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Isabel L. Nunes *Editor*

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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 night sections presented in this book:

Section 1 Management of Productivity in Smart Manufacturing and Industry 4.0
Section 2 Competencies and Culture for Smart Manufacturing and Industry 4.0
Section 3 Security and Crises Management
Section 4 Human-Systems Design
Section 5 Assistive Technologies, Affordance and Accessibility
Section 6 Human Systems Design in Transportation Applications
Section 7 Interaction Design in Educational Applications
Section 8 Complex Human-System Interactions

Each section contains 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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July 2020 Isabel L. Nunes

Contents

Management of Productivity in Smart Manufacturing and Industry 4.0

Optimizing Inspection Process Severity by Machine Learning Under Label Uncertainty

Lukas Schulte[1(✉)], Jacqueline Schmitt[1], Florian Meierhofer[2], and Jochen Deuse[1,3]

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Abstract. The increasing competition forces manufacturing companies striving for Zero Defect Manufacturing to constantly improve their products and processes. This vision cannot be realized completely however, so cost-efficient inspection of quality is of high importance: While no defects should remain undetected, this always comes at the expense of pseudo defects. As this effect is common knowledge, the automatically generated inspection results have to be verified by human process experts. As this manual verification leads to tremendous inspection costs, reducing pseudo defects is a major business case nowadays. This paper presents an approach to reduce pseudo defects by applying Machine Learning (ML). A decision support system based on recorded inspection data and ML techniques has been developed to reduce manual verification efforts.

Keywords: Machine learning · Quality improvement · Label uncertainty · Pseudo defects · Decision support system

1 Introduction

Due to rising product complexity, customer requirements and global competition, high product quality has become a major competitive advantage. However, customers require increasingly high quality standards. This demand forces manufacturing companies to improve their products and processes constantly. In order to secure high quality standards, an inspection of every finished product is not always avoidable, as - especially for functional and safety critical product features - no defects should remain undetected [1]. By securing the discovery of nearly all defects, these systems become highly sensitive to variations in product characteristics, thus the economically optimal adjustment of the inspection severity leads to high pseudo defect rates. As this effect is commonly known, the automatically generated inspection results for parts that had mostly been declared defective have to be verified manually by process experts. While

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the automated inspection is often based on univariate evaluated numerical data, the verification usually requires images, which can then be interpreted with mandatory expert knowledge. On the one hand, this leads to additional inspection time and costs, and, on the other hand, to some degree of uncertainty due to human error and variability in expertise. Therefore, the implementation of more efficient and reliable support systems has become of great interest from an economical point of view.

This paper addresses the optimization of inspection process severity under consideration of the uncertainty induced by the operator during the verification. As data-driven approaches have proved to be very efficient for this matter, Machine Learning (ML) techniques were used to build a decision support system for industrial quality inspection processes.

2 Related Research

Due to the increasing availability of data in various fields, Machine Learning (ML) has become a strategically important future technology, especially by supporting decision-making processes [2]. As human expert knowledge cannot be replaced by artificial intelligence (AI), the interaction of AI and humans is an important field of development. In this context, the application of ML, as a rational AI technology, can increase work performance by reducing human cognitive workload [3].

The reliable inspection and continuous monitoring of product quality, especially for function- or safety-critical features, is of high importance for manufacturing companies and therefore mostly supported by latest technologies such as imaging inspection techniques [4]. The image interpretation however cannot be achieved by the simple evaluation of statistical features or individual image properties. It is therefore still performed manually by corresponding experts on a regular basis and affected with uncertainties accordingly [5].

For this reason, the improvement of such image and expert based inspection processes through ML-based decision support systems is gaining great interest in recent research. The current state of the art features widespread applications across different fields of activity, especially using Neural Networks (NNs). Tabassian et al. showed that NNs can be used to automatically assign image sections to several different classes [6]. Yang et al. proposed a similar application by applying Bayesian NNs to mark conspicuous image areas [7]. Wickstrøm et al. used Convolutional Neural Networks (CNNs) to segment vulnerable regions in MRI scans [8]. Wang et al. also used CNNs to quantify the uncertainty of individual image pixels and to support the segmentation of conspicuous areas [9]. A major drawback of NNs however is their limited interpretability and understandability. Because of that they are also referred to as Black Box models [8]. Regardless, transparency and interpretability are mandatory features of the model, especially when it is important to understand how the decision support system works. In this case, ML algorithms such as Support Vector Machines (SVM) can be used to create support systems which deliver a result to support a specific decision as well as to generate improved knowledge on the decision-making process itself [10, 11].

Further research is needed however to include a larger variety of data into the modelling of such decision support systems. State-of-the-art systems mainly use image data to train ML models, but do not take into account additional numeric data which is also often generated in industrial inspection processes as well [12]. The underlying research hypothesis, though, is that it is precisely this combination of different inspection data that provides a higher degree of information and thus contributes to an improved decision support system for automated quality inspections with human verification.

3 Technical Background

In the field of ML there is an increasing variety of methods and algorithms that can be used for all kinds of learning tasks. In the following, therefore, only the methods relevant for this paper will be described. In general, two different classes of ML techniques, namely supervised and unsupervised learning, can be distinguished. Supervised learning requires the existence of a well defined target variable, also referred to as the label of the learning task. If this label is not available or appropriate, unsupervised learning can be used to identify yet unknown structures and patterns, e.g. clusters or outliers, in the data [13, 14].

The method proposed in this paper consists of two sub-methods, the first requiring unsupervised learning and the second requiring supervised learning. The One-Class Support Vector Machine (OCSVM) was chosen for the unsupervised part, because it is well known to perform good in outlier detection on the whole data set when trained on the main class only [11]. For the second, supervised part, Decision Trees (DTs) were selected, as they are easy to apply, highly interpretable and less complex compared to other supervised methods [15].

3.1 (One-Class) Support Vector Machine (OCSVM)

Support Vector Machines (SVMs) can be used for classification tasks in which they separate the data points into classes based on their feature values. A hyperplane is calculated which separates the data points in a way that the homogeneity within the classes and the heterogeneity between the classes are as high as possible. Thereby the minimal distance between the hyperplane and the data points shall be maximized, why the SVM belongs to the group of large margin classifiers [14].

While the SVM usually separates data points into two, predefined classes, the method can also be adapted if only one class is of greater interest or if the population of the second class is too small to learn a separating hyperplane. This so called One-Class SVM (OCSVM) is trained only on one class, usually the only or larger one, of the data set [9].

3.2 Decision Trees (DTs)

Decision Trees (DTs) are among the most widespread and frequently used supervised learning methods. They hierarchically partition the data set with the objective to create the most distinct class separation possible. DTs consist of the tree root, from which a hierarchical structure of nodes and edges emerges up to the leaves of the tree in the training phase. At each node, the data partition is split by a certain feature value so that each leave represents a data partition to which a certain class is assigned [15].

In the application phase the classification path can be read from the split criteria at the nodes such that the result is completely transparent and interpretable. This is a major advantage compared to more sophisticated and complex models as the model does not only deliver a classification result for unseen data but also influencing features and values as a reference for targeted optimization measures [16].

4 Developing a Two-Stage Method for Inspection Process Severity Optimization by Decision Support

Finding the optimal inspection severity in industrial quality inspection processes is a complex optimization problem, especially for automated quality inspections with human verification. Therefore, a decision support system was developed using measurement and inspection data and ML techniques. The definition of the learning task is based on the structure of the conformity assessment. The final inspection result, a decision based on automated univariate conformity assessment and manual image-based verification, became the target of the ML task. The measurement and inspection data was used for training ML models (see Fig. 1).

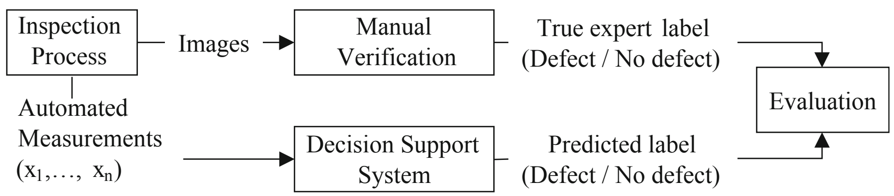

Fig. 1. Data flow of the method

In the training phase, historic data is needed, containing the actual measurements as well as the final inspection result, allowing to train a prediction model using supervised techniques. The final inspection results, however, are assumed to be uncertain. First, if all measurements are within their specification at univariate consideration, no multivariate or image-based assessment takes place. Second, if one or more features are not conforming, a manual image-based verification takes place which is affected by the operators individual expertise, strictness, and attention.

Therefore, the first stage of the method neglects the inspection results and only takes into account the proportion of defective labeled objects. A OCSVM is trained on the measurements to find a definition of good objects based on their measurement values. Corresponding to the known number of defects in the data set, the respective proportion of objects that fit least with the learned class description are determined to be outliers and re-labeled as defects accordingly.

The comparison of the OCSVM-generated labels and the expert labels is considered an indicator of the uncertainty in the inspection results but needs further interpretation.

If the labels are equal or very similar, it indicates that the verification results can be reproduced by the multivariate evaluation of the measurements. If, however, the labels are different, the respective objects should be further investigated. On the one hand, the deviation may be due to the uncertainty induced by different operators. On the other hand, the image may contain other or further information relevant to quality which is not included in the measurements. In this case, the proposed method is not appropriate and an alternative solution should be considered.

On the assumption, however, that the last case does not occur, the generated label is supposed to reflect the true quality assessment less uncertain than the expert label as it is based on reliably recorded measurements.

While the main task of an inspection process is to inspect and secure product quality, there is an essential linkage to the cause analysis of occurring defect patterns. Therefore it is essential to not only provide a binary conformity assessment in the sense of defect/no defect, but to provide access to the decision criteria, recurrent defect patterns, and potential causes. The OCSVM however, cannot be interpreted easily and does not allow the above-mentioned considerations. Respectively, the method is extended by a second stage in which an interpretable model for the extended functionality is to be developed.

For this reason, a DT model is trained on the re-labeled data set and implemented as a decision support system in the verification stage of industrial quality inspection processes. While it can be used to support the operator in his decision by merely displaying the result, it can also take responsibility by issuing a warning signal in the event of deviating results between model and operator, forcing the operator to double check his decision.

5 Application to Solder Paste Inspection in SMT Assembly

The developed method was applied within a Solder Paste Inspection (SPI) process in surface mount technology (SMT) assembly in electronics manufacturing. SPI is conducted in automatic inspection systems, which measure the solder paste position and geometry on printed circuit boards (PCBs) and capture images of potentially defective solder pads. While the evaluation of the measured values with the corresponding specifications is fully automated, the images are interpreted manually by an operator.

For the application of the proposed method, the scope was limited to one SPI facility and the defect pattern of an insufficient amount of solder paste. For the modelling a historic data set of 34,278 inspected parts, where only 92 parts (0.27%) were defective, was extracted, transformed, and processed accordingly.

Based on the seven SPI measurements a OCSVM model (RBF kernel, nu = gamma = 0.001) was trained and 0.27% of the population were re-labeled as defects. Based on the re-labeled data set a DT model was trained, optimized, and validated in a 10-fold cross-validation. Table 1 shows the confusion matrix of the predicted label compared to the true expert label for the evaluation of the achieved classification performance.

Table 1. Confusion matrix of the final classification result (DT, maximal depth = 4, split criteria = gini index, minimal leaf size = 1)

Accuracy 99.91%		True expert label		Class precision
		Defect	No defect	
Predicted label	Defect	*27*	*8*	77.14%
	No defect	*1*	*10,248*	0.01%
Class recall		96.43%	99.02%	

As the results show, 99.91% of the predicted labels comply with the expert assessment. Therefore, it can be concluded that the SPI verification result cannot only be received by image-based manual assessment but likewise by using the proposed method which evaluates the recorded measurements in a multivariate way.

However, since it cannot be ensured that new, previously unknown defect patterns are detected by the model with sufficient certainty, its deployment as a decision support system for the operator is of great interest. The model was initially implemented as a background application to monitor and evaluate the performance during ongoing manufacturing operations. In the next step, a warning signal shall indicate a deviation between the operator's own assessment and the model result, so that the operator can double check and adjust his assessment.

6 Conclusion and Outlook

In this paper, a decision support system was developed using measurement and inspection data and ML techniques to optimize the inspection process severity in industrial quality inspection. This allows to assist operators in finding less varying and more comparable verification results and to reduce the human inspection workload.

However, further research questions arose during the development of this method. First, the distinction between different defect patterns instead of the binary defect/no defect classification should be examined. Second, a solution for inspection processes where the image contains further information compared to the recorded measurement should be sought. Finally, the evaluation of further supervised and unsupervised learning techniques for a broader variety of applications should be the focus of further research activities.

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The Use of AI-Based Assistance Systems in the Service Sector: Opportunities, Challenges and Applications

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Abstract. The growth in digitalization and, above all, the use of artificial intelligence offers major opportunities for companies but also poses substantial challenges. Current technology is beginning to reshape and redistribute the division of labor and the responsibility for decision-making between humans and technological systems. This necessitates new approaches to work design as well as new skills on the part of employees. This paper first considers various scenarios for the future of work and then focuses on the service sector. We examine the challenges that such scenarios represent as well as their potential to increase productivity while also reducing the workload on employees. On the basis of two examples of AI-based assistance in the service sector, we illustrate current and future uses of this technology.

Keywords: Future of work · Artificial intelligence · Assistance system · Work design · Service sector

1 The Evolution of Work in the Digital Age

"Artificial intelligence (AI) has emerged from the lab and is now permeating everyday life and the world of work at breathtaking speed" [1]. The growth in digitalization and, above all, the accompanying use of artificial intelligence (AI) are the subject of much discussion in political, business and academic circles worldwide [2, 3].

Digitalization – understood as the practically unlimited availability and analyzability of large volumes of data, the connectivity of cyber-physical systems within and among companies, and the redistribution of responsibilities between people and increasingly autonomous technological systems – is now remolding economic systems and social structures [4–6].[1]

[1] "TransWork – Transformation der Arbeit durch Digitalisierung" (TransWork – the transformation of work through digitalization), a project funded by the German Federal Ministry of Education and Research (FKZ 02L15A160), examines these aspects.

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The drivers of this change are new business models that, with the help of digital infrastructure, are now creating new value chains. This has unleashed trends such as a greater customer-centricity and the emergence of increasingly personalized services [5, 7].

At the same time, the use of new technologies such as AI-based assistance systems is changing the working environment. Artificial intelligence is a "branch of information technology, which uses algorithms in order to emulate, within a computer system, cognitive capabilities such as learning, planning or problem-solving. The concept of AI also denotes systems that exhibit behavior that would generally be held to presuppose human intelligence" [8]. As a self-learning system, AI is able to efficiently process abstractly described tasks and problems without each step having to be explicitly programmed by a human. Furthermore, such a system should be able to adapt to changing conditions and its environment [6, 8].

As the current discussion shows, the changes to the workplace brought about by digitalization present both challenges and opportunities for companies of all kinds. The advent of AI promises not only to increase productivity and enhance the use of resources but also, and most importantly, to generate major new market potential [9].

In order to utilize this potential – with regard to its technical, organizational and social aspects – it will be necessary to design new and intelligent work systems. This is a task now being pursued in the field of human factors engineering and ergonomics.

In this paper, we first consider various scenarios for the future of work and then focus on the service sector. In the process, we look at the current challenges facing the service sector as well as the potential of AI-based assistance systems to increase productivity while also reducing employee workload.

The impact on employment of increasing digitalization and, in particular, the use of artificial intelligence has been the subject of some controversy. For example, there are studies based on job categories that predict a widespread replacement of human tasks by (AI-based) automation over the next 10 to 20 years (see, for example, [10]). By contrast, studies focusing primarily on the likelihood of tasks being automated anticipate a substantially lower level of replacement (for an overview, see [11, 12]). Finally, forecasts based on specific digitalization scenarios assume that the overall impact on the labor market in the period until 2030 will be almost neutral [13, 14].

What all these studies underline is that over the next few years we can expect to see fundamental changes to the labor market as a result of the automation of various activities and the emergence of new tasks and jobs. All of these will involve the design of new forms of work [15].

The nature of these (future) jobs will be defined primarily by the way in which the human-technology interface is designed. Two scenarios illustrate how labor might be divided in the future: the specialization scenario (also known as the technology-as-tool scenario) and the automation scenario [16]. In the specialization scenario, technology assists in the human decision-making process and may also, on this basis, be used for employee-training purposes. At the same time, workers retain a larger share of responsibility for medium-order and, if appropriate, lower-order decisions. In the automation scenario, by contrast, (AI-based) technology is used to optimize processes and solve problems automatically. Given this reduction in employee autonomy, it is assumed that this scenario will entail a stark polarization in qualification levels – with, on the one hand, low-skilled employees and, on the other, highly qualified ones being retained for a small number of residual tasks [3, 16, 17].

