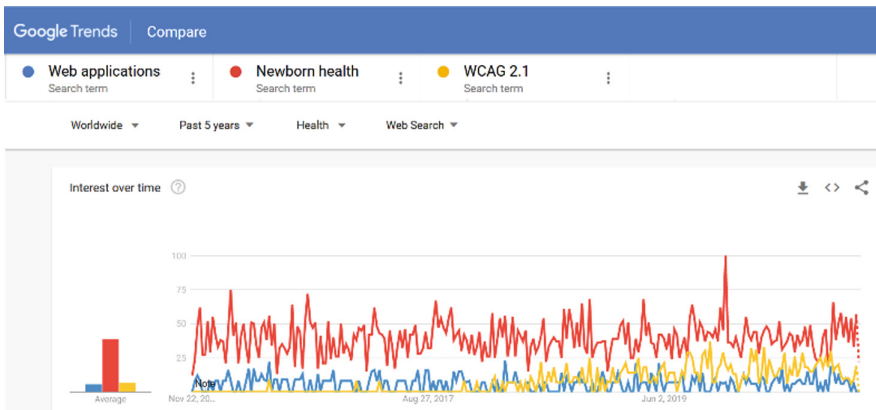
Fig. 1. The trend in web applications related to newborn health.

One of the main motivations in using these web and mobile applications for the medical area is to cover the need to access the patients' health information and facilitate the decision-making process for risk-stratified clinical management. Web projects focused on technology applied to health must be designed considering aspects such as web browsing. An important parameter is web accessibility, which must be present from the beginning of the application development to ensure success and much more in a field as important as health.

Web accessibility [6, 7] aims to make web pages usable by the maximum number of people, regardless of their knowledge, personal abilities, and the assistive technologies used. In other words, any application designed for the web is universal and accessible by any person, mainly if web users work in stressful environments like hospitals or primary health care centers.

Depending on the research topic, we found studies on accessibility in health applications that have been carried out. The study [5] indicates that the trend in eHealth is to digitize the services associated with health care, each time the users who access these services are people with disabilities, taking into account that doctors and nurses will use the Bebe score, the issue of accessibility is essential in web applications. Web accessibility problems create exclusion barriers. The study describes the web accessibility problems identified in 22 hospital websites according to the Webometrics ranking. Due to the barriers encountered, the study suggests the need to strengthen legislation and implement best web accessibility practices with WCAG 2.0. Websites are inclusive, making content accessible to all users, including people with disabilities.

According to the World Health Organization, the study [6] indicates that 15% of the world's population has some disability. There are many patient care websites, but not all are accessible, even for healthcare workers. The study indicates that it is necessary to develop accessible websites for health services that comply with the Web Content Accessibility Guidelines 2.1. The research proposes an evaluation method to measure the accessibility of health-related web applications.

Research [8] addresses population growth and the increase in non-communicable diseases represent a challenge for society, especially for the health system, including palliative care. Keeping sites accessible is essential for all types of people to interact on the web. To solve this need, we propose designing a website in the palliative care area, applying standards based on the Web Content Accessibility Guidelines 2.1, so that the largest number of people can access it. Research results can provide a reference for the construction of more inclusive health websites.

The study [9] notes that several websites and mobile content are inaccessible to people with visual, hearing, and cognitive disabilities. The COVID-19 pandemic highlighted these problems of access to information on the website of health authorities. For which they indicate that the Web Content Accessibility Guidelines (WCAG) provide the accessibility of websites. The results indicate that there are countries with inaccessible websites for people with disabilities. Government health websites can be considered the most trusted sources of preventive health information and accessible to everyone, regardless of ability.

In this study, to achieve adequate access, we recommend applying the Web Content Accessibility Guidelines 2.1 [10] and 2.2 [11]. A web application is currently being developed in Ecuador to predict, stratify, and clinically manage the neonatal risk of mortality. For these reasons, we believe that web applications should have accessibility standards. Given the importance of accessibility to health care professionals to web-based tools, even in rural contexts with low internet accessibility, we will evaluate web accessibility in a health application to predict neonatal mortality [12] – The Score Bebe ® – considering WCAG 2.1.

These guidelines detail how web content should be worked on to be more accessible, especially for people with disabilities. WCAG 2.1 considers the four principles of accessibility perceptible, operable, understandable, and robust. It also includes three levels of accessibility: Level A, when it meets minimum accessibility standards. Level AA is an intermediate level of accessibility and complies with level A. Level AAA is the highest level of accessibility when it complies with levels A and AA.

3 Method and Case Study

As a case study, we have evaluated five screens from the Score Bebe website, located at https://scorebebe.com/. Table 1 contains the identifier assigned to the screen, the screen name, and the description.

Table 1. Description of the "Score Bebe" screens.

ID	Screen	Description
A	Homepage	Score Bebe main page
B	Login	Login with authentication to Score Bebe
C	Test	Indications for the test
D	Form 1	Contains the initial part of the test
E	Form 2	Contains part two of the test

The method applied in the evaluation of the accessibility of Score Bebe comprises six phases described in Fig. 2.

Phase 1	Phase 2	Phase 3	Phase 4	Phase 5	Phase 6
Select a random sample	Define the test scenario	Run the web evaluation tool	Record the results	Analyze the results	Propose improvements
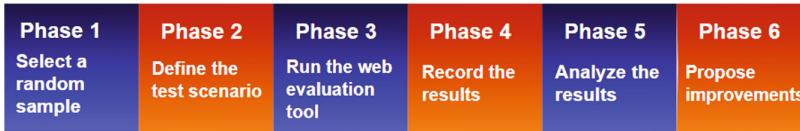
Fig. 2. Method to evaluate accessibility in the Score Bebe

Phase 1: Select a random sample; in this phase, we randomly select five "Score Bebe" screens, detailed in Table 1.

Phase 2: Define the test scenario; in this phase, we define the expert's activities on each screen during the evaluation process.

Phase 3: Run the web evaluation tool; in this phase, we apply the WAVE tool that includes a browser plug-in component, in this case, Google Chrome, which allows us to evaluate the applications that contain authentication easily. Provides visual information on the accessibility of web content, enabling secure evaluation of the intranet, password-protected local web applications, and other sensitive web applications.

Phase 4: Record the results; the automatic evaluation results with WAVE are recorded in a spreadsheet, the same available in the Mendeley repository[1] for its review and replication of the experiment.

Phase 5: Analyze the results; in this phase, the analysis of the data obtained is carried out, indicating the detailed findings in greater depth in the results and discussion section.

Phase 6: Propose improvements; in this phase, some recommendations are presented to achieve a level of AA accessibility in Score Bebe considering WCAG 2.1, with more detail, we present in the results and discussion section.

4   Results and Discussion

Table 2 contains the results of the evaluation of the five Score Bebe screens evaluated with the WAVE.

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[1] http://dx.doi.org/10.17632/v9xbtfywpb.1.

Table 2. Evaluation of the accessibility of Score Bebe.

ID	Errors	Alerts	Structural elements	Contrast errors	Features	ARIA	Missing alternative text	Missing form label	Very low contrast	Empty button
A	0	3	0	0	1	0				
B	2	3	2	3	2	2	1	1	3	
C	1	3	2	5	1	0		1	5	
D	8	5	2	17	1	6		7	17	1
E	0	3	4	6	14	0			6	
Total	**12**	**20**	**11**	**33**	**19**	**9**	**1**	**10**	**33**	**1**

Figure 3 shows that the most accessible screen corresponds to the Homepage with cero (0) errors, followed by Login and in third place on the Test screen. Accessibility barriers are presented to a greater degree for contrast problems; errors can be solved using tools that help improve the contrast between the text and the background color. The success criterion 1.1.1 related to Non-textual content, represents 18.2% and 1.4.3 related to Contrast (Minimum), corresponding to 81.8%. Contrast problems can be corrected with tools such as the Color Contrast Analyzer[2] (CCA), which allows you to determine the legibility of text and contrast visual elements. Includes 1) WCAG 2.1 compliance indicators; 2) raw text input, RGB sliders, color picker; 3) support for alpha transparency in foreground colors. 4) color-blind simulator. On the other hand, the AIM Web site offers a simple but effective means to validate the contrast between colors according to the recommendations of WCAG 2.1. Allows to select colors visually from the palette or use RGB notation.
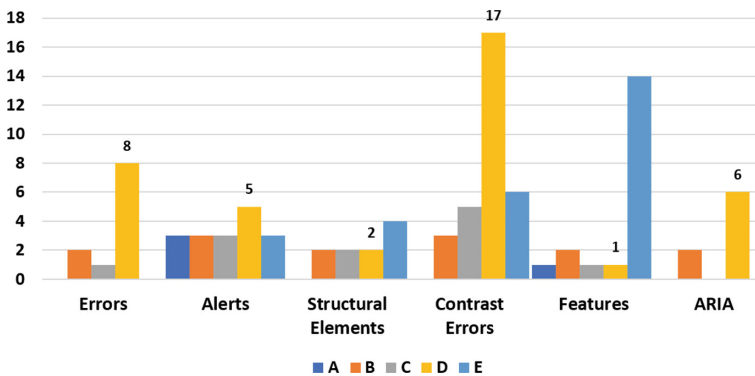
Fig. 3. Evaluation of the accessibility of Score Bebe

Of the errors found, the following stand out 1) Failure to include the alternative text for the images; this error can be corrected by placing a text in the "alt" attribute describing the function of the image or indicating whether it is decorative. Failure to provide suitable alternatives renders the content inaccessible. 2) Problems related to contrast can be corrected during the tool development process using applications that help the developer test the background and font contrast. The recommended solution is based on trying to darken the background image, creating a translucent layer with CSS somewhat opaque to give a more significant contrast effect to the text.

5   Conclusions and Future Works

Score Bebe ® is a web-based application with proper standards of accessibility for healthcare workers, but some fields require improvement. We suggest applying for the review with automatic tools. They are helpful for experts and non-experts in web accessibility. To achieve a higher level of accessibility, we can apply a combined method [13] and a heuristic method [14] that adds automatic and manual review tools. The manual review would help detect barriers that cannot be detected with the tool. This research can contribute to studies of any website that wishes to evaluate accessibility with the WCAG 2.1 guidelines. We suggest that accessibility is considered an essential parameter in each country's policies, even more so when technological tools are essential to developing various activities, including virtual access to health and control systems. As future work, we suggest carrying out accessibility evaluations of the web platform with users with different disabilities to test the application's functionality.

Furthermore, we suggest including a mobile application that considers the WCAG 2.1 standards up to the AA level of accessibility accepted in most countries' legislation.

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Usability Inspection of a Serious Game to Stimulate Cognitive Skills

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Abstract. When creating user interfaces, usability considerations are important to ensure the target population an efficient and effective user experience. For this reason, recommendations are proposed for a preliminary prototype of a serious gaming application called HabCog, which consists of a collection of minigames designed for monitoring and evaluating certain cognitive abilities in users. The target population consists of adults with intellectual disabilities who use the services of the FINE Foundation, whose objective is to develop skills and abilities for full inclusion. According to the results, usability recommendations are provided so that the application is better adapted to the target population.

Keywords: Usability · Heuristic evaluation · Serious game · Cognitive abilities · HabCog

1 Introduction

The inclusion in the labor market of people with intellectual disabilities is one of the main concerns of modern societies. Governments and civil society organizations make efforts to improve the living conditions of people with intellectual disabilities. When creating user interfaces, usability considerations are important to ensure the target population an efficient and effective user experience. This document summarizes the heuristic evaluation of the preliminary prototype of the HabCog application that consists of a collection of minigames to stimulate the cognitive abilities of attention, perception, and memory for global or specific training. The HabCog development process is carried out at the isEASY Laboratory of the "Universidad Politécnica Nacional" from Quito - Ecuador, making use of the iPlus serious game design methodology [1]. At the same time, the

refinement of the interface is driven by a collaborative user-centered methodology [2], where user interfaces are considered one of the essential elements.

Both the usability evaluation and the recommendations consider the needs and requirements of people with intellectual disabilities who use the services provided by the FINE Foundation, whose objective is to develop skills and capacities for the full inclusion of this group. To analyze the application, three independent experts carried out a set of three heuristic evaluations based on a revised set of usability heuristics to evaluate interactive systems [3]. The results of carrying out the heuristic evaluation to evaluate the usability of the application have made it possible to formulate a series of recommendations that could be applied to improve the functionality and user interface of the application in development and thus allow it to better adapt to the target population.

The document is organized into five sections: the next section reviews some work related about the most know serious game for stimulate cognitive skills. Also, this section presents some related work to useful to conducting heuristic inspections. Third section presents all the details of the usability inspection experiment. This section summarizes the technological needs of the target population. Likewise, also, the HabCog application and the objectives to apply a heuristic usability analysis as a case study are described. Then, we present a description of the heuristic analysis protocol and the results obtained. The fourth section presents the discussions about the results. We continue with the description of some of the new interfaces designed based on the recommendations. The fourth section concludes the document by summarizing the findings of the experiment and discussing future efforts.

2   Related Work

2.1   Serious Game for Stimulate Cognitive Skills

Nowadays, serious games (SGs) are considered a new alternative in the game-based learning. Serious games (SGs) are widely used as a tool that enables learning and the development of student skill [4, 5]. [6], states that SGs provide entertaining and self-empowering that motivates students. They also allow the development of creativity, intellectual competence, emotional strength, and personal stability. SGs promote learning in academic settings [7]. SGs can have several purposes, among which the development of training skills can be highlighted [8]. Teaching and assessment of generic competences has been studied by [9], considering aspects such as entrepreneurship and problem solving, where learning scenarios and situations are defined.