The challenge is therefore to design forms of work that remain humane while also promoting skills and boosting productivity. To achieve this, we need to generate synergies between human capabilities and the potential offered by technology. A good example here is the use of AI-based assistance systems that combine high technical performance with the human ability to react and adapt. Such systems provide employees with individually tailored support within an optimized work process. This not only improves work performance but also creates a working environment that fosters learning and innovation [18].

2 AI-Based Assistance Systems in the Service Sector

In a study conducted in 2019, Fraunhofer IAO asked company representatives – from the secondary and tertiary sectors – about the current and future role of AI within their own company. Of the companies surveyed, 75% said they were currently working on issues related to artificial intelligence. Sixteen percent of companies said they were already using concrete applications in this field and, on this basis, rated their current value to the entire company as "high" (4 out of 5 possible points) and expect them to become "increasingly important" (4.4 points) in the future. The study also shows that the chief benefits anticipated from AI are accelerated processes and increased workforce productivity. The majority of the companies already using AI employ it to assist with customer-related processes and processes with a high degree of customer interaction. AI-based assistance is primarily used in processes related to the provision of services (59%), followed by customer service and support (39%) [3].

The results of the study, along with an expectation that the transition to the digital economy will accelerate the structural shift towards more services, underscore the importance of looking more closely at changes in the service sector [13].

In contrast to manufacturing, the service sector involves a high degree of communication, coordination and cooperation with the customer. At the same time, it deals in an intangible, customized "product" with a high degree of customer input. As such, it features a host of areas in which digitalization can be used to improve productivity and help design forms of work that promote learning on the job [19, 20]. The use of digital assistants, especially those based on artificial intelligence, will create opportunities for new and innovative products, for the design of better and more-efficient processes, and for a speedier communication with the customer [6]. For example, AI-based systems can be used to provide employees with a highly versatile decision-making tool that analyzes data, provides updates on the job status and predicts future developments [21, 22]. This in turn helps remedy any temporary difficulties in service provision, thereby enhancing the entire process for the company, the workforce and the customer alike [19].

From a human factors and ergonomics perspective, it is important, when using artificial intelligence, to pay particular attention to the design of the decision-making architecture and the form of human-technology cooperation. In order to make proper use of employees' existing skills and to ensure they retain responsibility for certain tasks, technology should essentially be used to provide assistance and support. In the case of AI systems equipped with advanced cognitive skills such as problem-solving abilities, it is particularly important to ensure that employees are still required to perform tasks that require a higher cognitive input, if the work environment is to remain one that promotes learning on the job. For the same reason, it is also important to avoid overburdening employees with tasks that require excessive cognitive input [3].

3 Examples of AI-Based Assistance Systems for Sales Representatives and Office Workers

In the provision of a service, both the provider and the customer are part of a collaborative, integrative process and therefore have an interdependent relationship [20]. Service provision is a process that contains both autonomous and integrative components. In the autonomous sphere, the service provider is responsible for instructing employees on processes and quality standards, and for gathering, processing and providing, in a structured form, all the relevant information for this purpose. In the integrative sphere, service provision also involves active cooperation and coordination with the customer. Individual customer specifications and highly dynamic processes – due, for example, to conflicting objectives on the part of different actors – make standardization difficult in the service sector [19, 20].

To increase the productivity of service-related activities, modifications can be made to each of the various elements of service provision: autonomous, relational and heteronomous. For example, productivity on the self-controlling, service-provider side (the autonomous element) is influenced by material and social factors such as standardization in work organization, process optimization and the use of technology. Alternatively, if the aim is to increase productivity by improving the interaction and communication with the customer (the relational element), this can be achieved by professionalizing interactive processes, both direct and indirect. Finally, potential for increased productivity also lies in ensuring that customer processes are compatible with established provider processes. This concerns customer coordination and management of the customer relationship (the heteronomous element). Designing these three elements in such a way as to increase productivity will result in an improvement along the entire value chain [19, 20].

The following two examples are intended to illustrate how AI-based assistance systems can be used to provide support for service-related processes.

In the first example, we consider the autonomous element of service provision on the basis of the principal tasks performed by a sales representative. In the autonomous sphere, there are three design approaches to increasing productivity in service-related activities: a technologizing of processes, a standardizing of processes, and learning on the job.

The chief task of a sales representative is to manage existing customer relationships and forge new ones. For this purpose, a sales representative must carefully prepare and document customer meetings. This demands a knowledge of each individual customer's needs and of any services and products they may already use. Sales representatives are each assigned a large portfolio of customers. This can make it difficult to keep track of all the names and information. When preparing for a customer meeting, a sales representative will manually collate all the available data from a variety of company systems. An average day in the life of a sales representative is made up of meetings, unexpected alterations to the schedule, and downtime as a result of last-minute cancellations.

How might a new digital assistant help sales representatives to be better prepared for appointments and to make more productive use of downtime? Such a digital assistant uses AI-based methods to gather and summarize all the relevant customer information according to previously defined criteria. It therefore helps prepare the sales representative for all customer meetings as well as any appointments that are arranged at short notice so as to fill downtime. On the journey to the customer, the assistant provides the sales representative with concise and condensed learning nuggets – info modules, in either spoken or written form – that are user-specific and can be completed in a matter of minutes. These learning nuggets provide the sales representative with all the available facts on the customer – including recent reports, company information, services already used etc. It is an opportunity for the sales representative to refresh key facts while on the road – a courtesy that the customer will value.[2] The same applies when it comes to documenting the appointment: that evening, the sales representative can instruct the digital assistant, via voice command, to perform routine tasks such as updating the customer file. Following this voice input, the assistant will perform further AI-supported activities such as forwarding personal messages (e.g., compliments) and dispatching product information. In other words, the digital assistant enables employees to make more profitable use of their downtime.

The second example illustrates how an electronic listening assistant for use in communications with the customer can provide support in the relational sphere. Here, the design approach for increasing productivity in service-related activities is twofold: a technologizing of the informational elements and a professionalizing of the communicative and emotional elements [19]. A pilot application, currently being developed and tested at Fraunhofer IAO, provides support for call-center employees while on the phone. The digital assistant records, transcribes and analyzes the call in real time. On this basis, the assistant is able, for example, to identify the customer and then supply the hotline employee with the relevant customer file from the company system. While the customer explains the reason for the call, the digital assistant scans previous conversations for specific keywords so as to identify any opportunities for upgrading the current contract or marketing new business. These cross-selling and upselling recommendations are displayed onscreen to the hotline employee. At present, hotline employees must manually enter into the system every item discussed, either during or after the call. In this case, however, the electronic listening assistant automatically generates call notes and, if necessary, provides the employee with relevant contract documents or information material. This system is intended not only to improve customer communications and increase productivity in the value-creation process but also

[2] "Learning Systems", an AI Innovative Center funded by the Baden-Württemberg State Ministry for Economic Affairs, Labor and Housing, is to evaluate by means of a quick check "DafNe" the feasibility of downtime optimization for sales representatives.

to lighten the employee's load. By providing product information specific to the employee's needs and learning nuggets containing details on current offers, it also enables the employee to learn about the precise content of selected services. At the same time, the data generated by the electronic listening assistant can be used for the purposes of machine learning, thereby contributing to the system's continuous enhancement and enabling the company to undertake validated improvements to services, processes and products.

It is therefore clear that AI offers potential in various spheres for designing work processes that not only promote learning on the job but are also more effective and efficient. However, the examples presented here also demonstrate that there is no one specific AI-based system that will improve a specific service. Indeed, there are many different design approaches. These include not only the development and utilization of digital tools and assistance systems but also, and above all, modifications to work organization and a requisite redesign of work activities and a reformulation of the related requirements made of employees. The identification of the most suitable design processes for this purpose and their implementation will remain major fields of research. Here, at Fraunhofer IAO, we will continue to investigate these topics.

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Achievements and Opportunities of Digitalization in Productivity Management

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Abstract. Digitalization changes the handling of data and information by offering new and extended opportunities for collecting, transferring, evaluating and exploiting information. This allows increases in effectiveness and efficiency and also opens new opportunities for productivity management. To analyze how these opportunities are used in the German industry and which potential for further development is estimated, the Institute of Applied Industrial Engineering and Ergonomics conducted an online survey querying specialists and managers in the year 2019. Partial results for the German metal and electrical industry are described and discussed in this contribution. They prove the increasing use of digitalization and the related expectations within this significant industrial branch.

Keywords: Digitalization · Productivity management · Human factors

1 Opportunities of Digitalization and Relevance of Productivity

Digitalization refers to the increasing presence and use of digital technologies. It generally enhances the opportunities for handling data and information. This affects the complete handling process [1], starting with a mostly sensor-based acquisition of data, which usually works automatically and includes digitization – the building of digital representations of the acquired data. In this way, data get prepared to be transferred fast and secure via digital networks – wired or wireless. Afterwards, available data can get processed as required by using appropriate software and algorithms, which may include artificial intelligence or machine learning. Thereafter, information can be made available to employees or technical systems while considering specific needs of the actual situations or specific requirements of a specific human. Finally, employees or technical systems can use received information for a wide variety of purposes. Thus, the effectiveness and efficiency of data handling can be increased significantly.

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This leads to new and enhanced opportunities also for productivity management [2]. An increased availability of data includes historical as well as real-time data which can be analyzed and used for improving productivity. Due to that, needs for action of productivity management can get recognized and communicated faster. Consequently, adequate measures can get developed and implemented earlier. Similarly, control loops can get implemented or improved faster as well as integrated into holistic considerations of corporate issues. This facilitates the alignment of productivity management with corporate strategies. Further developments of digitalization are illustrated for example in the "German Standardization Roadmap on Industry 4.0" [3].

2 Methodology

The use of digitalization for productivity management in the German industry as well as its effects on employees were subject of a nationwide online survey conducted in the year 2019. Selected questions from previous studies from the years 2015 [4] and 2017 [5, 6] were replicated to be able to analyze development tendencies. Most of the questions were asked with pre-defined answering options, some of them could be supplemented by a free text answer. Estimations of future changes were recorded either as percentages to be entered freely or using three to four-level scales.

A total of 178 specialists and managers answered the questions in the period from May to August 2019 (16 weeks). The majority of these are from the industry (77%; especially the metal and electrical industry) and the service sector (17%). Other economic sectors are represented in the sample only marginally.

Within this contribution, only answers from the German metal and electrical industry are considered ($n = 112$). These participants' majority (78%) works at company locations with more than 250 employees. This also applies to the company size: 94 percent of the participants stated to work in companies with more than 250 employees. According to the EU definition [7], these are large companies. Compared to the size distribution of all companies in Germany, large companies are over-represented in the sample. The participants' majority works in production management (25%), corporate management (19%), human resources (19%) or industrial engineering (16%).

The survey results were analyzed descriptively using SPSS and Excel. A significance level of $\alpha = .05$ was chosen for correlation analyses [8]. Alternative answer options rated on Likert scales were sorted based on the summarized proportions of positive and negative answers.

3 Availability, Presentation and Use of Data for Productivity Management

As data and the contained information are the basis of digitalization, participants were queried which productivity-relevant data are available digitally, how they are presented and how they are used.

Different kind of data and their actual, planned or non-planned availability are illustrated in Fig. 1. Historical data are available in 88 percent of the companies the participants work for. To plan or not-plan realizing an availability of historical data answered 3 percent each. This item has the lowest uncertainty (6%) of all items of this question. Real time data are available for 58 percent of the respondents. Nearly a third (31%) is planning such and 4 percent do not. There is availability of data from other locations of the own company for 48 percent of the participants. Further 12 percent are planning such and 19 percent do not. The lowest agreement was given to the availability of data from other companies within the value chain (21%). Further 13 percent are planning such kind of cooperation with other companies and 39 percent do not. This item caused the highest uncertainty to the respondents (28%) within this question.

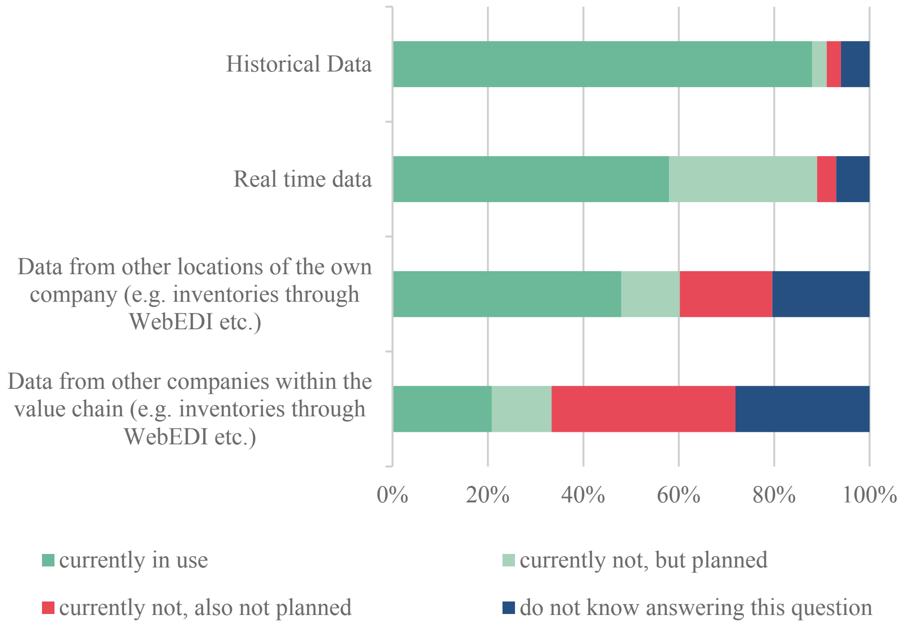

Fig. 1. Which productivity-relevant data are available to you digitally? (n = 96–100)

Compared to the results of the same question from the year 2017 [5] the availability of historical data is merely constant. The availability of other kinds of data increased a little each (1–7 percentage points). The planned availability of real time data increased strongly (12 percentage points).

Digital access to productivity-relevant data is given by different kinds of display technologies (see Fig. 2). In most companies, classical computer displays are in use (87%) or planned to be used (11%). Only 2 percent of the participants responded, such displays are not in use and will not be. Video projectors – also a more classical technology – are used a little less than classical displays: 67 percent use them and 4 percent plan to. The use or planned use of newer technologies as tablet computers

(89%) and smartphones (78%) is very common. While the aforementioned technologies are for the most part in use and only the smaller percentage of the participants indicated to use them in the future, smart glasses and watches show a contrary structure. There are more respondents planning to use them then are already using them. Compared to the results of the same question from the year 2017 [5], the use and the planned use have increased for all display technologies by 5 to 27 percentage points. Smartphones show the largest increase (from 33 to 60 percent).

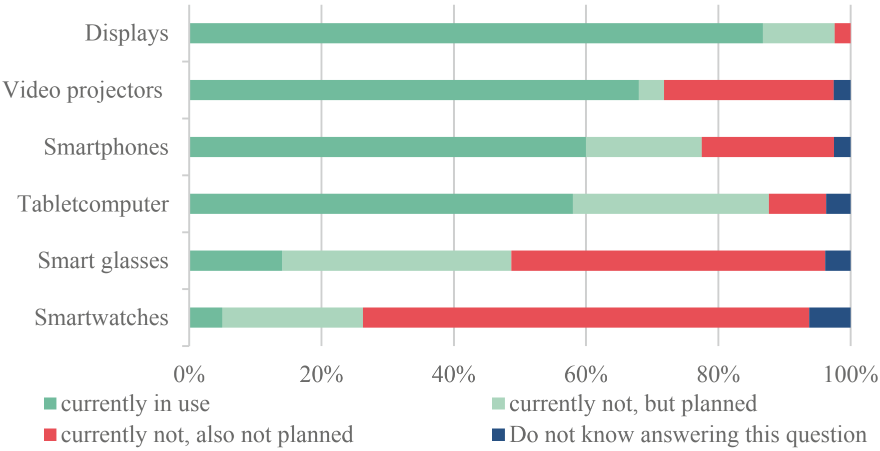

Fig. 2. Do you use the tools listed to provide productivity-relevant data? (n = 78–81)

The gained data are used for productivity management in different intensity and consequence. This heterogeneous use among the participants is illustrated in Fig. 3: Most respondents (33%) compare targeted and reached values to derive targeted actions for influencing and improving productivity. Nearly a quarter of the respondents tracks their past development (26%) or does at least the comparison (25%), while some use them only if necessary (8%), view them irregularly (5%) or use them differently (3%). Answers to the latter were: everything depending on the department, in meetings, online on the shop floor, for annual planning, in live dashboards, for monthly reports.