2.2   Usability Inspection Methods

Usability inspection methods, based on heuristic metrics, are useful to evaluate the early design of an application. The most known usability heuristic metrics are the 10 usability heuristics of [10]. Subsequently, these heuristics have been extended together with ergonomic criteria [11]. More recently, Pribeanu [3] presents a set of heuristics categorized into 4 ergonomic principles, such as a focus on the end-user, control and freedom of the user, user effort, and user support. The usability inspection, the object of this work, makes use of the Pribeanu heuristics for considering them more wholly categorized.
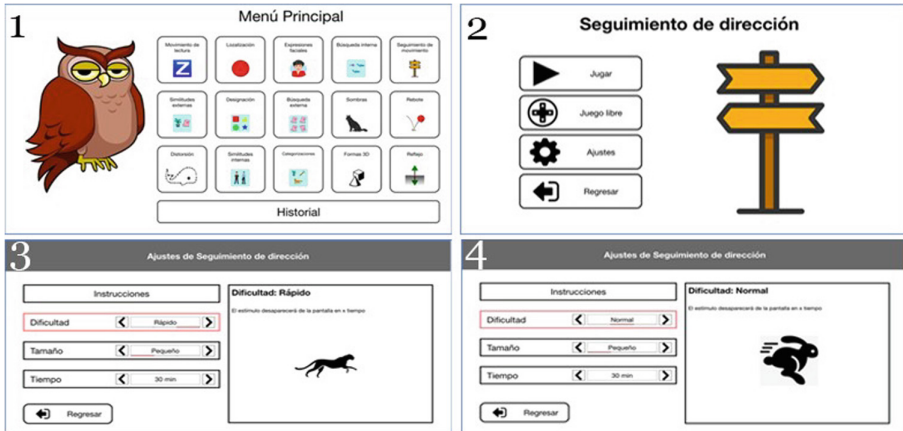
Fig. 1. Scenario: Change the difficulty of the minigame: Direction Following.

3   The Experiment

3.1   The Technological Needs of the Target Population

In previous works, the details of the process and the results of characterizing the target population were reported [12]. The 35 users of FINE services constitute a population with associated or multiple disabilities that involves not only the sum of the types of disability but the interaction of singularities, characteristics, and identities that make the condition of disability more complex.

Age-related variables are considered, as well as the association with health factors and severity. Besides, health problems and the combined presence of some conditions and syndromes, the most common are mentioned: Language and verbal expression restrictions, Difficulties in understanding/decoding, Cerebral Palsy, Epilepsy, Scoliosis, Autism Spectrum Disorder-ASD, Behavioral Disorders, Muscular Dystrophy, and others. The analysis of the use of technology and use of devices results in the need to incorporate the following requirements:

1. Scanning and image zoom options into the framework.
2. Mouse-adapted according to the psychomotor needs of the users.
3. The need to use PCs and tablets.
4. Posing specific situations through videos or images.
5. Creating resources that imply autonomous and independent use would not lead to the achievement of the project's objectives.
6. To optimize the execution time and it may be useful to incorporate time indicators in some games, to motivate the user to carry out an activity with a shorter duration.
7. To carry out activities of daily living, the target population requires extensive supports such as direct directions or partial physical help. Accordingly, serious games should be designed based on the levels of support required by users.
8. To consider the level, frequency, and type of support required due to the high level of support required by users.

3.2 The Case Study: The HabCog Serious Game

The Application. The HabCog application is intended to preferentially stimulate attention, perception, and memory among various functions, faculties, and socio-cognitive skills through games that allow specific activities for specific or global training. The app tracks user actions, such as the number of hits, errors, restarts, and time played to assess progress during sessions. This application is made up of a set of minigames to stimulate the user's cognitive abilities.

Fig. 2. Scenario: The Direction Following minigame.

The Scenarios and Tasks. Three situations were corresponding to the HabCog application, where users can carry out activities for global training or specific for the development of socio-cognitive skills. Each scenario is divided into a set of tasks that represent the series of actions that the user must perform. Figure 1 presents the first scenario called "*Change the difficulty of the minigame: Direction Following*". It consists of visiting the configuration interface of the indicated minigame and increase the difficulty level. The second scenario concerns completing a session of the minigame Direction Following. Figure 2 shows the mockups of the sequence of steps of the game "*Direction Following*" minigame corresponding to the second scenario. Finally, Fig. 3 shows the steps that a user must follow to view the historical data for a particular user who has used the "*Location*" minigame.

3.3 The Heuristic Evaluation Method

The Evaluation Checklist and Severities. To carry out the evaluation, 14 heuristics proposed by Pribeanu [3] were considered. Likewise, a 5-point Likert severity scale was defined. A severity value of 1 represents the lowest severity level, whereas 5 represents more serious usability issues.

The Evaluation of the UIs. The heuristic evaluation process began after analyzing the characteristics of the target population and the insights resulting from observations of the applications used in the foundation, to know the needs of each of the user profiles.
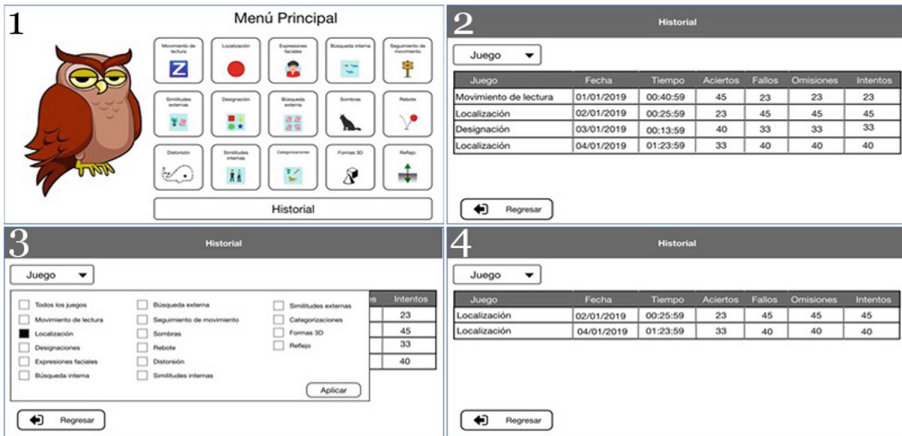
Fig. 3. Scenario: View the history data of the Location minigame.

After the researchers informed the usability experts about the characteristics of the target population, the heuristic evaluation was performed under the guidelines of an evaluation protocol. The evaluation protocol offered all the guidelines and the procedure to be followed by the experts to carry out the heuristic evaluation. Furthermore, each expert received a user guide along with the evaluation protocol describing the functionalities of the HabCog mobile application.

The Usability Experts. Three usability experts evaluated the HabCog application to detect potential usability concerns. Each evaluator received an evaluation protocol containing the instructions to carry out the evaluation. The evaluation results performed by each of the three experts were consolidated and analyzed by consensus.

3.4 The Results

The cumulative results of the severity ratings given by each expert are summarized in Fig. 4. Most of the results (36 out of 90) fall under a severity category of 1. This result means that there are not usability issues. More importantly, in the global results, 30 classifications fell into severity category 4; they are serious usability issues that need to be addressed. 18 ratings were given low severity level 5 disaster means usability. In the next section, we offer usability recommendations to improve detected issues.
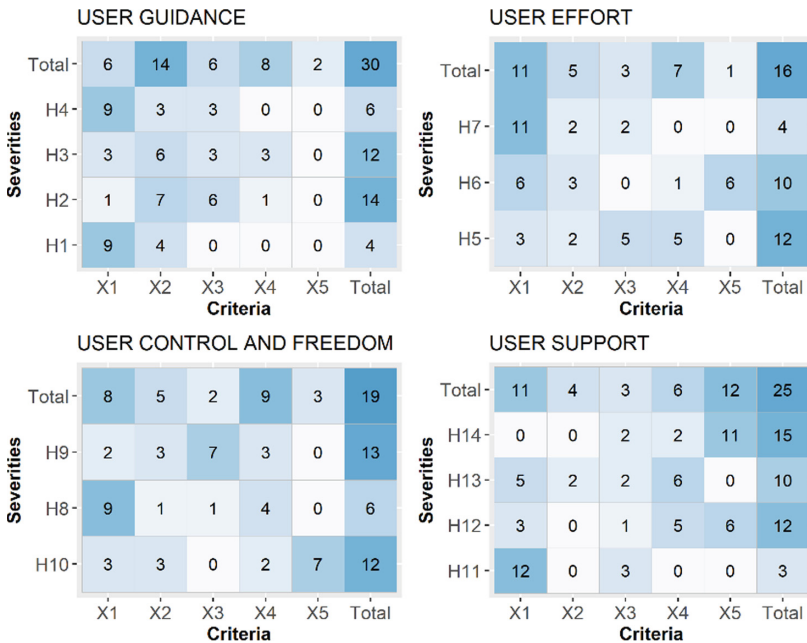
Fig. 4. Global results from applying the three heuristics evaluations.

4   Discussion

Recommendations for improving the application are formulated in this section. The suggestions are based on the comments provided in the heuristic analyzes performed by the three usability experts. Illustrative figures are presented, showing possible improvements to the models presented for analysis. Recommendations are organized into the tasks described above. Consistency in button design between the different user interfaces is recommended. Also, add buttons to in-corporate audio options, as well as instructions on how to play. An example of how it could be designed is shown in the Fig. 5.

An alternative is recommended in the options menu to return to the default values. To clarify the options, it is suggested to disable the buttons that decrease/increase the values when they are in their minimum/maximum settings. A button is recommended to return to the previous screen. These recommendations are presented in the Fig. 6. The interfaces corresponding to the history display scenario do not allow the user to observe the totalization of the different resulting values. We suggest dividing the screen into two parts. The left side should correspond to a list of multiple selections containing the minigames. On the right side, it is suggested to present the statistics with the totalization of the resulting values. For statistics, the X-axis can represent the timeline from the first day the user has made use of the system. The Y-axis, the average value for each day where results are available. At the bottom of the screen, it is suggested to append an option to consult the statistics details based on the selected games on the left side of the screen.
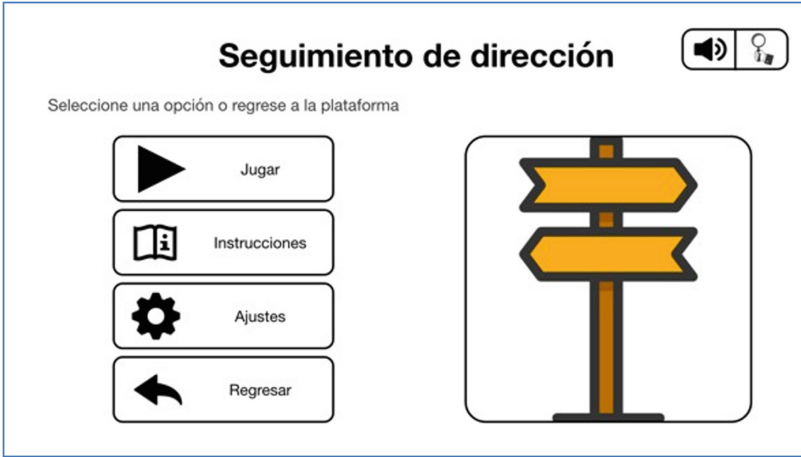
Fig. 5. Mockup showing how recommendations could be incorporated into the minigame "Direction Following".
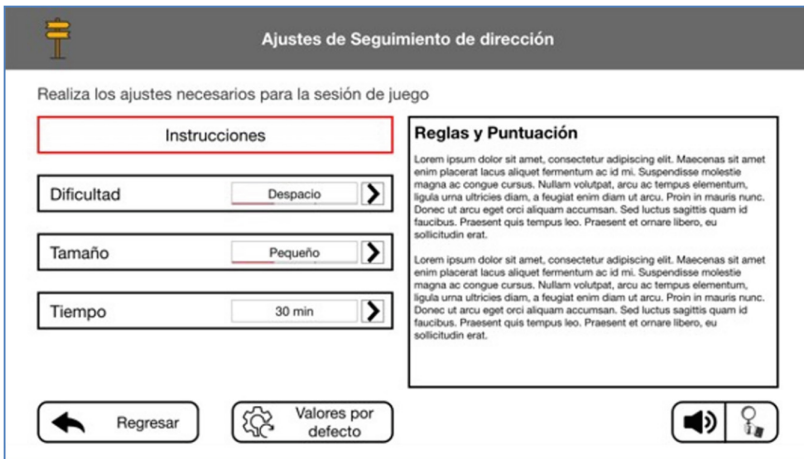
Fig. 6. Mockup showing how recommendations could be incorporated into the setting screen of the minigame "Direction Following".

5   Conclusion and Future Work

Heuristic analysis has provided the identification of a set of usability problems with the HabCog application. With the help of three usability experts, recommendations could be provided to potentially improve the application and better tailor it to the needs of the target population. It is of great importance to have detected serious usability problems and make suggestions to solve them. The value of this work is the degree to which you can help HabCog designers implement changes and adaptations at the application design

stage to anticipate potential usability issues and create an effective user experience for those who use it.

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Designing Serious Games for Stimulating Cognitive Abilities Using iPlus Methodology

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Abstract. The current research focuses on building a set of games for training and improving people's cognitive abilities with intellectual disabilities. Serious games (SGs) can be an effective training coaching and assistance method for persons with intellectual disabilities because they are effective learning tools that motivate students. The application to stimulate cognitive abilities development consists of 22 mini-games hosted on the LudoMinga platform. For better development in the environment, it is essential that people with intellectual disabilities develop cognitive functions, understood as the mental processes necessary to carry out any task, enabling the reception, selection, transformation, storage, processing, and retrieval of information. For the development of the application, the user-centered design approach of the iPlus methodology is followed. This article illustrates the development of the application using iPlus.

Keywords: Serious game design · Game development process · iPlus · Intellectual disability · Education

1 Introduction

Education is a fundamental human right and an essential condition for individual development and full and effective society participation. According to [1], the Sustainable Development Goal 4 (SDG 4) of the 2030 Agenda aims to "ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" by 2030. The SDG 4 calls us to build and upgrade education facilities that are disability sensitive and provide inclusive learning environments for all.

The integration of Information and Communication Technologies (ICT) into every aspect of our day-to-day lives has had profound implications for how people learn, facilitating a positive interaction, helping to be accessible information, and empowering

the abilities of people with disabilities, allowing their limitations to be reduced to a minimum.

The use of serious games for educational purposes can have a very positive effect and reduce the impact of disability since they provide an effective way to engage people like individuals with intellectual disabilities in learning activities and have the ability to stimulate cognitive processes like acknowledging displayed information, deductive and inductive reasoning.

The development of a serious game requires knowledge of the learning domain and must be designed using an appropriate methodology. The player has to feel that he is playing a game where the learning is a consequence of the playing actions. The lack of a correct design of the SGs can cause that games to lose both their attraction and their game essence; even more, they no longer fulfill serious objectives.

The current research focuses on constructing a serious game for stimulating the cognitive abilities of persons with intellectual disabilities. Here, we illustrate the application of the iPlus Methodology, which incorporates a user-centered design approach, participatory, flexible and uses creative techniques that combine entertainment and serious aspects, as well as comply with a user-centered design approach that includes the participation of experts and makes use of techniques that are easy to understand for all participants.