If data are not used for deriving targeted measures, the relevance of collecting them should be evaluated. Furthermore, their suitability for closing control loops and improving productivity should be checked [6].

4 Impact on Human Factors and Future Expectations

Independently from the way productivity management is organized in different companies, it affects human factors and expectations on future developments.

Consequently, these aspects were part of the survey. It was found that productivity management improves or improves strongly the employees' productivity in most cases (97%, see Fig. 4). Furthermore, all respondents agree on productivity management

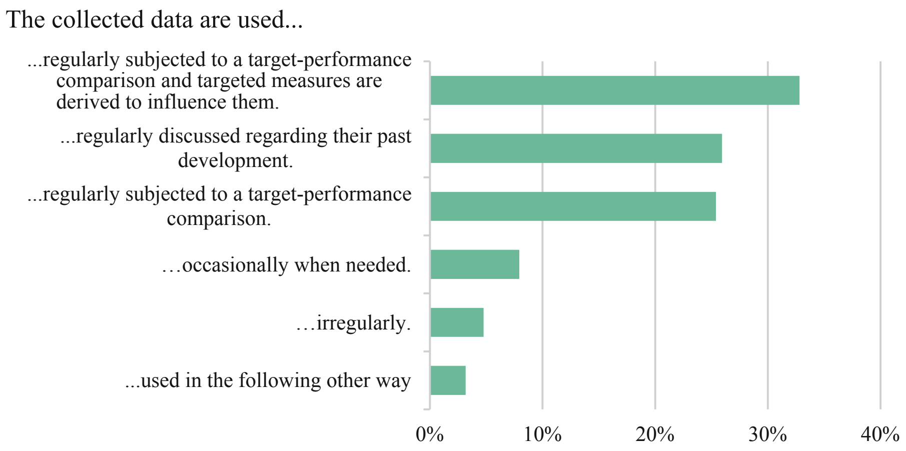

Fig. 3. How are collected data used for productivity management? (n = 91; multiple choices possible, 189 answers in total)

improving or improving strongly the ergonomic workplace design (100%). Also, the employees' ability to work (91%) as well as their qualification level (85%) and ability of autonomous decisions (68%) are improved or improved strongly by the help of productivity management. Additionally, the employee's flexibility is improved by productivity management. This applies to content flexibility (80%, range of executable tasks), temporal flexibility (75%, variation of working hours) and spatial flexibility (70%, variation of workplaces).

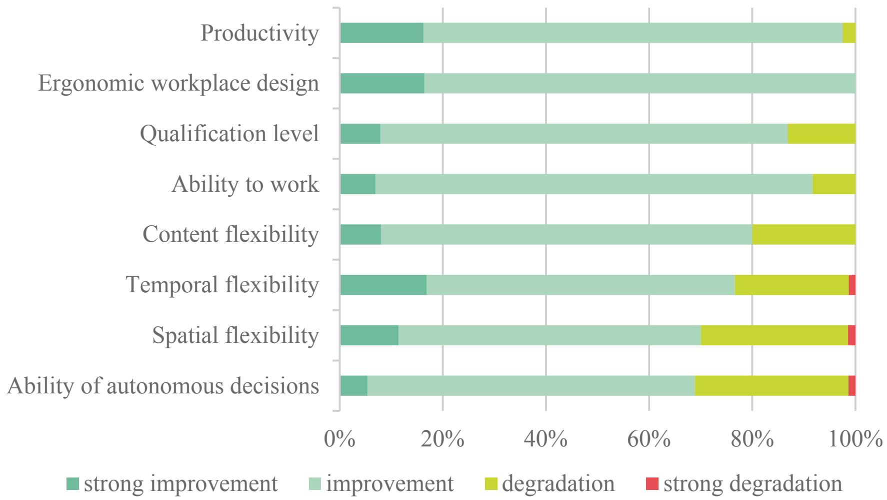

Fig. 4. How are your company's employees influenced by productivity management? (n = 100–111)

Compared to the results of the year 2017 [5], there are only little changes for most items; only the ability of autonomous decisions was estimated better by 35 percentage points in the year 2019.

Since productivity and its management are depending increasingly on digital technologies and digitalization, it was queried which increases in productivity are estimated due to this. These estimations were queried for/until the year 2022 and the year 2027. Since this question was replicated from the prior survey [5], the actual and the past results can be combined. To do so, all results are illustrated in Fig. 5. It shows a clear and steady tendency which reaches from an estimated increase of productivity of 22 percent on average in the year 2020 up to 38 percent on average in the year 2027. The deviations in the estimations increase with the forecast horizon as it can be expected.

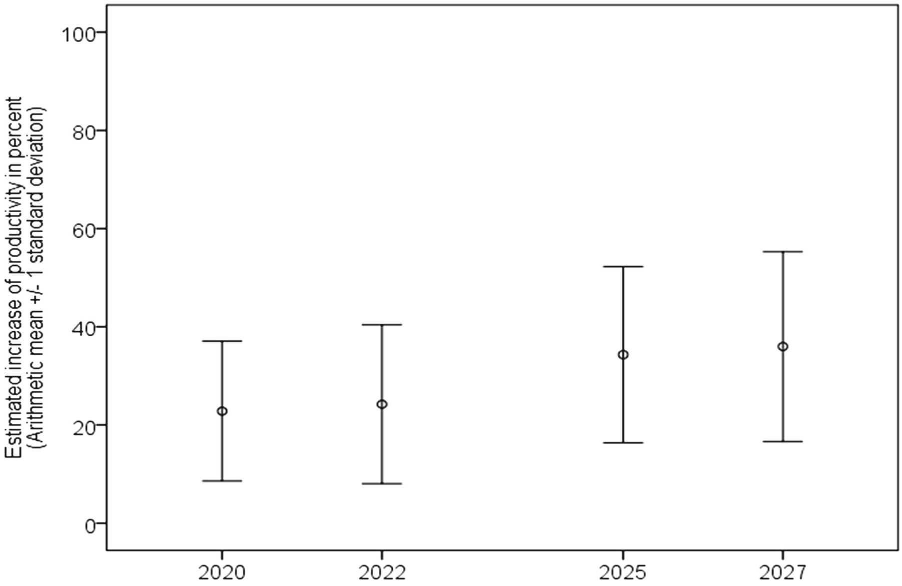

Fig. 5. How much productivity gain do you estimate due to digitalization or the introduction of digital technologies in your company? (n = 70–72 until the year 2020 respectively until 2025; n = 85–87 until the year 2022 respectively until 2027)

5 Summary and Outlook

Digitalization opens new opportunities for handling data and improving productivity thereby. For analyzing the actual use and the expectations on future potential for improving productivity, an online survey has been conducted in the German industry. Within the questionnaire, some questions were replicated from two previous studies to allow an estimation of development tendencies.

Selected results for the German metal and electrical industry are illustrated and described in this contribution. The findings show that the availability of data and information has increased between the year 2017 and the year 2019, while especially the planned availability of real time data increased significantly. The technologies for presentation of data and information are merely classical computer displays and video beamers. Within the last two years, especially the use of tablet computers and smartphones increased, while the planned use of smart watches and smart glasses increased, too. The participants' majority uses productivity-relevant data regularly to compare targeted and reached values and to derive adequate measures for influencing and improving productivity.

The answers to the impact on human factors are quite constant and show improvements in individual productivity, ergonomic workplace design, flexibility (content, temporal, spatial), ability to work and qualification level. The ability of autonomous decisions was estimated significantly better by 35 percentage points than two years before. Estimations on future potential of digitalization for productivity show a steady increasing development up to 38 percent on average until the year 2027.

Thus, the results proof the impact of digitalization on the German metal and electrical industry and its potential for improving productivity within. The complete study – containing more and more detailed analyses of all branches – is available online for free on www.arbeitswissenschaft.net/Studie_Digitalisierung_2019.

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How to Configure Assembly Assistance Systems – Results of a Laboratory Study

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Abstract. Manual assembly is shaped by increasing product complexity with higher scope of work and fluctuating demands. To cope with these changes, employees need to collect and process more information. Companies, therefore, face a wide range of challenges, particularly in terms of information supply. Informational assistance systems provide employees with cognitive support, helping to manage complexity. To evaluate the potentials of such systems a laboratory study is accomplished at the Laboratory for Industrial Engineering of the Ostwestfalen-Lippe University of Applied Sciences and Arts. In this paper, selected results of the laboratory study are presented and recommendations for a configuration of assembly assistance systems are derived from the results.

Keywords: Informational assistance systems · Manual assembly · Human-machine interaction · Laboratory studies

1 Introduction

Assistance systems are used in various ways in industrial production to support employees. For instance, screwdrivers may be set automatically, or cameras may be used to check components and ensure they were assembled correctly. Particularly in light of the persistent trend towards more complex products with a large number of different configurations [1], the potential for using assistance systems in manual assembly is growing [2, 3]. Employees have to receive and process varying specifications or information to properly execute a broad range of given tasks in a short time. In the long-term, these changes result in uncertainties during the assembly process leading to increased cognitive strain for employees [4]. As a consequence, they may fail to meet both quantitative and qualitative production targets [5]. Combined with the imminent shortage of skilled workers and an aging workforce in western industrialized nations, companies are facing a large number of challenges [6]. One central challenge is optimizing informational workflow. Assistance systems can offer employees support by providing them the right information at the right time and in the right form [7–9].

Several empirical studies [10–12] confirmed the potential of informational assistance systems. However, those studies primarily involved assembling Lego models with a fairly low level of complexity, resulting in lower transferability and validity for real world industrial assembly processes. Furthermore, the training times and variant changes were only insufficiently recorded in those studies. In this context, a laboratory

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study is conducted at the Ostwestfalen-Lippe University of Applied Sciences and Arts, which considers the identified deficits focusing on five hypotheses to verify the human-oriented and economic potentials of different informational assistance systems in comparison to a paper-based information provision [13]. In this paper selected results of the laboratory study are presented. The results relate to the following three hypotheses [13]:

1. The use of an informational assistance system results in shorter training times in comparison to using paper-based instructions.
2. The use of an informational assistance system results in shorter execution times for the first assembly of a new product in comparison to using paper-based instructions.
3. The use of an informational assistance system results in a smaller number of picking and assembly errors in comparison to using of paper-based instructions.

Based on the presented results of the laboratory study, recommendations for the configuration or design of informational assembly assistance systems are derived.

2 Research Design

A 4 $\times$ 3 factorial research design with measurement repetition on the second factor is chosen to investigate the hypotheses, as already described in the publication Bendzioch et al. [13]. The first factor includes the assembly supporting mediums used to carry out the assembly task. The paper-based provision of information (I) is used as the control medium. This is compared with a smart glasses-based assistance system (II), a projection-based assistance system (III) and a tablet-based assistance system (IV). Participant receive the necessary information stepwise through one of the four supporting mediums to complete the assembly task. That information includes bill of materials, information of tools to be used, assembly hints and step-by-step instructions [13]. Only the bill of materials differs in how they are prepared. These were adapted to each specific support medium, so that the particular characteristics of each individual assistance system could be taken into account. In this way, the container positions are displayed for all assistance systems (II, III, IV). The products which need to be assembled are pneumatic assemblies from a mechanical manufacturer, each involving 21 to 48 individual parts. These products are divided into three degrees of complexity – easy (A), medium (B) and difficult (C) – based on the entropy measure (second factor). This measure is used in the context of complexity description or determination [14]. Each of the individual products are assembled four times in series (measurement repetition) in ascending complexity with the aid of one of the four supporting mediums. Completing the assembly task four times is sufficient to detect any training effects [15]. Participants are assigned to the four groups randomly.

Assembly time, assembly errors and picking errors are used as dependent variables to test hypotheses 1 to 3. The assembly time is defined as the total time to complete a product. Assembly and picking errors are recorded using a standardized error list [13]. Assembly errors include the following aspects: necessary tool not used, mounted in incorrect position, component in incorrect orientation, component not installed and other assembly errors. The following error categories are distinguished for picking errors: incorrect tool picked, incorrect part picked and too many/too few parts picked.

In order to assess the suitability of each participant for the study, an eye test and a motor skills test is conducted [13]. The smallest font and greatest viewing distance are used as reference variables for the eye test. The motor skills test is conducted using a Lego bricks car model and a paper-based assembly instruction similar in format and scope to those used in the main test.

3 Results

In the first data collection stage, 32 participants (eight per support medium) took part in the empirical study. Of these persons, 5 are female and 27 are male, with ages ranging from 21 to 37 (M = 25.31; SD = 3.76). The majority of participants (93.75%) are students. Statistical analysis is conducted using SPSS 26. An ANOVA with measurement repetition is used to test hypothesis 1. The analysis shows that there is a significant main effect between repeating the assembly task and assembly times for each product ($F_A(1.62, 45.35) = 91.90$, $p < .001$; $F_B(1.77, 49.51) = 124.65$, $p < .001$; $F_C(1.69, 47.36) = 202.38$, $p < .001$). This effect can also be identified descriptively from the mean values of the assembly times shown in Fig. 1. Assembly times decrease down to a certain level of performance as the number of repetitions increases. Therefore, the results suggest a training effect resp. a reduction of the assembly times through the repeated assembly of the products.

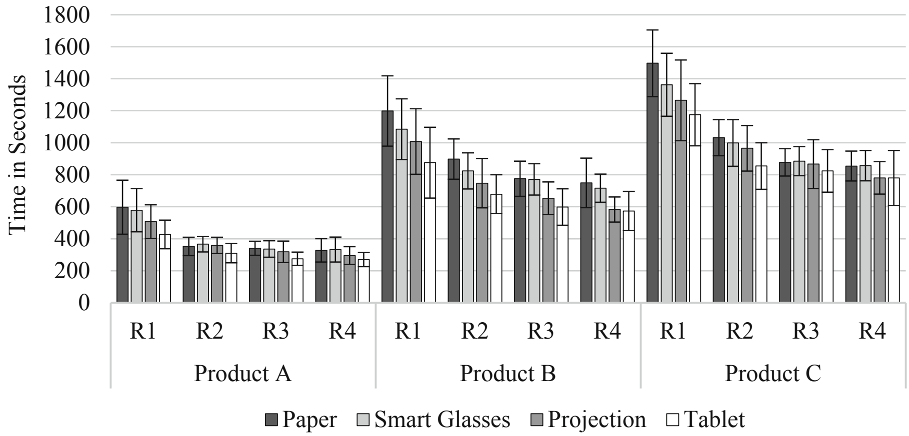

Fig. 1. Assembly times (mean values and standard deviations) for the products and repetitions, depending on the assistance systems used (I–IV).

Furthermore, Fig. 1 shows that assembly and training times vary depending on the complexity of the product and the used assistance system. This effect can be proven for product B through a significant main effect, which the used support medium has on assembly times ($F_B(3, 28) = 4.33$, $p = .013$). Regarding product B, pairwise comparisons in consideration to the Bonferroni correction showed a significant difference between providing information on paper and a tablet-based assistance system ($p = .017$). However, no significant difference is noted between the other support mediums or products. Therefore, hypothesis 1 must be rejected.

Referring to the second hypothesis, the initial assembly time (R1) for each product and support medium is considered. The values can be seen in Fig. 1. In average, all informational assistance systems are faster in completing the task for the first time than the control medium. However, a single factor variance analysis only shows a significant main effect for product B between the assembly time and the support medium used ($F_A(3, 28) = 2.56$, $p = .075$; $F_B(3, 28) = 2.94$, $p = .050$; $F_C(3, 28) = 2.90$, $p = .053$). Furthermore, the post-hoc test (Bonferroni correction) for product B shows that the use of a tablet-based assistance system results in shorter assembly times for initial assembly, in comparison to the control medium ($p = .044$). Since no support medium indicates significant differences across all products, the second hypothesis must be rejected.

To evaluate hypothesis 3, the picking and assembly errors, summed up over all products and repetitions, are investigated separately for all support mediums (Fig. 2). It should be noted that all errors are recorded, including those which were corrected during the assembly process. Both types of error do not have a normal distribution, therefore the Kruskal Wallis test is used for independent samples. The statistical analysis shows that the used support medium does have a significant influence on picking errors ($H(3) = 14.47$, $p = .002$). However, this influence cannot be confirmed for the assembly errors ($H(3) = 1.96$, $p = .582$). Post-hoc tests completed afterwards (Bonferroni correction) show that fewer picking errors occur with a projection-based assistance system in comparison to a paper-based provision of information ($z = 3.77$, $p = .001$). Therefore, the third hypothesis cannot be confirmed completely, and must be rejected.