The paper is organized into four sections as follows. The next section describes the design using iPlus methodology and the case study to which it applies. In Sect. 3, the result of the implementation is illustrated, and finally, the conclusions developed as a result of the investigation are presented.

2 Designing a Serious Game Using iPlus Methodology

2.1 An Application to Stimulate the Development of Cognitive Abilities

For better development in the environment, it is essential that people with intellectual disabilities develop cognitive functions, understood as the mental processes necessary to carry out any task, enabling the reception, selection, transformation, storage, processing, and recovery of information. The application is aimed at people with mild to moderate intellectual disabilities, and they should not present physical difficulties that prevent the regular use of technological devices. Significant limitations characterize intellectual disabilities both in intellectual functioning and adaptive behavior, expressed in conceptual, social, and practical adaptive skills. People with intellectual disabilities have difficulties with learning, understanding, and communicating.

Depending on the characterization of the target population, the games emphasize the perceptual-visual functions. The general objective is to develop or improve cognitive abilities, privileging the basic ones: perception, attention, and memory, based on visual functionality and efficiency - using their vision and understanding what they see - through stimuli to be interpreted for progressive development.

We aim to reduce difficulties related to cognitive abilities, emphasizing the basic or primary: perception, attention, and memory. Particular attention was paid to motivation, understood as resistance to distraction and activation process. The use of geometric shapes, drawings, and photographs Stimulate spatial orientation. Sensory information

utilizing physical characteristics of the stimulus (extrinsic factors): size, color, shape, movement (speeds), position, intensity, complexity, relevance, and novelty. Global and local processing to stimulate recognition of the whole and the parts. Tasks that consider reaction time, detection, discrimination, search, identification, recall, direction, and recognition. Integration of verbal and graphic symbols. Auditory stimuli that do not alter the nervous system.

2.2 iPlus Methodology

iPlus is a user-centered methodology for SG design [2–4] that presents a participatory approach, offering a phase for the ascertainment of consensual requirements through the participation of various experts, such as a subject matter expert, the product owner, end-users, pedagogical experts, software developers, video game designers, psychologists, and players.

Using our methodology, the game script and user stories that allowed for refining the purposes and gameplay can be obtained and used in any software development methodology that receives user stories as input. This methodology specifies the entry to any of the methodologies of the development phase.

iPlus comprises a series of ordered steps organized into five phases, and Fig. 1 shows the integration of iPlus enriching the normal flow of Scrum with a participatory approach. Below we describe each phase and its application.
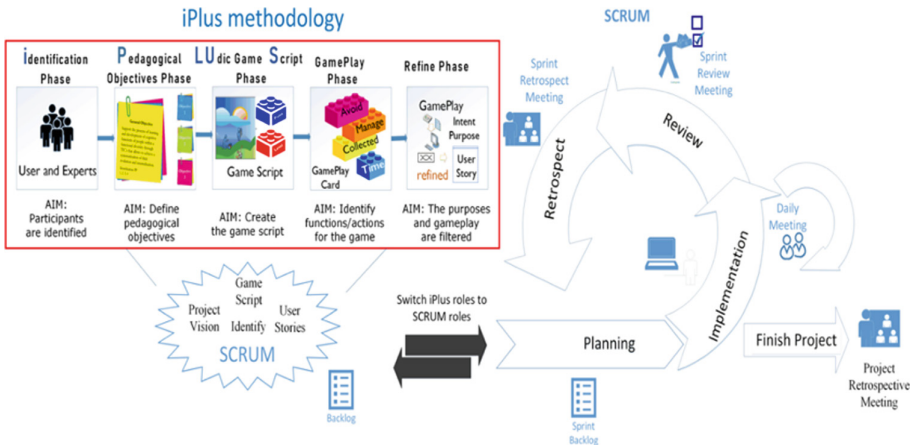
Fig. 1. Integration of the iPlus methodology with SCRUM.

Phase 1. Identification

Resultant artifacts: Here, the general problem is defined by the interested party, and, depending on the situation, participants in the methodology are identified.

Description: An application is required to reinforce the cognitive abilities. This case study involves an expert in pedagogy, responsible for defining pedagogical objectives, the product owner, experts in the treatment of disabilities, a video game designer, the software developer, and the concerned students.

Phase 2. Pedagogical Objectives

Resultant artifacts: In this phase, the general and specific objectives are defined in a participatory and agreed manner, under the pedagogical expert's guidance.

Description: We interview with a subject matter expert to understand the needs of the users. An affinity diagram is used to define the objectives. Figure 2 illustrates the general objective and an example of a specific objective.
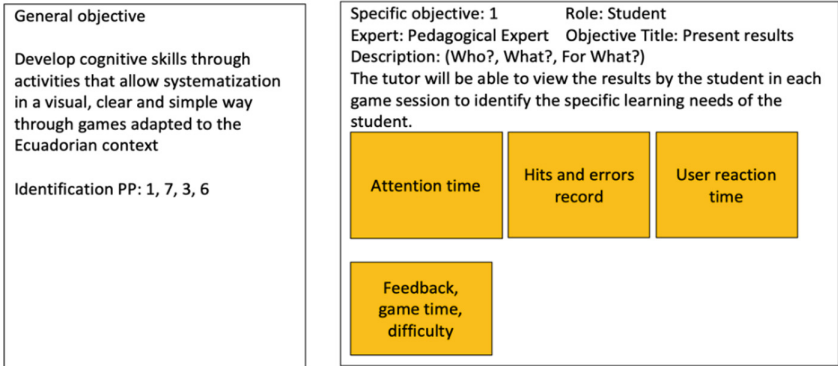
Fig. 2. General objective and specific objective

Phase 3: Ludic Game Script

Resultant artifacts: This phase aims to create the "Game Design Document" (GDD) based on the Product Owner's needs or requirements. Then, with the selected ideas, the participants and the subject expert create the game script that contains the narrative, characters, and gamification elements [5] and [6] such as badges, points, prizes, among others, which can be implemented in the SG.

Description: The result of this phase is the game script format or consensual story. See Fig. 3.
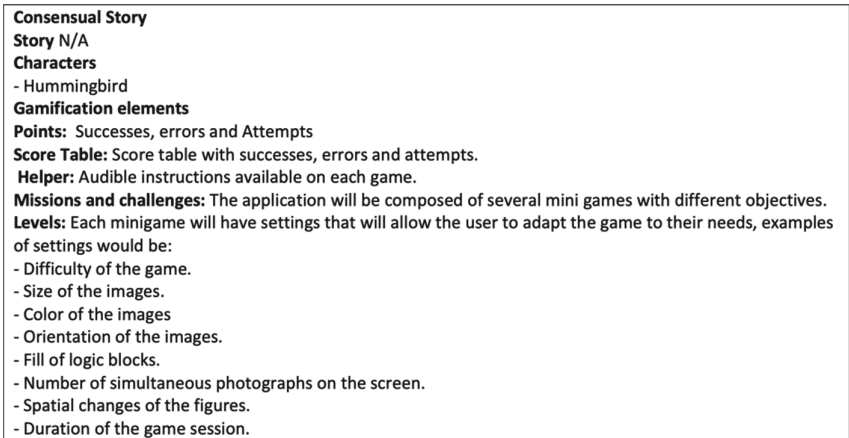
Fig. 3. Game script for the serious game

Phase 4: GamePlay

Resultant artifacts: Here, experts participate in defining the GamePlay blocks [7, 8] and [9]. They are used to describe the functionalities that are part of the game. Additionally, the genre of the game is identified [10, 11].