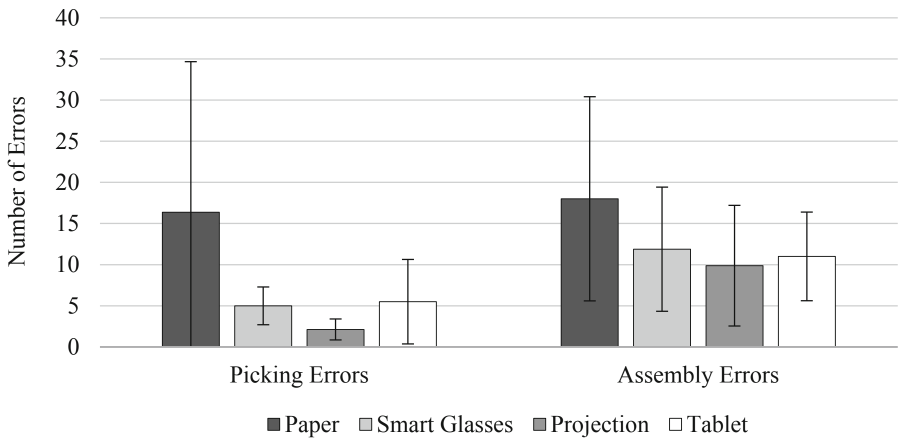

Fig. 2. Picking and assembly errors across all products and repetitions (mean values) depending on the assistance systems used (I–IV).

4 Conclusion

The results presented above show that hypotheses 1, 2 and 3 must be rejected, based on the available data. There are significant differences between individual assistance systems, but these do not persist across all products and all types of errors. This may be due to the sample size, but may also be due to the high deviation among assembly times and errors. However, a descriptive consideration of the results indicates that assembly assistance systems can help shortening assembly times and reducing errors. Furthermore, configuration and usage recommendations for informational assistance systems could be derived based on the results.

The usage of an informational assistance system does have the potential to reduce training times in a reasonable manner (hypothesis 1). Comparing the paper-based provision of information with the tablet-based assistance system, reveals a chance to reduce training times by about one-fifth. The average reduction in assembly time – across all repetitions – for product A is 20.77%, for product B 24.70%, and for product C 14.72%. The potentials of the tablet-based assistance system are also reflected in the initial assembly times for each product (hypothesis 2). Compared to the control medium the initial assembly times could be reduced by 28.52%, 26.95% and 21.48% for products A, B and C respectively. In addition, the results regarding the second hypothesis show that using a projection-based assistance system is one possible alternative to the tablet-based system (product A 15.13%, product B 15.93% and product C 15.46%). Furthermore, picking errors can be reduced most by using a projection-based assistance system, in comparison to the control medium (87%). Additionally, the other two assistance systems also help considerably to reduce picking errors (greater than 60%). These results are likely due to the fact that the container position was not represented visually in the control medium. There are no major differences between the individual assistance systems in terms of assembly errors. However, working with any of the assistance systems leads to an average decrease of 40% in assembly errors in comparison to the control medium. Based on the percentages for total savings, the application potentials shown in Table 1 can be derived for the three informational assistance systems. These relate to the main areas of investigation of hypotheses 1 and 3. In this way, Table 1 supports an application-specific selection of an assistance system based on the study results, such as using a projection-based assistance system to reduce picking errors.

Table 1. Application potentials of the informational assistance systems in light of the potential for reducing picking errors, assembly errors and training times.

Assistance systems	Application potentials		
	Reduction of picking errors	Reduction of assembly errors	Reduction of training times
Smart Glasses	Helpful	Helpful	Slightly helpful
Projection	Highly helpful	Helpful	Helpful
Tablet	Helpful	Helpful	Highly helpful

Furthermore, even in preparing the study, important findings on the best way to deliver assembly information could made. Initial pretest showed that information in the form of text should be reduced to a minimum, because texts were mostly not used by the participants. Using pictures, figures or symbols led to better results. The laboratory study also showed that providing information centrally, as is the case with the tablet-based assistance system, makes completing the assembly work subjectively simpler. There is no need for workers to search for information, since it is all displayed on the output medium. In contrast, with projection-based assistance systems workers must first locate information in the working system. So Information should be prepared in such a way that employees can view it in a set location and with a single glance. However, this recommendation for providing information centrally only applies to classic single workstations with a limited width. Otherwise, providing information centrally would require a significant amount of walking. In addition, the study shows that the tablet probably achieved such good results (for instance in terms of training times), because test persons were already familiar with the medium and how it works (in contrast to smart glasses) before starting the test.

The presented results of the study indicate that informational assistance systems can help to prepare information in line with employee needs and to increase productivity. In order to assess the potential of informational assistance systems more precisely, the study should be extended to a larger number of participants in the next project phase.

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Operating Assistance System for Machine Tools

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Abstract. The acquisition of in-process measurement data for the optimization of machined components is carried out using different measurement principles. Depending on the required information content, analyses are carried out by specialized production engineers under production-related or laboratory conditions. However, due to the complex interrelationships of different process parameters, optimization must be carried out under real production conditions. In order to achieve this, process analyses carried out on a milling machine are presented, which are performed by means of internal sensors. For use in the industrial environment, the user-oriented processing of this kind of measurement data is an essential requirement. The combination of machine-internal measured values and additional machine parameters enables an efficient and objective process optimization by qualified skilled workers on workshop level.

Keywords: Data visualization · User experience · Human machine interface · Process analysis · Machining

1 Introduction

The processes of metal-cutting production are subject to continuous pressure to optimization, especially due to increasing requirements with regard to efficiency, quality and flexibility of the production processes used [1]. At the same time, decreasing batch sizes and an increasing number of variants require even faster optimization of these processes.

Previously chosen practice-oriented approaches allow flexible reactions due to short-term changes in requirements. However, this does not provide the necessary information to be able to react more efficiently to similar disruptions in the future. This requires an assistance system that provides internal machine sensor data and thus enables objective process assessments. Machine operators can combine this data with their expert knowledge to solve similar tasks more effectively.

In the following, the user requirements determined and the usual procedures for in-process measurement are dealt with first. Subsequently, these are categorized with regard to their areas of application and existing optimization potentials of data preparation are shown.

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2 User Requirements

For all applications of optimization tools at the workshop level, a consistently practical orientation of the entire user experience is crucial. Only if this is ensured, will an assistance system gain sufficient acceptance among production employees, even in areas with high performance pressure. Requirements analyses carried out in manufacturing companies to date have identified three problem areas as particularly serious, from which specific user requirements arise:

First of all, it is necessary to reduce downtimes of production machines due to unforeseen interruptions. Due to a variety of influencing factors, these also occur in mature machining processes of series production. However, the monitoring effort required so far decisively limits the attainable productivity, since employees cannot perform any other productive tasks during this time. A notification about critical process changes can reduce this effort. This enables intervention before protracted downtimes occur and creates free capacities.

In addition, especially for small and medium batch productions, no complex studies for the optimal adjustment of a process are realized. The experience of a qualified worker is often decisive. Therefore, manufacturing processes are usually only optimized to the extent necessary to ensure economic production. Here, a data basis is missing to make objective statements about the tool utilization in a process. A target-group-oriented visualization of existing tool loads already opens up significant optimization potentials within a process.

Due to the prevailing time and performance pressure, solutions and results achieved are rarely documented in such a way that other employees can apply this expertise to similar problems. For this reason, documentation close to the machine, at best fully automatic, must be able to record process parameters and faults. This assured expert knowledge increases productivity and ensures that the company has the corresponding process knowledge of the employees carrying out the work.

3 In-process Sensor Systems

For the solution of the first two problem areas a multitude of sensors already exist for the acquisition of the necessary in-process measurement data from machining processes [2]. Depending on the user group, information content and required accuracy of the diagnosis, however, these differ enormously in the required effort, see Fig. 1. The signal acquisition and processing is the subject of numerous investigations. Especially a user-oriented and clear processing of recorded measured values is not sufficiently performed. For the different applications, there are different requirements for measured values and operators, which will be explained in the following.

Piezo electric force sensors are ideal for fundamental investigations of machining processes due to their outstanding measuring characteristics, but they also require the greatest measuring and evaluation effort of the methods mentioned here [3]. The sensitive measurement setup consisting of sensors, data connection, charge amplifier and measuring computer is not suitable for measurements under rough conditions during production. The interpretation of the measurement data is carried out subsequently and can only be carried out by specialized laboratory personnel.

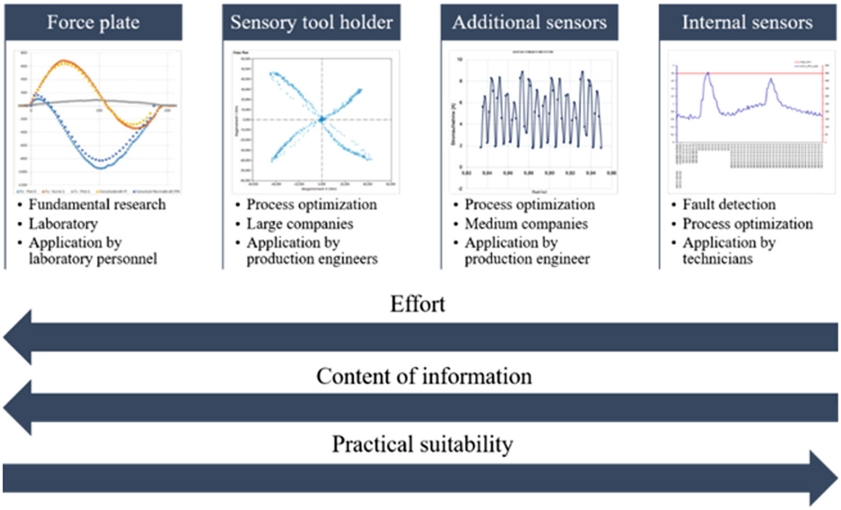

Fig. 1. Application areas and requirements of different sensor systems

In production-related measuring tasks, sensor-based tool holders based on strain gauges or vibration sensors are increasingly used. These systems partly provide measured values in the rotating tool reference system, which enables additional information and clear evaluations [4]. Data is transmitted wirelessly so that measurements can be carried out in a production-ready manner. However, the required sensor technology and measuring electronics reduce the rigidity as well as the possible temperature range and thus also the range of application of the tool. In addition, these systems require a single sensor for each tool used if all process steps are to be monitored. Due to their complexity, these systems are usually only used by specialized production engineers.

For analyses under production conditions, the use of existing internal machine sensors is recommended. Measurements are carried out under real conditions, without negative mechanical influence on the process. At the same time, machine manufacturers are now using a large number of sensors, which are used to monitor and control the machine status [5]. These data contain a very large optimization potential regarding the achievable efficiency of a production process. In manufacturing companies, however, they have hardly been used so far, since access to these data can only be achieved with great effort and by control-specific trained specialists.

4 Use of Existing Sensor Technology

The use of sensors already available within the machine offers a number of advantages over additional measuring systems. The following two examples describe which additional process information can be obtained from an existing GROB G350 machine tool (Fig. 2).

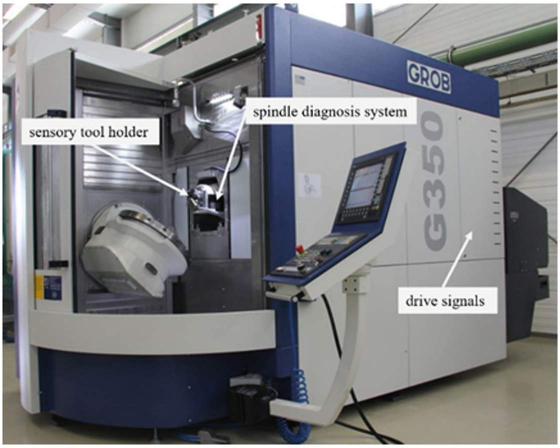

Fig. 2. 5-Axis machine tool GROB G350 with possible signals used as demonstrator

On the one hand, acceleration data is recorded by a fixed spindle diagnosis system via a vibration sensor at the height of the front spindle bearing and processed by means of evaluation electronics within the machine tool. This system is included in the scope of delivery of the investigated machine tool and was originally used there for spindle condition monitoring [6]. These signals are processed to transmit warnings and error messages about the status of the main spindle to the control system and to perform emergency shutdowns.

In the investigation carried out, simple process data were initially recorded. For this purpose, occurring oscillations are automatically processed into existing frequencies and their associated amplitudes by means of FFT analysis. By this data processing existing tool speeds can be determined on the basis of the occurring excitation frequencies. In addition, the amplitude of the vibration excitation is used to assess the cutting forces that occur. A worn tool causes higher cutting forces and thus higher amplitudes. Without an exact analysis of the vibration behavior of the machine tool, only relative comparisons between tools at constant speeds are possible.

Further use of machine-internal sensors for process optimization can be achieved by analyzing existing motor currents. This data is available due to the control of each drive motor and can be obtained from existing machines without additional sensor technology or hardware conversions. However, they are usually only used to optimize energy efficiency [7]. Up to now, several possible fields of application for an evaluation of occurring motor currents have been identified. In milling processes, for example, tool breakage due to high load gradients of the main spindle motor can already be detected. In addition, occurring force changes due to tool wear and varying application parameters can be reliably determined. Comprehensive process optimizations based on drive data and thus improved tool utilization enabled the machining time of the roughing processes investigated to be reduced by an average of 39%.

Even though an evaluation of drive signals has been possible for several years, it has not yet been able to establish itself as a process monitoring system. One of the reasons for this is the lack of machine and process data when motor currents are detected by external sensors. This makes a correct interpretation of the measured data and subsequent adaptation of the production process more difficult. However, by combining measurement and status data of the machine tools, the required evaluation effort can be greatly reduced.

5 User Experience

Due to the lack of focus on the needs of the user up to now, an optimization of manufacturing processes is only possible with considerable measurement and evaluation effort. A user-oriented preparation makes data evaluation even easier, so that it can also be carried out at workshop level. This enables a deeper understanding of the complex interrelationships within machining production processes and thus significantly simplified process optimization through targeted parameter adjustments.

In the examples presented here, a combination of measured values, as well as the current tool position and NC programming of the machine was carried out. This combination of already existing data allows a clear assignment of the previously programmed machining steps and parameters to the actual measured signals.

For an application at workshop level, data is prepared using an intuitive dashboard, which provides information on current machine states, NC programming, tools and machining times in addition to measured value trends. Measurement value interpretations are simplified by useful parameter combinations and filter options. The presentation of a possible structure is done in Fig. 3. This dashboard is to be implemented

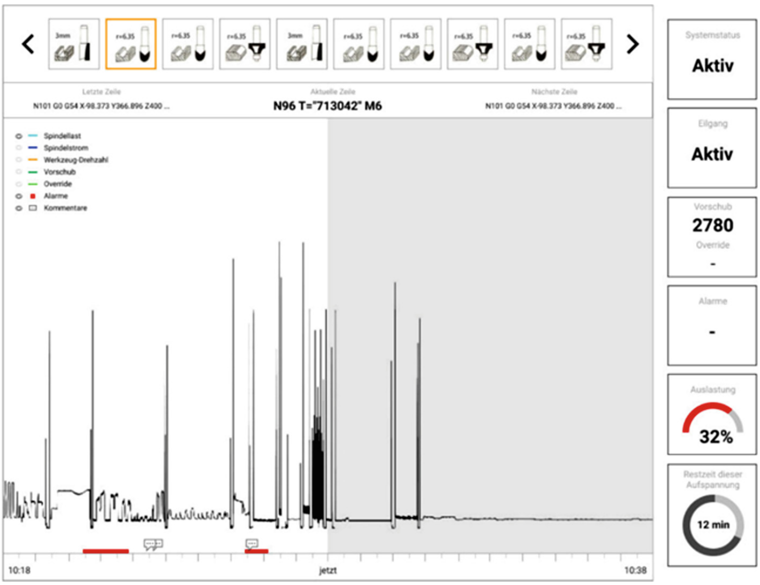

Fig. 3. Dashboard for the visualization of internal machine sensor data

as an additional application on the machine's own HMI, thus providing the machine operator with additional information and highlighting potential for improvement. The automatic backup of program changes made in connection with recorded measured values results in an objective and traceable process optimization. This secured knowledge enables a more efficient and agile production of similar components in the future.