Description: The Gameplay blocks are related to hold, move, position, and points such as "A player win points when hold, position or move an object. Figure 4 shows an example of the proposed Gameplay blocks. Additionally, Stakeholders define the game genre as reasoning because it involves the use of problem-solving skills.
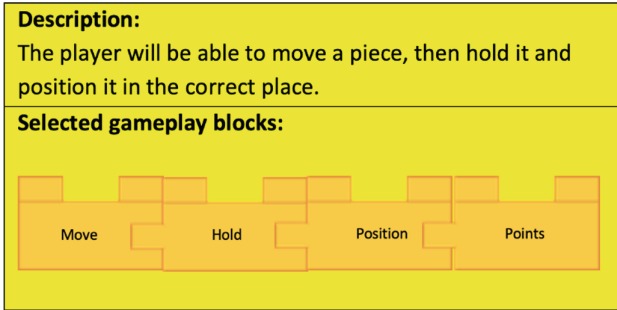
Fig. 4. GamePlay card

Phase 5: Refine

Resultant artifacts: After going through the ideation process, GamePlays needs to be filtered to eliminate aspects that are repetitive or are not possible to create from the pool of ideas.

Description: User stories that represent a short description of characteristics of the game expressed as user needs. See Table 1.

Table 1. Resultant epic user story

Epic User Story		
Id: T01 Role: Tutor		
Title Story: Support in the realization of the game session.		
Priority: High (H)		
Description: The tutor selects the game and settings to carry out the game session (difficulty, size of the stimuli, number of stimuli, game time) to allow the user to develop as naturally as possible in the application.		

3   Game Implementation

As mentioned above, our case study deals with the proposal of a web application development composed of several modules as mini-games; the use of each of these contributes to the stimulation of cognitive abilities.

The user's home screen offers access options based on role. The platform administrator module allows access to the list of video games, name and type of organizations, and identification of the organizations' administrators with their respective registration forms. The organization administrator module enables the management of tutors, users, skills to develop, time (period), intervention plans, reports, daily schedule, and customization of games. See Fig. 5.
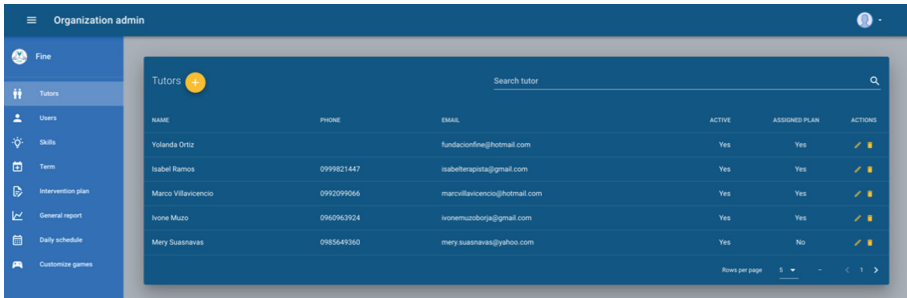
Fig. 5. Menu and screens to manage tutors and users.

Each game has a description of the stimuli, the mechanics and functionality, and the objective. In the example, the player is expected to discriminate attributes of shape and color while identifying them with the model. In Fig. 6, the standard stimulus is a blurred silhouette. Among several photographs, the user must select the one that corresponds to the silhouette.

The specific instruction for each exercise is indicated, the feedback is immediate, both visual and audible; it was taken care that the sounds that indicate if the exercise was done well or was wrong are soft, not disturbing.

Fig. 6. Exercise to identify a figure with its silhouette.

Once the game is over, the results are presented based on the user's time, the number of attempts hits and misses. The tutor can enter comments related to the work session. See Fig. 7.
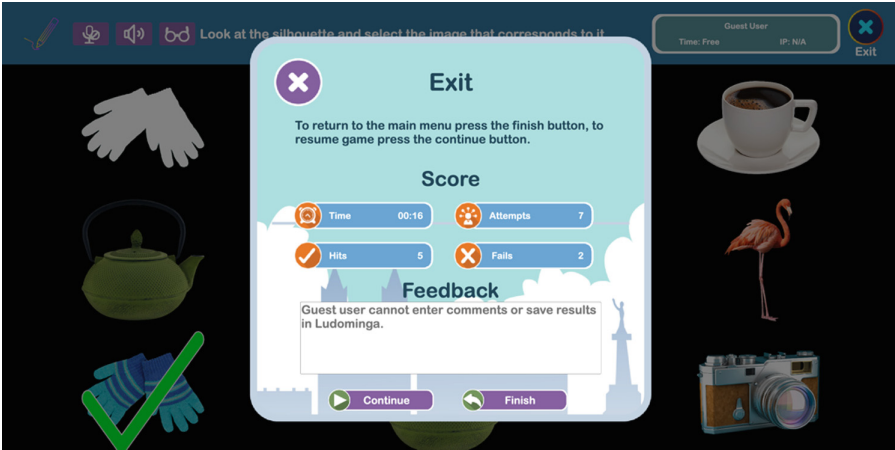
Fig. 7. Completion screen with the game report.

Depending on the skill of the user, it is possible to configure: the degree of distortion; the position of the pattern stimulus (no spatial changes, rotation, or symmetry); size and number of stimuli; the possibility of pointing out the error or not; and, the duration of the game. See Fig. 8.
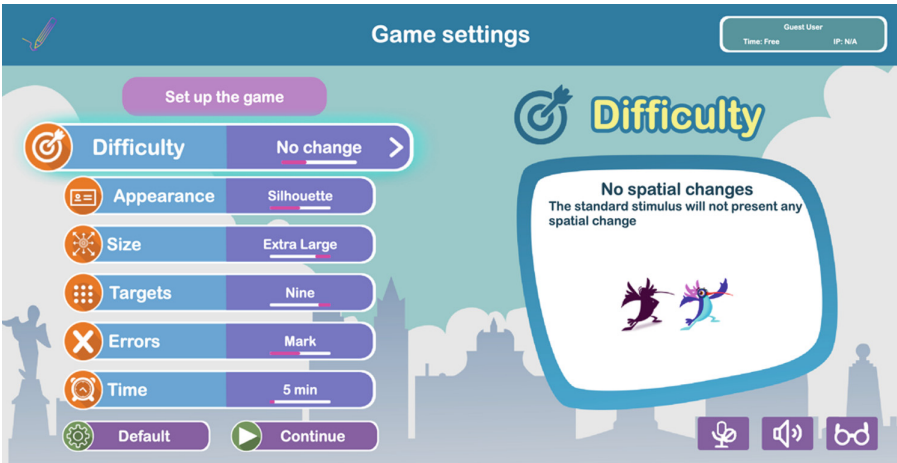
Fig. 8. Serious game training module

In this particular case, the game contributes to cognitive abilities development through the next cognitive functions, faculties, and abilities. Visual functions: Optics,

Optical-perceptual, and Perceptual. Faculties: Visual-motor coordination, Figure-ground perception, Perceptual constancy, Perception of position in space, Perception of spatial relationships. Cognitive abilities: Perceptual-visual, Attention, Memory, Reasoning, Space-time orientation, Language.