6 Summary and Outlook

A large number of systems are already being used for the analysis and optimization of machining production processes. However, this does not sufficiently focus on the target group of well-trained skilled workers. However, a more sophisticated processing of measurement data gives this group of people the opportunity to contribute their comprehensive knowledge of machining processes based on objective data. This is decisively enabled by a combination of different machine-internal measurement data as well as a clear and user-oriented graphic processing.

Further investigations promise a significant increase in efficiency, as well as failure and process reliability, even for smaller batch sizes of machined components. A consistent orientation towards the needs of the manufacturing companies should be ensured by continuous tests and feedback from employees of the manufacturing companies.

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Human-Robot-Collaboration in the Context of Productivity Development and the Challenges of Its Implementation: A Case Study

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Abstract. Human-Robot Collaboration (HRC) is associated with the digital transformation of industrial processes. This paper provides an overview of potential fields of HRC implementation followed by a six-step procedure for analyzing potential workplaces for HRC suitability. Finally, an industry-based case study is presented, in which this procedure was applied and a productivity increase as well as a reduction of physical strain on the workers was achieved. It is shown that a structured integration of HRC into existing workplaces is worthwhile to gain the best results both for workers as well as the operating corporation.

Keywords: Human-Robot-Collaboration · Productivity management · Ergonomics · Machine interaction

1 Introduction

Human-Robot Collaboration (HRC) is associated with the digital transformation of industrial processes and is considered as a modern way to design work in industrial production environments, taking into account economic and ergonomic objectives. By using collaborative robots, companies expect their productivity to increase and their working conditions to improve. To achieve this, strengths of humans are combined with the strengths of robots.

HRC describes an interaction form in which no distinction is made between a working space for the robot and one for the human being. Touching is basically considered as necessary and desirable within the processes performed. However, unintentional contact must be recognized as such and adequately responded to by the robot in order not to cause injury [1]. This is made possible by intelligent sensors in

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combination with (limited) artificial intelligence in the form of sophisticated software systems. The ongoing technological evolution of collaborative robotics continues to expand its scope of application while reducing costs. However, companies wishing to integrate HRC are facing the challenges of determining the right fields of application for it and the possibilities that HRC brings to their existing processes.

The present contribution shows in which range of applications HRC can find its way into companies. Building on this, challenges associated with the implementation are addressed. Afterwards, a structured, multi-level approach for the selection of workplaces for HRC integration, including an assessment of the adaptation requirements for these workplaces for a best possible use, is presented. Finally, a case study is presented that was conducted at a company of the German marine industry in cooperation with the Kiel University of Applied Sciences.

2 Potential Fields of HRC Application

Collaborative robot systems are used where the strengths of humans are to be combined with the strengths of a robot to gain productivity improvements [2]. Human strengths include intuition, flexibility, decision-making and judgments. Robots, on the other hand, impress with their enduring, reproducible and precise movements. Taking this into regard, the process design is important to ensure efficiency and effectiveness of the robotic use. Collaborative robots are mainly considered to reduce physical strain on people, such as handling heavy loads. Therefore, HRC increases productivity of manual workstations, especially if they are not suitable for full automation for whatever reason.

2.1 Economic and Financial Issues

Human work is characterized by a constant development of unit costs and is particularly suitable for small quantities, whereas the fixed costs for a robot-based automation are distributed to the manufactured number of units, resulting in cost curves with a regression shape (Fig. 1).

HRC might be called a “centerpiece” between pure human labor and full automation and is characterized by unit costs that need to be calculated on a sufficiently large number of items to be manufactured, which justifies the investment for and use of these robots, but is too small to have full automation implemented [3].

Process designers therefore need to familiarize themselves with the cost structures of collaborating robots in order to know the impact on operating costs from an economic point of view if HRC should be used. To sum up the findings, HRC is used when manual work predominates, but the minimum number of pieces to be produced is large enough to justify the acquisition and set-up costs for such a robot system.

2.2 Technical, Organizational and Personal Issues

Workplaces considered for collaborating robots have to be regarded from a technical, organizational and personnel point of view (“TOP”). The technical view primarily

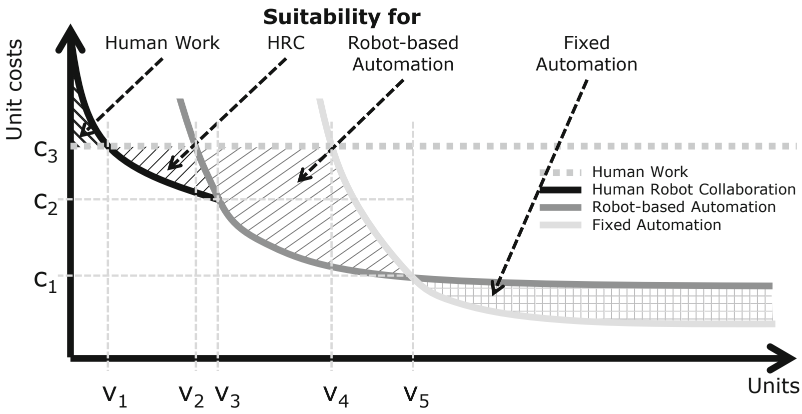

Fig. 1. Unit costs per type of robot and for pure human work [3].

focuses on hardware and software-related options as well as technical restrictions of the robot systems themselves. The organizational design of work, mainly in the context of the division of activities among human and robot, is based on the technical possibilities and restrictions. From a personal point of view, those aspects that are of primary interest to people at work, in particular their safety and abilities, must be considered [4].

Ergonomic aspects should be explicitly considered in process development involving HRC. In many cases, the hope for improvements in ergonomics represents a significant reason, in addition to cost-effectiveness, why companies decide to use HRC [5]. The responsibility for an ergonomic and safe use of robotic systems can be fundamentally attributed to the manufacturers of collaborative robotic systems, the companies that operate them and the workers using them at the workplaces. These three "actors" must design the use of the robot system, the tooling used and the workpieces to be operated to ensure safety and best possible ergonomics. For all these aspects, standards are given, mainly the ISO/TS 15066-2017 which especially addresses collaborative robots, among several others that are in general applicable for machine use at working places.

3 Multi-level Approach for HRC Implementation

Based on the aforementioned findings, a recommended procedure for companies that plan to use collaborative robots is outlined below (Fig. 2).

First of all, it has to be examined whether, in terms of process technology, collaborative work is possible at all. That means, the work organization specifies the further test procedure. The second step is to examine the suitability of the components and parts to be fabricated. For example, as a rule, sharp or hot parts are just as unsuitable for working with collaborating robots as pliable components. In the third step, the robot system to be used has to be checked with regard to its suitability for collaboration. It is recommended to implement specially designed robots from specialized manufacturers.

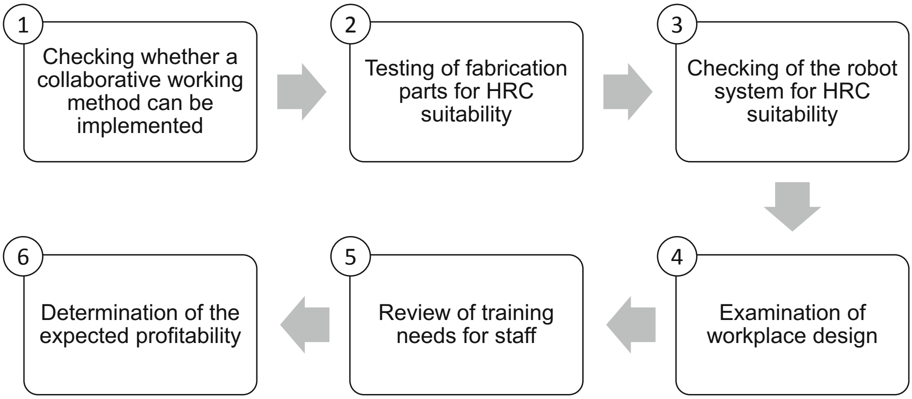

Fig. 2. Process model for testing for suitability for collaborative robots [1].

Subsequently, the examination of the workplace, at which HRC should to be used, takes place in the fourth step. Aspects such as the positioning of the robot and the handling of workpieces and tools are considered. For example, a variety of standards and regulations generally applicable to industrial robotic systems, which places emphasis on ensuring the safe use of HRC (e.g. ISO/TS 15066), must be considered. Afterwards, the fifth step is for checking whether the personnel, which should be assigned to the HRC workplace, is sufficiently qualified. It may be necessary to cover additional training needs. Lastly, in the sixth step a return-on-investment calculation should be made taking into account costs from the previous test steps [1].

The case study in the next chapter uses this six-step model for selecting a workplace for HRC implementation. The productivity potential of HRC is shown in this case study as well.

4 Case Study: Productivity Improvement Within the Industry

In the context of the potential of an HRC implementation mentioned in the beginning, several objectives emerged for the present case study. An empirical experimental approach was used to investigate how an implementation of the HRC concept affects time-economic variables of assembly tasks as well as the resulting work productivity. In addition to this, the final part is the answering of the question of how aspects change regarding the responsible employee as well as the required working procedures.

In the course of this empirical study, a distinction is made between two different experimental designs, namely the analysis of the current situation and the experimental design HRC. Afterwards a final consolidation of the generated results is given. The generated contents were developed in cooperation between the University of Applied Sciences Kiel and a partner company.

4.1 Analysis of the Current Situation

The analysis of the current situation at the selected assembly workplace was the first part of the project and serves as the reference point for the empirical survey. It was carried out in the course of applying a time recording procedure in accordance with REFA [6]. By summing up these time records, current total actual times of the assembly process were calculated.

Referring to [7], three criteria were used for the selection of the assembly workstation. The first criterion is the ability to standardise the whole executed process and the associated defined sequence of activities. As the second criterion, the capacity of the whole process and the actual number of pieces produced were considered. The third criterion is the frequency of repetition in combination with the long-term existence of the process in its defined sequence. In addition to these three criteria, the possibility for an execution using a lightweight robot was taken into account for the analysis and selection of the workplace.

For this latter purpose, mainly technical parameters such as the payload or the range of the robot were considered. Taking these parameters into account, a suitable assembly workplace was defined to be analysed in the present study. This assembly workplace is used to produce an industrially manufactured electromechanical device.

In the following, individual times of all human movements and assembly work operations as well as the required operating resources and environmental conditions were analysed. All work operations include the complete assembly of all relevant components to a device which is ready for dispatch. To complete the selected device, 28 work operations are required in which a total of 64 individual components are assembled. All these components include individual screws, electronic components, and the appropriate case. As a result of the analysis, it was determined that all cumulated individual times of the 28 assembly work operations cover a time period of 17.30 measured minutes which is required to produce one assembled device ready for delivery.

After completing the analysis of the current situation, the actual work productivity was determined. The determination of the productivity indicator was based on [8], in which work productivity is the quotient of a manufactured production quantity divided by the amount of required time. Thus, the result of the work productivity indicator is equivalent to a ratio of 0.0578 assembled devices per measured minute of work without using HRC. This corresponds to a production capacity of 3.5 units per hour.

4.2 Experimental Design HRC

The further procedure was characterized by the experimental investigation of all work operations at the selected workplace in order to check their suitability for applying them to a lightweight robot. The robot model used for this experimental investigation is a lightweight robot type KuKa LBR iiwa. The selection of the work operations was based on the consideration and evaluation of the aforementioned six different categories of Sect. 3. As a result, two work operations were selected which fulfil all six aspects. On the one hand, this is an operation of precise insertion of a selected component and on the other hand it is the operation of lifting a component weighing 8 kg.

In analogy to the analysis of the current situation in Sect. 4.1, the time-recording method by REFA was also used for the lightweight robot. The result of the lifting and subsequent insertion of a component corresponds to the cumulative time of 12.61 s (28.29 s without HRC). The individual times generated for the following tool replacement accumulate to a total of 10.03 s (new operation in the HRC case). The accumulated amount for the subsequent lifting and alignment of the heavyweight component resulted in a value of 14.53 s (34.25 s without HRC).

4.3 Implementation Results of HRC

The third and final section includes the reproduction of the future workplace, the demonstration of the potential work productivity development and the changing aspects regarding the employee. In the course of the above-mentioned combination of results and the reproduction of a new design possibility, the aim of finding the potential solution was pursued by applying the morphological principle. The result corresponds to the combination of the previously described work operations within a hybrid workstation concept. In the course of the implementation of a lightweight robot and the associated rearrangement of the work operations, the cumulative number of work operations increased to 31, which were partially rearranged.

The next step was the combination of the newly arranged operations and the time management variables generated in 4.1 and 4.2 to form a new type of work schedule. As a result of using HRC and the associated possibility of parallelizing three work operations, the total amount of cumulated individual times decreased to 16.21 measured minutes. The result of the division of the output quantity and the new number of collected working minutes corresponds to a ratio of 0.0617 mounted devices per measured working minute. This corresponds to a higher production capacity of 3.7 units per hour. The outcome of the productivity development within the examined area of consideration corresponds to an increase of approximately 6.75% compared to the original assembly process.

With a constant weekly production quantity, in addition to the time-based productivity improvement the physical relief for the employee is equivalent to a weight of approximately 32 kg per day. This is a major contribution to improved workplace ergonomics. Thus, the consequence is a reorganisation of the usual work operations, in which HRC helps to support the employees and to increase output (Table 1).

Table 1. Comparison of results between HRC and without HRC.

Unit	Characteristic	
	Without HRC	With HRC
Minutes of production per unit	17.30 min	16.21 min
Units per hour	3.5	3.7
Maximum payload by employees per unit	10 kg	2 kg

5 Summary

Collaborative robotic systems are a relatively new type of robot that is becoming increasingly popular in the industry and has its strengths in combining human capabilities with the advantages of a robot. For integration into existing workplaces, a structured analysis of the possible applications is worthwhile. Depending on the work process considered, a significant productivity potential – measured in terms of time and costs – can be raised, supplemented by improved workplace ergonomics and product quality.

This potential has been evaluated in a case study which was presented and led to an increasement of productivity of nearly 7% while relieving employees from physical strain.

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App Development via Low-Code Programming as Part of Modern Industrial Engineering Education

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Abstract. The Industrial Engineering Laboratory at the Ostwestfalen-Lippe University of Applied Sciences and Arts researches the user-centered, customer-oriented and efficient design of work and production systems. Its research focuses on investigating different technologies from the context of digitalization in industrial production. Software used to digitally support work processes must be adapted specifically to work systems. It is difficult to take various user requirements into account in standard software. Therefore, IT experts must continuously adapt software in order to make it suitable for different applications. One possible alternative is for software applications to be designed by industrial engineering or users themselves. In low-code programming, in contrast to classic software development, it is possible to create software applications without extensive programming knowledge. In the laboratory, a teaching unit on app development using a low-code platform was designed. It was integrated into an existing teaching concept for industrial engineers, then evaluated using a questionnaire.

Keywords: Cognitive assistance systems · Low-code programming · Didactics

1 Initial Situation and Objectives

The Industrial Engineering Laboratory at the Ostwestfalen-Lippe University of Applied Sciences and Arts researches the user-centered, customer-oriented and efficient design of work and production systems. In the course of its activities, demonstrators have been implemented to research different digitalization technologies in industrial production and to integrate them into teaching. Cognitive assistance systems are one example [1, 2]. In its integration of research into teaching, the Industrial Engineering Laboratory focuses on linking new digital technologies with proven methods of the Toyota Production System. For example, a business game developed several years ago to teach the Kanban method was supplemented by information technology components [3].

Software used to digitally support work processes must be specifically adapted to individual work systems. It is difficult to take various user requirements into account in standard software. Therefore, IT experts must continuously adapt software in order to make it suitable for different applications. Frequently, such solutions can be cost-

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intensive for the customer and can require long waiting periods, since there is a lack of IT professionals and IT departments therefore are subject to heavy workloads [4, 5]. One possible alternative is that industrial engineering employees or software users design operation-specific software applications quickly and easily by themselves, in order to digitally support and optimize existing work processes. This can be done using low-code platforms. In low-code programming, in contrast to classic software development, it is possible to create software applications without extensive programming knowledge using a graphic user interface [6].

A teaching unit for developing software applications around specific operational needs using low-code programming was designed in the laboratory. One requirement was that the software developed should be suitable for use on mobile devices, and therefore should be developed in the form of an app. The teaching unit was integrated into the scenario of the existing business game and was evaluated using a questionnaire. The goal of this paper is to show by using an example, how app development can be designed using low-code programming and how this approach can be integrated into industrial engineering education. Characteristics of low-code programming are described in Sect. 2. Section 3 deals with the integration of app development using low-code programming into the existing teaching concept. Section 4 contains a conclusion and an outlook.

2 Characteristics of Low-Code Programming

Five generations of programming languages can be distinguished. These range from machine language (first generation language) to artificial intelligence (fifth generation language) [7]. The term "low-code programming" has become established for the fourth generation of programming languages, also called declarative programming [6]. In low-code programming, in contrast to previous generations of programming languages, it is possible to create software applications without extensive programming knowledge using a graphic user interface. The code is created automatically in the background [6, 7].

Different screen views of the software can be created in the user interface of the low-code platform. Via drag & drop function, control elements, such as input fields, navigation buttons or drop down fields, can be inserted into the individual screen views. The screen views and control elements can be linked together using prefabricated functional modules. A complete software application can be constructed step-by-step using this method. Data sources such as spreadsheet files are typically stored in the cloud so that different app users can use the same database.

Martin used the term fourth generation language as early as the 1980s for software development that involved very little programming [8, 9]. Low-code programming is becoming more and more important, due to the lack of IT professionals and the heavy workload imposed on IT departments [4, 5]. At the same time, the demand for software applications designed around specific operational needs is increasing, in particular in app form for mobile devices. Such applications can help optimize processes and services and increase work productivity [10–13].

Low-code programming can help to deal with the described mismatch between increasing software requirements and limited IT resources. Industrial engineering can play a key role in this respect, since industrial engineering employees have the process expertise necessary, and since low-code programming provides them a tool for digitalizing business processes. Low-code programming offers a way to design software quickly and easily and to avoid time spent waiting for IT experts to complete programming services. Furthermore, there is a good potential of finding a customized solution, since the employee, as a process expert, understands the requirements best and can design the software as needed. In addition, an increased use of low-code programming can potentially lower the workload in IT departments and allow them to focus on more complex programming tasks. As a consequence, the low-code platform market is projected to grow very quickly, from 4.3 billion dollars in 2018 to 21.2 billion dollars in 2022 [6].

3 Integration of App Development Using Low-Code Programming into Industrial Engineering Education

Section 3 presents the didactic concept used in the Industrial Engineering Laboratory at the University of Applied Sciences and Arts (3.1). Then, the newly designed module for app development using low-code programming as part of the existing teaching concept is described (3.2). The section concludes with a description of the evaluation and assessment of results for the developed teaching module (3.3).

3.1 Didactic Concept of the Industrial Engineering Laboratory

The Industrial Engineering Laboratory contributes with various teaching modules to the education of industrial engineers at the Ostwestfalen-Lippe University of Applied Sciences and Arts. These modules include the production systems module, in which the developed teaching concept was applied. Essential teaching contents of the module are structure, methods and development stages of production systems. Business games are particularly well-suited to transmit the teaching content [3]. Therefore, students are taught methods for designing production systems via business games.

In recent years, demonstrators were implemented in the laboratory to research different information technologies in industrial production and to integrate these into teaching. The laboratory focuses in particular on linking new, digital technologies to proven methods of the Toyota Production System. For example, a business game developed several years ago to teach the Kanban method, has been supplemented with information technology components [3]. The object of the Kanban business game is a diverse vehicle assembly that must be supplied with material from a warehouse. The vehicles are made of LEGO® bricks. The developed business game is played in several rounds. The first round simulates a classic material supply scenario. In the second round, material is supplied following the Kanban method. The third round involves digitalizing the flow of information maintaining the Kanban method. A pick-to-light system, sensory lights and an RFID reading head are integrated into the material supply and assembly process, for instance.

In further stages of the business game, the focus is on using assistance systems in assembly. For instance, the students must plan and implement the introduction of an image processing system for quality assurance of assembled LEGO® vehicles. To do so, they configure the image processing system by means of various software tools in such a way that the assembled vehicles can be identified as accurate or defective via diverse characteristics.

3.2 New Teaching Module for App Development Using Low-Code Programming

Due to the increasing importance of low-code programming and available software applications for mobile devices (Sect. 2), a teaching unit for app development using a low-code platform was added to the teaching concept described in Sect. 3.1. The primary learning objectives of this newly developed teaching unit in the production systems module are that students recognize the importance of low-code programming for industrial engineering and collect initial experience with this kind of programming. The new teaching unit is to fit into the existing business game for the assembly of LEGO® vehicles.

In order to achieve the learning objectives, students are asked to develop an app to support quality assurance for assembled LEGO® vehicles using low-code programming. To do so, they design screen views first for the start menu, second for recording samples of tested LEGO® vehicles, and third for analyzing the samples. On the one hand, the focus is on the design of input and output mechanisms via control elements (frontend design). On the other hand, the outsourcing and delivering of data sets using cloud services is of importance (backend design).

It should be possible to enter the inspector name, the tested products, the sample results and the error code on the "Record sample" screen view. The product, the sample results and the error code should be shown in drop-down fields, so that the app user can enter information with as little work as possible. The current date and time is to be documented automatically during the recording of samples. In addition, the "Record sample" screen view should be designed so that the entered data is written into a spreadsheet file in the background that is saved in cloud storage.

In the screen view "Analyze" the user of the app should be shown a table with all completed recordings, which can be sorted by individual filters for date, product, inspector, sample result and error code. For this purpose, the above-mentioned spreadsheet file is to be accessed. The low-code platform used is browser-based. Along with the use of a cloud service, the developed solution can be used on all commonly available mobile devices with an internet connection.

The focus of the teaching unit is not the development of the software concept, but the implementation of the given concept via a low-code platform. To do so, students working in small groups of three to four people receive a detailed task description, which also provides step-by-step instructions for developing the app. The first steps of app development are described in detail in the instructions. The amount of assistance is reduced as the tasks progress.

After completing the app, the students test the software application they have developed for quality assurance of assembled LEGO® vehicles, making any adjustments as needed. Figure 1 shows an example of a screen view to be designed in the quality assurance app.

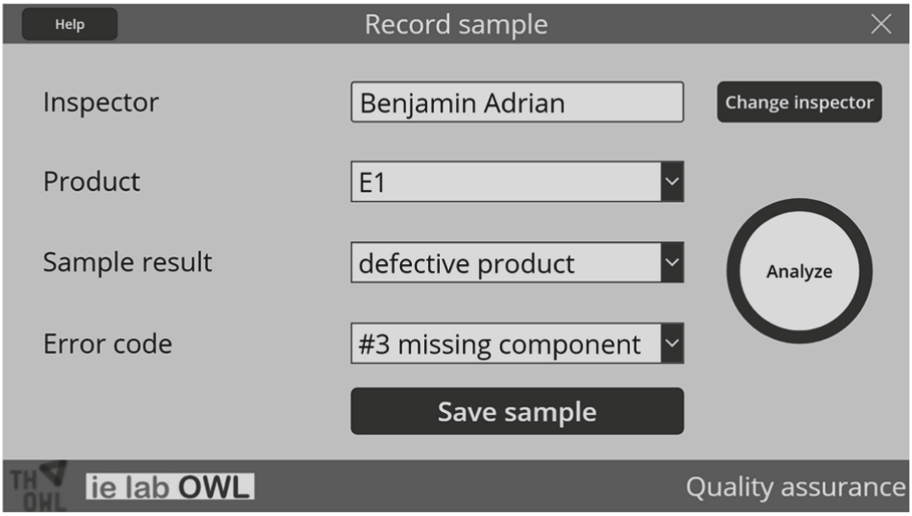

Fig. 1. Example of a screen view to be designed in the quality assurance app.

3.3 Evaluation of the Developed Teaching Module and Assessment of Results

The teaching unit for app development using a low-code platform was tested and evaluated in regular teaching. Ten industrial engineering students were surveyed. The questionnaire used for the evaluation was divided into the sections “Organization and structure of the teaching unit”, “Execution of the teaching unit”, “Learning success and practical benefit” and “Overall assessment of the teaching unit”. The questionnaire contained 27 items in total in all four of the above-mentioned areas. Of these, 20 items were Likert-scaled with five values (1 = completely correct, 5 = not at all correct) and four items with three values (individual for each item). Free text answers were queried in three items.

In the Likert-scaled part of the questionnaire with five values, respondents evaluated the teaching unit as a supporting tool for the learning process (mean value (mv) = 1.3; standard deviation (s) = 0.5) and the selected teaching format as suitable for practically deepening theoretical course contents on the topic of low-code programming (mv = 1.1; s = 0.3). In the opinion of the respondents, developed low-code apps can contribute to process optimization (mv = 1.1; s = 0.3) and can provide people with useful support in completing their work (mv = 1.1; s = 0.3). Participants rated the level of requirements (exactly right (100%)) and group size in the teaching unit (exactly right (100%)) as appropriate on the Likert-scaled part of the questionnaire with three values. In the free text fields, respondents positively emphasized, among other things, the high percentage of independent practical work, as well as the instructions and support received during the teaching unit. One negative note was that, in some cases, there were long loading times during programming.

4 Summary and Outlook

In this paper, it is shown by an example how app development using low-code programming can be integrated into industrial engineering education. In a new teaching module as part of an existing business game, industrial engineering students are taught how apps in the context of industrial engineering can be developed as needed in a short time and without extensive programming knowledge. This is done using the example of developing digital support for quality assurance. Thus – following the example of existing teaching units of the business game – a way is shown to support the philosophy of the Toyota Production System through new technological approaches. Digital tools like app development using low-code platforms can be used to optimize processes and avoid waste that occurs, for instance, in hand-written documentation and data processing. Integrating the topic of low-code programming into education is intended to enable industrial engineers to digitalize business processes by developing simple apps. Thus, the goal of creating consistent digital process chains and a paperless factory is taken into account.

The evaluation of the teaching module that was conducted showed that integrating low-code programming into the existing business game experienced a high level of acceptance, and was perceived to be conducive for the learning process. Since the number of respondents was relatively small, an expanded evaluation is planned. In the future, it is intended to add further expansion levels to the business game to connect the organizational and personnel aspects of the Toyota Production System with aspects of digitalization, thereby ensuring that production is both highly productive and humane. In addition, further use cases of low-code programming for cognitive assistance systems should be tested. One example can be the design of assembly instructions for manual assembly via low-code programming.

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Competencies and Culture for Smart Manufacturing and Industry 4.0

Leadership and Corporate Culture as Key Factors for Thriving Digital Change

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Abstract. Digitalization, artificial intelligence (AI) and in particular increased availability of data enables companies to develop new or changed business models and generate additional revenues. In order to use these potentials successfully, the implementation of hybrid business models and new technologies often also requires a change in the existing management and corporate culture. Nevertheless, many companies neglect to accompany technological changes by developing the skills of managers and employees. Therefore, the Institute of Applied Industrial Engineering and Ergonomics conducted a Germany-wide online survey of specialists and executives (n = 178) to analyze the status quo and the requirements for personal development and leadership of companies from the German metal and electrical industry [1, 2].

Keywords: Leadership · Corporate culture · Digital transformation · Hybrid business models · Change management

1 Introduction

The "Digitalization is shaping organizations, work environment and processes, creating new challenges leaders have to face" [3]. Digitalization and artificial intelligence (AI) also have numerous new possibilities and opportunities to make work more productive and healthier. One reason for these changes is that AI extends the systems by the ability to process tasks independently, which includes that AI can take over decisions and control processes entirely (autonomous) or partially (hybrid; semi-autonomous). Thus, it can be assumed that the introduction of AI systems in companies, can influence the decisions of managers and the collaboration between them and their employees and may also have an impact on the corporate culture. At the same time, the existing corporate culture in the company determines whether and how digital technologies (including AI) are integrated and used in the company [4, 5]. A study examining the impact of leadership styles on the digital transformation of an organization, found out that "…leadership styles are influential in organizations and can implement norms, expectations, and desirable outcomes during large-scale transformative projects" [6].

However, the concrete knowledge about the influence of the digital transformation on leadership is only at a starting point [7, 8]. One reason might be, that the implementation of AI procedures in German companies can be regarded as rather low [9].

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The aim of the present study was therefore (1.) to determine whether the assumed changes by AI in leadership and corporate culture can already be observed in the companies and what these changes look like. Likewise, (2.) it was examined what the companies do or what can be done to prepare managers for the socio-technical changes.

2 Method

In order to clarify the above-mentioned questions, a two-step approach was applied. In the first step, an online survey was conducted within the research project TransWork. The goal of this survey was to obtain an overview of the changed requirements, needs and activities of the questioned companies. In the second step, based on the results of the online survey, a concept to change leadership and corporate culture is being developed. The development, testing and implementation of the concept takes place within the research project AnGeWaNt in three medium-sized companies that are introducing a hybrid business model.

2.1 Procedure, Sample and Analysis of the Online-Survey

The Germany-wide survey was conducted using the SoSci Survey platform in the time from May to August 2019 (16 weeks). The questions were initially tested in a preliminary study. Specialists and managers of companies and of the employers' associations of the metal and electrical industry in Germany were informed about the survey and invited to participate. In addition, press releases and an invitation to participate were sent out by e-mail to motivate further experts from other economic sectors to participate. The survey consisted of seven thematic question blocks. The results of the present paper refer to the seven questions from the thematic question block "leadership and digitalization" [1, 2, 10].

The sample of the online survey consists of 178 specialists and managers, which work in different economic sectors - 77 percent of the respondents are from industry and manufacturing, 17 percent are from the service sector, the remaining persons are employed in the transport and traffic, agriculture and forestry, energy and construction sectors. The surveyed specialists and managers work predominantly as managing directors or production managers (40%) as well as in the areas of personnel, logistics and industrial engineering (35%). 17 percent of the participants work in small and medium-sized companies (<250 employees), the majority, 83 percent of the participants, comes from large companies (250 to >1000 employees [1, 2, 10]).

2.2 Procedure and Sample for the Concept Development

Based on the results or needs identified in the online survey, a concept for changing an existing management and corporate culture will be developed for companies that either already use AI applications or plan to use them. The concept will be developed in form of a methodological toolkit, which companies can use to analyze the necessary requirements and select the required instruments and methods. The development and testing of the concept respectively the methodological toolkit will take place in three

SMEs, in which hybrid business models are currently being introduced. Therefore, four development phases (analysis, conception, implementation and evaluation phase) are intended.

In the first phase, the status quo of management and corporate culture in the three sample companies will be determined (analysis phase). For this purpose, a first workshop with the executives and the management was held in August 2019 in one of the companies. The aim was to find out what the participating managers and the general manager expected from the changes in leadership and corporate culture and to derive initial goals for the development of the methodological toolkit. The workshop also served to provide the managers with an idea and information on possible changes in leadership and culture by implementing new technologies or a hybrid business model. With regard to the upcoming change process in the company, the method "The four rooms of change" [11, 12] was conducted to get deeper insight of the status quo of the change process. In addition, interviews with the persons responsible for management and organizational development from the HR department are currently being conducted. The purpose of these interviews is to determine, whether management guidelines are available and which measures for management and cultural development have already being used in the company. To determine the perceptions and attitudes of employees and managers of the current management and corporate culture additional surveys may be conducted.

In the subsequent conception phase, concrete methods (e.g. coaching, learning concepts, information materials) will be developed and compiled according to the analyzed needs. In the following implementation phase the selected methods and instruments are implemented in the companies. In the final evaluation phase benefits and effects of the implemented methods are assessed and improvements are incorporated.

3 Results

In the following, the results of the online survey as well as the first results of the development of the methodological toolkit for adapting or changing the existing management and corporate culture are presented.

3.1 Online-Survey

The central results of the question block leadership and digitalization of the online survey show [10, 11]:

a) 72 percent of the respondents ($n = 105$) answered that they want to change the leadership culture in their company.
b) According to 81 percent of the respondents ($n = 108$), the implementation of digital technologies has changed the demands on managers. The more the respondents were employed in large companies, the more they indicated that demands have changed ($n = 94$; $r_s = .35$; $p = .001$).

c) Regarding the question which demands have changed for the managers, they mostly answered, that the qualifications needed and the required leadership style itself have changed. They also named a need for faster decision-making processes based on improved data and a changed communication especially because of the use of digital "tools" (see Fig. 1).