4 Conclusions

In this paper, we illustrate the game process development using iPlus methodology. This work aims to implement serious educational games incardinated to develop cognitive, adaptive, and work skills in favor of the inclusion of people with intellectual disabilities, based on the characterization and detection of a case study's needs.

The methodology and the resulting games contribute to improving the target population's quality-of-life made up of adults with intellectual disabilities.

iPlus identifies the crucial elements to be considered when designing an SG, such as the story or narrative of the game, rules, game mechanics, serious content, and gameplay. The result is a set of resultant artifacts allowing us to generate the game design document used by any software developer.

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Improvement of Accessibility in Medical and Healthcare Websites

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Abstract. Health information on the Web can make patients better informed about a disease, which according to several studies leads to better treatment results. However, the health information found on the Web is not accessible because it presents barriers that prevent people from easily accessing it because it does not comply with the standards of the Web Content Accessibility Guidelines (WCAG) 2.1. Therefore, in this study, we present an analysis of the accessibility of the seven most visited health websites in the world. To analyze the accessibility of medical websites, we apply an automatic review method. The results show that health websites have frequent problems related to the lack of alternative text, empty links, and contrast errors. This research can contribute to future work related to accessibility in health and medical sites. Finally, we suggest designing a combined method to review each website's accessibility barriers to complement the automatic review.

Keywords: Accessibility · Assessment · Improvement · Medicine websites · Web content accessibility guidelines · WCAG 2.1

1 Introduction

The Web has revolutionized our day to day, becoming a source of information, knowledge, consultation, and provision of services in various areas. Medical and health-related services are revolutionizing technology around the world. According to the 2020 statistical data from the, We Are Social and Hootsuite reports, they indicate [1] that more than 4.5 billion people use the internet, that digital, mobile, and social media have become an indispensable part of everyday life for people. While Although the World Health Organization indicates that 15% of the world's population suffers from a disability, the

goal of web accessibility is to ensure that web pages are usable by the maximum number of people, regardless of their knowledge or skills and regardless of the technical characteristics of the equipment used to access the Web.

Therefore, this article describes the web accessibility issues identified in the seven most visited medical websites globally. To analyze the accessibility of medical websites, we apply an automatic review method that includes six phases: 1) select the websites to evaluate, 2) navigate through each website, 3) define the test scenario, 4) apply the automatic review tool, 5) record the results and 6) propose improvements to reduce the accessibility barriers found.

The numerous problems identified regarding the accessibility of websites indicate that it is necessary to strengthen accessibility policies, motivate and disseminate accessibility guidelines among developers and web designers to apply the standards throughout the development cycle of websites.

The rest of the document is structured as follows: in Sect. 2, we show the antecedents and previous work; in Sect. 3, we describe the methodology and the case study; in Sect. 4, we show the results and discussion, and finally, in Sect. 5, we incorporate our conclusions and future work.

2   Background and Related Work

According to Google Trends, Fig. 1(a) reviewing the trends in Google Trends in the last 12 months from November 17, 2019, to November 17, 2020, worldwide. The term "Health Website" and "Web Content Accessibility Guidelines" tend to grow significantly since March 22, 2020; Due to the SARS-COV-2 coronavirus and its disease, COVID-19, which is why a health emergency and social distancing were declared globally, many resorted to consulting health websites.

(a)   (b)
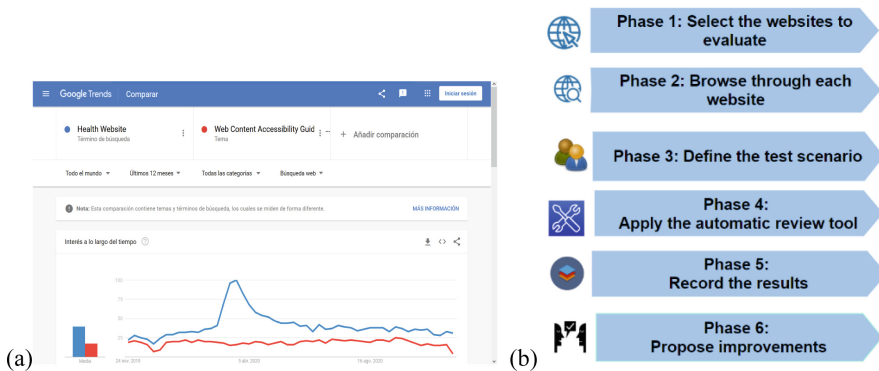
Fig. 1. (a) Trend in websites related to health. (b) Method to evaluate accessibility in the health websites.

According to the article [2], eHealth's trend to digitize the services associated with health care is increasingly recurrent, but health sites have neglected web accessibility that generates exclusion barriers. The study describes the web accessibility problems

identified in 22 hospital websites according to the Webometrics ranking. The research-validated several hospital websites and the level of accessibility with WCAG 2.0 standards. Due to the barriers encountered, this study presents the need to strengthen the legislation and implement the best web accessibility practices.

In websites, it is also essential to define a method to assess the accessibility of online content publishers according to the study [3]; it is essential to consider the Web Content Accessibility Guidelines 2.0. The method includes 63 accessibility features that can apply to images, headings, and tables.

The study [4] indicates that population growth and the increase in diseases represent a challenge for society, especially for the health system, including palliative care. Therefore, it is essential to maintain accessible sites for all types of people to interact on the web. It suggests some parameters to design an accessible website inclusive in the health area by applying the WCAG 2.1.

Article [5] indicates that there are many patient care websites, but not all are accessible. Therefore, it is necessary to develop accessible websites for health services that comply with the Web Content Accessibility Guidelines 2.1; the authors propose an evaluation method to measure the accessibility of health-related web applications.

The web has innovated the most with technological development and the pandemic; what was initially a scientific communication system today is the most essential, instantaneous, and economical source of information. The possibilities it offers its users in terms of services are unlimited. Therefore, it has become a new work tool for health professionals that has revolutionized communication, training, and continually updating.

The results show that health websites have frequent problems related to missing alt text, missing form tags, empty links, and contrast errors. Medical websites analyzed in this study with WAVE [6] were found to violate web accessibility requirements based on Web Content Accessibility Guidelines 2.1.

There are various resources such as medical databases, bibliographic search engines, mailing lists, journals, electronic books, videoconferencing, teaching, capable of influencing daily clinical practice in medicine. Some years ago, it seemed impossible for us to attend clinical sessions from our home, treat patients between several hospitals simultaneously, contact the referral center from rural areas, and transfer files from hospitals or universities.

The web facilitates our patients' diagnosis and treatment; it is a necessary instrument for medical research. However, not all web sites are easily accessible, which is why we suggest applying WCAG 2.1 [7].

3   Method and Case Study

As a case study, we have evaluated seven of the most visited medical and healthcare websites globally, according to https://clinic-cloud.com/.

The method applied in evaluating the accessibility of health websites involves six phases described in Fig. 1(b).

Phase 1: Select the websites to evaluate; in this phase, we selected seven health-related websites. Table 1 contains the evaluated website, the acronym, the URL, and the sites' description.