Fig. 1. Answers of the specialists and managers to the following question: "Which requirements have changed for managers due to the implementation of digital technologies?" The size of the words corresponds to the number of answers in total.

d) According to the survey participants (n = 85; 414 answers in total; multiple answers possible), the changes are most evident in the areas of production (13%), planning and control (12%) and logistics (11%).

e) In opinion of the respondents (n = 74; 154 answers in total; two possible answers), middle (48%) and lower management (38%) are particularly challenged by the changes. Only 14 percent see upper management as particularly challenged by the introduction of new technologies. Respondents from larger companies stated less often that upper management is challenged by the introduction of digital technologies than respondents from smaller companies (n = 74; r_s = .30; p = .010).

f) In order to support managers to master the changes, 56 percent of the participants (n = 82) state that the company uses the following methods to do so: trainings, workshops, coaching and qualification courses (see Fig. 2).

Fig. 2. Answers of the specialists and managers (n = 82) to the following question: "Which methods do you already use to prepare managers for the implementation of digital technologies?" The size of the words corresponds to the number of answers in total.

g) Asked, which methods the managers generally consider to be most helpful in accompanying the change in the company, they (N = 76) stated that workshops and seminars (25%) as well as training (24%) and coaching (16%) are seen as the most helpful instruments.

3.2 Method Toolbox

The results of the first workshop show that the expectations of the participating managers (n = 9) include the following aspects [10]:

- more clarity about management tasks & a common understanding of leadership
- new and clear structure of cooperation across all levels
- getting to know methods and tools (to improve communication, performance)
- less routine - more creativity
- prepare the employees for the change
- making sure, that customers are able to use the new products (technical affinity)

The results of the method "The four rooms of change" [11, 12] indicate that the managers are aware of the need to change their leadership-style. This is the most important requirement for a positive development of the change process. The results have shown that the managers are willing to leave their own "comfort zone" to learn new behaviors and drive the change. In order to manage possible uncertainties (and possible fears) of the employees, the managers believe that on the one hand it will help to define a clear vision, how the new leadership culture can be "lived". On the other hand, they suggested to specifying concrete goals, what should be achieved with the implementation of AI in the area of leadership and culture and point out the personal use of the new technologies. In addition, the implementation of a pilot project would also be helpful to generate concrete and positive experiences with the new technologies.

4 Conclusions

Digitalization and AI make it possible for many companies to develop new or changed business models and generate additional revenues. A Germany-wide online survey of specialists and executives showed, that in order to use these potentials successfully there is a need to change or adapt existing management and corporate cultures. This fact was confirmed by both the managers and specialists of companies participating in the online survey as well as by managers of companies developing a new business model. Furthermore, methods that have been considered as helpful to drive the change process, were mostly methods with high practical use such as workshops, trainings and coaching.

Since one of the aims of this study is to develop a methodological toolkit to accompany the change of leadership and corporate culture while implementing AI in the companies, it can be noted, that the tools contained in the methodological toolkit should be of a high practical use. First ideas for concrete contents for these workshops can be for example to provide information about how to define criteria according to which intelligent software makes decisions. The most challenging fact for developing a methodological toolkit will be to find methods that are general enough to be applied by several companies and at the same time be of a high practical use for the specific company using the methods.

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Systematic Competence Building as a Success Factor for Establishing Hybrid Business Models

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Abstract. The article describes a dialogue-oriented concept for analyzing future competence requirements for establishing new business models. The concept has been tested within three German small and medium enterprises. Based on the results it is possible to develop strategies for building up skills the enterprises will need in future. In this context, it should be noted that competence gaps on the customer side can counteract the successful establishment of new business models. A consideration of this aspect as well as possible solution approaches, which were compiled in workshops with three pilot enterprises, will be presented.

Keywords: Hybrid business models · Competence building · Digitalization · Artificial Intelligence · Workshop concept

1 Hybrid Business Models Enhancing Competitiveness

Rapid change, driven by technology, can lead to changing markets. In very short cycles organizations are facing new challenges, such as suddenly emerging new market players with innovative products that jeopardize their competitiveness [1]. Companies must be prepared. They should be able to recognize future developments at an early stage and quickly develop alternative or complementary business models. In particular, the new technical possibilities, Artificial Intelligence (AI) and the availability of large amounts of data (big data) open up opportunities for companies with which they can generate added value for customers in addition to their actual physical products, generate additional revenues and increase or maintain their competitiveness [2, 3].

New data-driven hybrid business models and the introduction of the necessary technologies usually lead to changes in the company's work tasks, resources, environment, cooperation and teamwork. An essential success factor for the use of AI and the establishment of new data-driven hybrid business models is the appropriate competence of the workforce [2, 4, 5]. Therefore, changes due to the digital transformation and future competence requirements should be systematically analyzed in the companies as well as the requirements on the customer side. This can be considered already during the concretization of the business models and the strategic planning about their realization.

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In the BMBF-funded research project “AnGeWaNt - Arbeit an geeichten Waagen für hybride Wiegeleistungen an Nutzfahrzeugen” (FKZ: 02L17B050), three pilot enterprises (SMEs) are developing such data-driven hybrid business models. Besides the individual business models, the overriding goal in AnGeWaNt is to develop a common, cross-company business model and collectively create value.

The project follows a socio-technical approach, which ensures that the change process consider the needs of the companies as well as the needs of their employees. This includes, for example, preparing the workforce for the change process and analyzing the new competence requirements of employees and managers that accompany the changes and at least developing strategies to build up the necessary competencies.

In all three SMEs, the previous business model is based on the sale of physical products (scales, construction vehicles and attachments for construction vehicles) and related services such as commissioning, maintenance and calibration service. To expand their current business model into a so-called hybrid business model these products and associated services are intended to be expanded with digital technologies and data-based services (e.g. data collection and data analysis). The data of product usage can be exploited to provide hybrid services like data aggregation, supply and analysis, for predictive maintenance or benchmarking, as illustrated in Fig. 1.

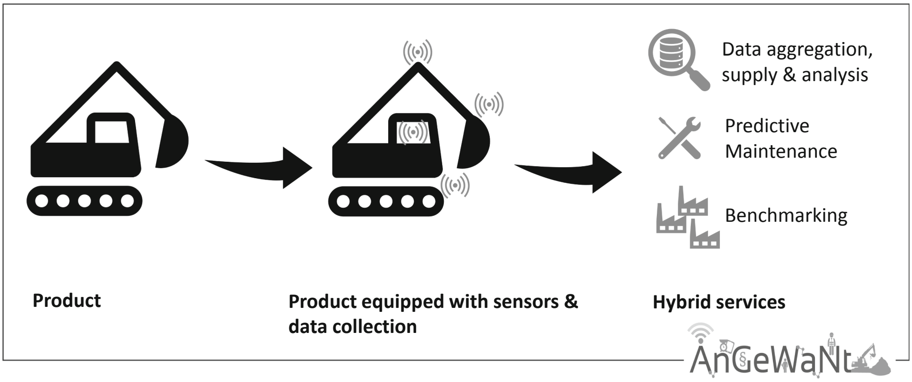

Fig. 1. Exemplary, simplified illustration of the development of hybrid services using the example of the product shovel excavator [6].

2 Competencies to Establish Hybrid Business Models

In all three pilot companies, competence requirements for the implementation of the business models were identified that could not be covered by the company so far. Especially competences in the field of data sciences (programming and data analysis) and for the development of IT infrastructures as well as legal knowledge are needed to extend the existing business models in the project AnGeWaNt.

Competence building is therefore one of the decisive activities that must take place in order to implement and establish the hybrid business models. The project will therefore develop an approach that ensures the following:

1. Early identification of competence requirements for the establishment of new business models
2. Development of strategies for competence building, considering the demands and resources of SMEs
3. Sustainable and resource-conserving development and maintenance of competences through work design that promotes learning and work-integrated learning concepts

In the following, the workshop concept, which is used to identify competence requirements (1.) and results from the pilot project, will be presented.

2.1 Changing Working Conditions Through New Business Models (Workshop Part I)

In the first part of the workshop, the reflection of actual business models was initiated with a focus on different aspects of change, especially tasks, working tools, working environment, cooperation and teamwork. In the following the results and possible changes reported by the employees of the participating companies are displayed in Fig. 2 and will be described:

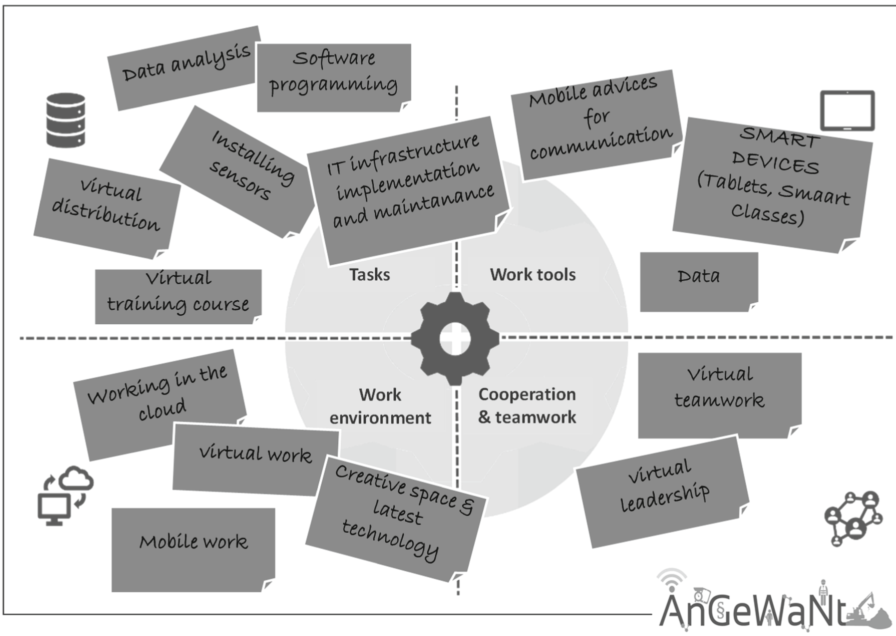

Fig. 2. Examples of changes in the pilot enterprises through hybrid business models (Workshop Part I) [7]

Internal project teams, worked out which tasks in the company will change as a result of the new business model, or whether completely new tasks will occur. One of the pilot companies is planning to record product usage data for customers in addition to its physical product, and to offer this data to customers as an additional service. The added value for customers is for example, the possibility of being able to estimate future construction costs more accurately based on past data, thereby making it possible to carry out a reliable calculation. In case of public tenders, for example from local authorities, this opportunity enables to prepare competitive and cost-covering offers and increase the chances of winning contracts. In addition, predictive maintenance can be made possible through usage data and a failure of machines can be counteracted. This requires new competencies, for example, for the installation of sensors or data collection and evaluation methods during operation (Fig. 2). In addition, new business models are accompanied by an increased use of technology and the introduction of new tools such as smart devices (tablets, data glasses and so on), which require new skills to operate them (Fig. 2).

The participants of the workshops assume that the implementation of the new business models needs to establish cloud services for exchange of data and subsequently the future working environment will be more virtual and flexible regarding time and place. In addition, technically equipped creative spaces should enable interdisciplinary project teams to develop new ideas quickly and makes it comfortable to test them directly with appropriate technology (Fig. 2).

A virtual, cloud-based working environment is also accompanied by virtual cooperation and leadership, which also change demands on the social and personal skills of employees (Fig. 2).

In addition, it was discussed which business areas will be particularly affected by the change process and which organizational structures develop differently through the new business model. The more concretely the business model ideas are worked out, so much sooner conclusions can be drawn on these aspects. Exemplary changes, which were worked out in the workshops with the project teams, are shown in Fig. 2.

An essential aspect that should also be considered is the technical change, or rather the digitalization at customer's side, because this influences their work and has an impact on the required know-how of employees. Therefore, the three SMEs in AnGeWaNt considered in the competence requirements analysis (Workshop Part 2 see Sect. 2.2) which competence levels their customers actually have. It could be assumed that the sale of access to databases may only be successful if the customers realize they have a benefit from it. This presupposes that they have qualified specialists who can analyze and interpret these data. It has been discussed to train a change manager or digitalization scout, who would advise the customers holistically and support them during the introduction of the technology.

2.2 Competence Gap Analysis for Establishing Hybrid Business Models (Workshop Part II)

Based on the results of the first workshop part, the second part explicitly addressed specific competence requirements that arise from digitalization and the hybrid business models. Based on a literature compilation of various core competencies, the participants were introduced about the anticipated future competence requirements in three categories 1) technological competencies, 2) digital competencies and 3) social and personal competencies [8]. The core competencies are described in the following (Fig. 3):

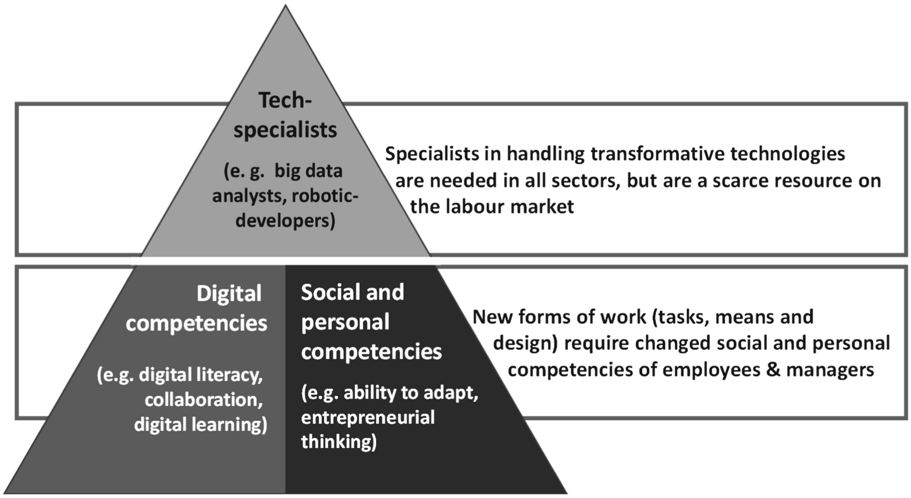

Fig. 3. Dimensions of future skills [8]

Re 1: The results of the study by [8] shown that in particular the so-called tech-specialists, i.e. those who are educated in data science, programming or hardware-robotics development, are needed in all sectors, but represent a scarce resource on the labor market. Exactly these technical skills, especially data science are also needed by the SMEs in the AnGeWaNt project to implement the hybrid business models successfully. The companies therefore faced with the challenge of building up technical expertise, without the business models cannot be developed.

Re 2: In addition, digitalization necessitates more digital competences. This includes, for example, the adequate handling of the diversity and quantity of data and information (digital literacy) [8]. The key competence is (self-)critical handling of digital information: finding valid information, producing it oneself and making information available digitally [9].

Re 3: The demands on the social and personal skills of employees are also changing through the digitalization. The rapid changes in different working areas require a high degree of adaptability and willingness to change on the employees' side [10, 11]. In particular, the implementation of technology can trigger fears and prejudices in the workforce, because not everyone has a so-called "digital mindset", is curious about innovations and technically skilled.

Following this thematic introduction of the core competencies, the project team in the workshops received a competence analysis portfolio which they used to evaluate the relevance of the described competencies for their new business model. The portfolio provides an overview of the necessary competences and their availability in the company, and whether they can be built up from internal resources or whether external specialists need to be recruited or cooperation with external providers is necessary. In addition, they discussed if their actual customers will also need to require this competence in the future. Finally, the participants of the workshop assessed the priority of the respective competences in connection with the new business models. Figure 4 shows an example of the portfolio structure based on the competence “Complex Data Analysis”.

Fig. 4. Competence analysis portfolio with the example of the core competence “Complex Data Analysis” (Workshop Part II) [7]

3 Summary and Outlook

The development of the hybrid business models in the pilot enterprises has shown that there will be many changes in their work environment. Working tasks, working tools, cooperation and teamwork will change rapidly and this requires new or different competencies in their workforce. The first results regarding necessary competence requirements from business model development workshops were taken up and deepened in a further dialogue-oriented workshop. This workshop showed the companies, besides the necessity of competence development, that the new business models will lead to fundamental changes in the companies, which may affect the whole workforce. Tasks, work equipment, working environment, cooperation and teamwork will change. This will also have an impact on structures and processes. The competence analysis provides information about which competences are needed and are of high priority.

Based on these results, the next step is to analyze the current status of competence development and to create appropriate competence profiles. Further analyses in the companies should provide information about which methods and tools are currently being taken to develop competencies. The results of the analyses serve as a basis for developing strategies to build up future competencies.

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How to Teach Digital Tools for Process Automation in Industrial Engineering Education

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Abstract. Programmable logic controllers (PLCs) have become the industry standard and have replaced hard-wired electrical devices used to control production equipment. With its advanced use, the PLC is increasingly becoming an important part of engineering. Therefore, it is essential to effectively teach students how PLCs work and how to program them through practical exercises. The goal of this paper is to present a training set used to program a PLC that fulfills the needs of industrial engineering students. The training set presented here allows students to learn about different industrial applications of PLCs, and to program such PLCs themselves.