Table 1. Evaluated health websites

Website	Acronym	URL	Description
Medline	MD	https://medlineplus.gov/	It is a page of the National Library of Medicine of the United States; currently, it is the world's most extensive medical library
Webconsultas	WC	https://www.webconsultas.com/	It is a health portal aimed at all audiences; the objective is to improve the general population's quality of life. The portal has a health office and a symptom identifier
WebMd	WM	https://www.webmd.com/news/default.htm	It is one of the most visited health pages in the world. It is in the English language; it has a news section in Spanish updated quite frequently
Dmedicine	DM	https://cuidateplus.marca.com/	It is a health portal endorsed by the newspaper El Mundo. It has been advertised as the leading health newspaper on the internet since 2007. It offers an online store of medical services to search and compare the different centers and clinics' offers
Efesalud	EFE	https://www.efesalud.com/internacional/	The EFE agency is a news agency; it has a health news section from which most large newspapers feed
World Health Organization	WHO	https://www.who.int/home	The WHO website contains useful information on health topics. The most exciting thing and what differentiates it from the rest of this list's pages is its Data and Statistics section. This section contains health statistics that are of particular interest to researchers
Mujer y Salud	MS	https://www.mujerysalud.es/	It is one of the most popular sites; according to statistics, women tend to seek more health information than men. Hence the significant proliferation of portals dedicated exclusively to women's health

Phase 2: Browse each website; in this phase, we interact and navigate each page of the selected site.

Phase 3: Define the test scenario; we define the activities to be carried out on each of the selected websites.

Phase 4: Apply the automatic review tool; in this phase, we apply the WAVE tool that includes a browser plug-in component; in this case, we apply with Google Chrome.

Phase 5: Record the results; in this phase, the evaluation data are recorded in a spreadsheet, which is available in a dataset located in the Mendeley repository[1] for the review and reproduction of the experiment.

Phase 6: Propose improvements; in this phase, some recommendations are presented to achieve an accessible level of accessibility considering the WCAG 2.1 to reduce the accessibility barriers; in the results and discussion section, the data is analyzed in greater detail.

4   Results and Discussion

Table 2 contains the evaluation results of the seven health websites evaluated with WAVE.

Table 2. Evaluation of the accessibility of health websites.

Acronym	Errors	Alerts	Structural elements	Contrast errors	Features	ARIA
MD	0	15	19	0	22	25
WC	0	25	61	13	54	54
WM	0	23	70	1	31	25
DM	40	67	57	9	23	1
EFE	23	220	137	78	120	17
WHO	30	33	134	27	28	451
MS	3	195	23	40	60	1

Figure 2(a) shows that the websites with the highest number of serious errors and need to be corrected correspond to DM, EFE, WHO, and MS. Besides, the contrast errors between the background and the foreground content must be corrected, which must be high enough to guarantee readability. When designing accessible interfaces for different viewing capabilities, the WCAG 2.1 guidelines recommend the following contrast ratios to achieve an AA level for body text at the 4.5:1 scale, for large-scale text and active components of the user interface and graphical objects such as icons and graphics at the 3:1 scale, these parameters should be corrected on the WC, DM, EFE, WHO, and MS websites. Figure 2(b) shows that the principle with the most barriers is the one perceptible with 193 barriers, corresponding to 70.7%; followed by operable with 79, which represents 28.9%; then the understandable with 1, represents 0.4%; the robust principle is absent from the evaluated health websites.

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[1] http://dx.doi.org/10.17632/n468trh5my.1.
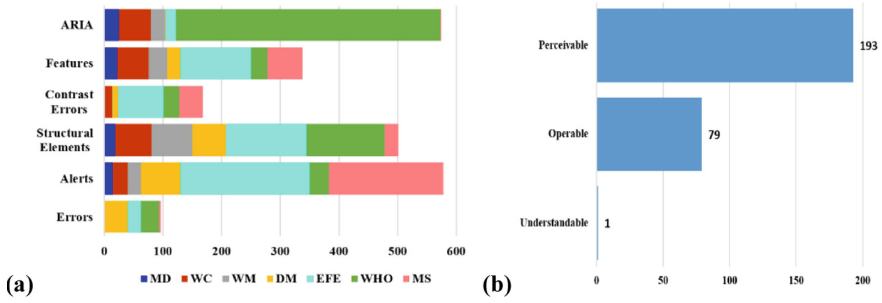
Fig. 2. (a) Evaluation of the accessibility with WAVE. (b) WCAG 2.1 accessibility principles.

Table 3 contains the principles, guidelines, success criteria, and levels of accessibility, and the total of barriers identified in the health websites during the WAVE evaluation process.

Table 3. Principles, guidelines, success criteria, and accessibility levels related to WCAG 2.1

Principle	Guideline	Success criterion	Level	Total
Perceivable	1.1 Text Alternatives	1.1.1 Non-text Content	A	25
Perceivable	1.3 Adaptable	1.3.1 Info and Relationships	A	4
Perceivable	1.4 Distinguishable	1.4.3 Contrast (Minimum)	AA	164
Operable	2.4 Navigable	2.4.1 Bypass Blocks	A	5
Operable	2.4 Navigable	2.4.4 Link Purpose (In Context)	A	68
Operable	2.4 Navigable	2.4.6 Headings and Labels	AA	6
Understandable	3.3 Input Assistance	3.3.2 Labels or Instructions	A	1

Figure 3(a) muestra los niveles de accesibilidad para el nivel AA presenta 170 barreras de accesibilidad, corresponde al 62.3% seguido por el nivel A con 103, representa el 37.7%.
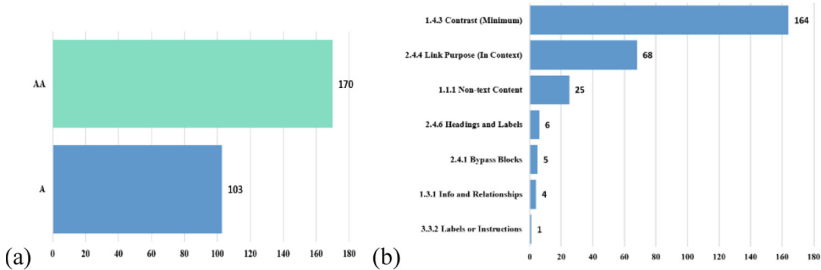
Fig. 3. (a) Accessibility levels. (b) Success criteria.

Figure 3(b) shows that the criterion with the highest accessibility barriers corresponds to 1.4.3 related to the contrast with a total of 164, representing 60.1%; followed by 2.4.4 of link purpose with 68, corresponds to 24.9%; the rest of the criteria have values lower than 10%. Therefore, link purpose and contrast issues should be corrected to achieve a minimum level of accessibility.

5   Conclusions and Future Works

To achieve a higher level of accessibility, we can apply a combined method [8] and a heuristic method [9] that adds automatic and manual review tools. We suggest that accessibility be considered as an essential parameter in the policies of each country.

As future work, we suggest conducting accessibility evaluations of each health website with different disabilities to test greater functionality.

This research can contribute to 1) Conduct future studies related to accessibility in medical and health sites. 2) Share and disseminate the dataset to replicate this accessibility assessment method and compare it in the future. 3) Design a combined method that allows reviewing each website to complement the manual's automatic review. 4) Design a method to apply accessibility heuristics that allow a manual review of websites. 5) Evaluate websites with users who have different types of disabilities.

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