Keywords: PLC · Digitization · Industrial engineering · Training set

1 Introduction

The twenty-first century is characterized by ongoing digitization, accompanied by increasing technical complexity. This results in growing demands on the expertise of employees in engineering in general, and in industrial engineering in particular. Industrial engineers must design work systems in light of relevant technical, organizational and personnel aspects. Increasingly, industrial engineering is tasked with planning and implementing digital support for work processes, turning the concept of the paperless factory into a reality. This requires changed competencies in industrial engineering. Increasingly, industrial engineers must be able to handle programming tasks themselves, or at least develop detailed concepts for digitizing work processes. These requirements apply in particular to assembly for complex products like machines. Assistance systems providing cognitive support to employees as they handle manual assembly tasks are becoming increasingly important in this area [1]. Programmable logic controllers (PLCs) are used to design these assistance systems, for instance to create pick-by-light systems. The education system must also be developed continuously to meet the changing requirements imposed on industrial engineers. New teaching and learning concepts are needed to transmit content of digitization in a practice-oriented way. The acquisition of competence should be achieved through active and socially cooperative action by the students [2]. Teaching units should be

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designed to allow students to independently complete tasks in small groups and then present their results. Dealing independently with the teaching content and practical implementation of the delivered content support the learning process.

A variety of training sets have already been developed by the industrial engineering laboratory at the Ostwestfalen-Lippe University of Applied Sciences and Arts to teach content on industrial digitization [3]. The goal of this paper is to present a training set used to program a PLC and explain the associated didactic concept. The training set has already been integrated into the teaching concept of the production system module and evaluated using a questionnaire. Following the introduction, the paper is divided into four further sections. Section 2 presents theoretical principles on automation and PLCs in industrial production. Section 3 presents the training set developed to teach PLC programming. Results of the evaluation of the training set are presented in Sect. 4. Section 5 includes a conclusion and an outlook.

2 Industrial Automation and PLCs

Industrial automation can be defined as a process that allows required procedures to be launched automatically, in order to achieve desired results in industrial production [4]. Automation is the foundation of modern technological progress [5]. In automation, PLCs have become established as standard control devices [6]. The popularity of the PLC is due to its functionality and flexibility in controlling a large number of inputs and outputs. Before PLCs were developed, hard-wired controllers were used to control production systems that involved electromechanical components such as relays. Most controllers were hard-wired, which made changes expensive and difficult. PLCs have changed this since their first application in the 1960s [7]. Modern controllers have a modular structure. This modular structure consists of a controlling processor with a memory and processing unit, a power supply and an input and output module [8]. In accordance with DIN EN 61131-1 [9], the term PLC is defined as follows:

"A digital electronic system for use in industrial environments with a programmable memory for internal storage of user-oriented control instructions to implement specific functions, such as logic control, sequence control, time, meter and arithmetic functions, in order to control different kinds of machines and processes through digital or analog input and output signals. The programmable logic controller and associated peripheral equipment (the PLC system) are designed so that they can easily be integrated into an industrial control system and used in all of their intended functions." A PLC, therefore, is a computer specially designed to handle control tasks.

The LOGO! small control system from Siemens offers a simple platform for learning PLC programming. This small control system is a universal logic module, used in industrial automation in machine controllers (such as motors, pumps, air compressors) and transportation equipment (such as conveyor belts, lifting platforms, silo systems). The system is ideal for installation in switch cabinets due to their conventional, space-saving design. The LOGO! offers eight basic functions (logical operators) and 26 special functions, replacing switching devices such as timers, relays, meters or auxiliary contactors. The LOGO! can be programmed using the integrated buttons and the logic module display, or via a computer with specialized application software for more complex programs. The advantages of programming on the computer are a better overview of the wiring circuit diagrams, simpler and more efficient circuit inputs, simulation possibilities, location-independent development and fast series programming of multiple devices with the same programs [10]. The programming process includes positioning and linking functional modules on the "worksheet" of the LOGO! Soft Comfort software. This makes creating control programs simpler, more efficient, and more clear [11]. The advantage is that no specialized programming knowledge is required and it makes it easier to get started programming a PLC [10].

3 Training Set for Learning to Program a PLC

The developed training set (see Fig. 1) was designed to deepen the theoretical knowledge and to simplify the introduction into industrial automation for industrial engineering students. Students can use the training set to program and operate a PLC using interactive tasks. Factors like the quality of the teaching materials and user-friendliness were considered when designing the training set. The components of the training set were selected after comparing them to other training sets available on the market. These components primarily include teaching documents, circuit diagrams, a LOGO! controller, LOGO! Soft Comfort software, a human machine interface (HMI) touch panel and three sensor lights. Sensor lights 1 and 2 are diffuse sensors (see Fig. 1) and sensor light 3 is a capacitive contact sensor equipped with programmable lighting functions.

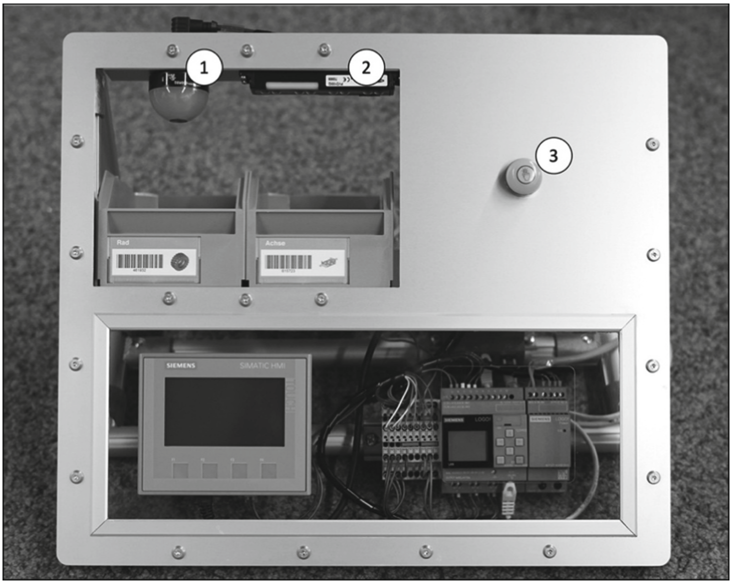

Fig. 1. The developed PLC training set

The training set allows students to solve complex control tasks without any previous knowledge of industrial automation and PLC programming. For this purpose, three tasks were developed. The degree of difficulty for the tasks increases successively from a task with introductory exercises to more complex industrial control tasks. The training starts with an introduction into the LOGO! Soft Comfort software. Students learn how to create a new project, use the inputs and outputs of the controller, and transfer their circuit diagram to the LOGO!. This introduction is intended to make it easier to get started with the LOGO! Soft Comfort software. After the introduction, students begin by programming the capacitive button (3) so that it flashes at a set frequency after being pressed, then stops flashing after a specified duration. Students are provided with a circuit diagram and step-by-step instructions for this purpose. Once students have successfully completed this task, they are requested to carry out different specifications on the circuit diagram without instructions.

As a third task, students must create a pick-by-light system with removal monitoring system. The capacitive button (3) is used to start the pick-by-light system in this task. After pressing the button (3), the diffuse sensor (1) first lights up and then goes out again once something is removed from the container below the diffuse sensor (1). The removal initiate the diffuse sensor (2) to light up. When something is removed from the container underneath the diffuse sensor (2), it should register the removal. Then the signal light on the diffuse sensor should go out and the pick-by-light system should be ended. The training concludes with information output on the display of the LOGO!. A message text displaying information on the quantity of objects removed, for instance, should be programmed.

4 Evaluation

The training set was evaluated using a questionnaire. First, a group of four students was surveyed for testing purposes. Afterwards, the training set was used during regular teaching on the production system module and a total of 13 industrial engineering students were surveyed. The questionnaire used for the evaluation was divided into the sections "Organization and structure," "Implementation," "Learning success and practical benefit" and "Overall assessment". The questionnaire contained a total of 25 items across all four areas. Of these, 20 items had five answers and five items had three answers on a Likert scale. Then students were asked to add comments and suggestions on the training set.

The students considered the training set to be clearly structured and easy to understand. They believed the training set supported their learning abilities, and felt the selected teaching format was suitable for deepening the theoretical content they had learned from the lecture on PLCs through practice. In general, the students' assessment was very positive. This assessment confirms that the overall concept of the training set does have the desired effect. For the items with three answers, the level of requirements (exactly right 92.3 %; not challenging enough 7.7 %) and group size (exactly right 100 %) were rated as appropriate. The practical benefit, clear structure, group size and support from teachers were all rated as positive in the free text fields. Suggestions were provided to expand the individual tasks, in particular for students who completed the tasks somewhat more quickly than others.

5 Conclusion

This paper presented a training set which helps industrial engineering students to understand PLCs and their programming and to collect initial programming experience. The exercises not only introduced students to the basic principles of industrial automation, but also taught them how to use PLCs through practical exercises, as shown by the evaluation results. Students are motivated by the fact that they can see the results of their work in real operation. In addition to PLC programming, the students also developed soft skills by solving control problems in teams and presenting their solutions. The newly developed teaching set should help industrial engineers learn how to develop work systems and in particular assembly systems, for instance by integrating assistance functions or automating inspection tasks. The plan is to complete another evaluation to identify potential areas of improvement. Furthermore, additional training tasks should be designed which involve more complex programming and integrate the HMI into the exercises.

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Evaluation of Augmented Reality Technologies in Manufacturing – A Literature Review

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Abstract. Augmented Reality (AR) applications are increasingly being used in many different areas, such as architecture, healthcare, manufacturing, and education. With AR, virtual information is merged into the real world. The use of AR systems in manufacturing opens up new ways of providing information and is shaping a new form of interaction of employees. Employees can use AR systems through devices like glasses, smartphones, tablets, and projectors, which are using voice commands and gesture recognition. These features allow hands-free working in manufacturing and offer an attractive advantage of AR glasses and projectors. Despite the apparent advantages of AR, it is used little in industry beyond the prototype stage. This could be explained that so far, the value added doesn't seem attractive enough. Other influences may be ergonomic aspects, usability, user experience, and acceptance. This paper offers a systematic literature research of evaluation criteria of AR systems published.

Keywords: Augmented Reality · Evaluation · Production · Manufacturing · Industry · Cognitive assistance

1 Introduction

Augmented Reality (AR) expands our physical world by adding virtual elements, and applications have spread in numerous areas. AR is used in architecture, healthcare, manufacturing, gaming, and tourism. Figure 1 shows the virtual continuum, where real environment is shown on the one extremum and virtual environment on the other end. While in Virtual Reality (VR) the user is immersed and cannot see the world around them. In AR virtual information is merged into the real world [1].

Focusing on manufacturing, there is an increasing demand for personalized products and short delivery times. Consequences are an increase in complexity in production by raising the number of variants and reducing reaction times. These are some reasons why the use of assistance systems becomes more popular for manufacturing companies, also industrial AR applications [2]. The use of AR systems in manufacturing opens up new ways of providing information for employees e.g., instructions might be easier to understand in 3D drawings in the actual environment than in a paper manual [3]. AR is shaping a new form of human-machine-interaction and is applied to reduce human errors in operation processes, to improve efficiency, reduce cycle or travel time, and maintenance costs [4]. External experts can easily be connected to the workstation to support local workers via remote applications. Complex tasks with a

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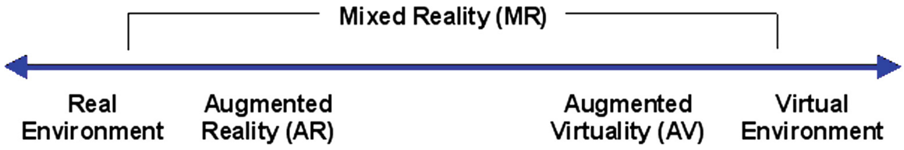

Fig. 1. Virtual continuum [1]

high searching effort can be supported with AR. Maintenance and repair actions can be more efficient and more flexible due to direct access of information at the workplace [5].

To use AR applications, various technologies are available such as handheld smartphones or tablets, projection-based spatial AR, or wearables, like AR glasses and HMDs (head-mounted displays). Voice commands and gesture recognition allow hands-free working in manufacturing and offer an attractive advantage of AR glasses, HMDs, and projection-based spatial AR [5].

Despite the apparent advantages of AR, the use beyond the prototype stage is low in industry. Sometimes connectivity to the cloud or to other devices and a lack of system integration prevents the area-wide deployment. Environmental conditions such as light, dirt, and heat must be suitable for the AR application. An assumption besides technical issues is that the cost-benefit effect often doesn't seem attractive enough. Other influences may be ergonomic aspects, usability, user experience, and acceptance. An additional hypothesis is that industrial AR systems are currently not evaluated on a multi-criterial basis.

1.1 Research Questions

This paper provides an overview of existing approaches for the evaluation of AR systems in an industrial environment. There are some studies about the impact on operators' work and performance, e.g., in assembly processes, or on the user acceptance of AR technology. In order to make a decision about the use of AR in industry, a multi-criterial evaluation is necessary. If the advantages for a company are shown clearly, the technology will be adopted and used more intensively in the future. The following research questions shown in Table 1 arise from these derivations.

Table 1. Research questions

RQ1	What criteria are used to evaluate AR systems?
RQ2	Which methods are used for the evaluation of the criteria?
RQ3	Is the evaluation reproducible with the given criteria and method?
RQ4	How many criteria are evaluated in the papers?
RQ5	How does the use of devices change over time?

2 Research Methodology

The systematic literature research [6] is divided into two phases: the screening process and the reviewing process.

2.1 Screening Process

The databases Scopus and Web of Science were searched for the screening process. Table 2 shows the defined keywords. The term “driving” was excluded from the search, as there is a lot of research on it, but it is limited to the assistance of a driver of a motor vehicle, which is too different from applications in the industry.

Table 2. Search terms in databases Scopus and Web of Science

Manufacturing OR Production OR Assembly
AND Evaluation
AND Augmented Reality
NOT Driving

The selection is limited to English articles with open access through the Vienna University of Technology. Only full papers from journals, conference proceedings, books, and book chapters from the field “engineering”, “computer science” and “business” are considered. No time limit to the publication date was set. After this step a total of 156 results were found, 136 results in Scopus on Sept 6, 2019, and 19 in Web of Science on Jan 22, 2020. Titles, abstracts, and keywords of these 156 publications were screened and 42 were defined as relevant.

2.2 Reviewing Process

All articles remaining after the screening process were clustered and sorted by the evaluation criteria and used evaluation methods. The used terms were clustered and generalized. All results are shown visually in Sect. 3. The article concludes by providing an overview of the results and a discussion of the need for a multi-criterial evaluation of AR applications.

3 Results of the Literature Review

Of 42 identified relevant publications, 19 are in production or production-like environments (e.g. learning factories and laboratories), 12 in (dis-)assembly and 11 in maintenance. The publications describe the evaluation criteria differently. Generalized terms cluster the criteria (RQ1) in Table 3 and a list of used methods to evaluate AR applications is provided (RQ2).

Table 3. Summarized terms used in reviewed publications

Keywords used in papers (number of usage)	Methods used in papers (number of usage)
Effectiveness/efficiency	
Effectiveness (7), Efficiency (7), Time (5), Assembly time (3), Task completion time (2), Task Duration (2), Task performance (2), Benefit (1), Easy to transport (1), Lead time (1), Operation time (1), Operators' performance (1), Overall execution time (1), Reducing documentation (1)	Questionnaire (1), Semi-structured interviews based on questionnaire (1)
Usability/user experience	
Usability (13), User Experience (5), Ease of Use (2), Perceived Usefulness (2), Advantages & disadvantages of wearable AR devices (1), User Interaction (1), User rankings (1), Utility (1)	System Usability Scale (SUS) (4), Questionnaire (2), ISONORM 9241/10 (1), ISONORM 9241-210 (1), Post-study System Usability Questionnaire (PSSUQ) (1), Questionnaire for Intuitive Use (QUESI) (1), Semi-structured interviews based on questionnaire (1), Smart Glasses User Satisfaction (SGUS) (1)
Quality	
Number of errors (7), Error rate (2), Number of questions asked (2), Product quality (2), Defect detection (1), Error occurrences (1), Detecting and avoiding errors (1), Quality of learning (1), Reducing the probability of failure (1), Total quality (1), Number of accurate stages completed (1), Decreasing the human error probability (1)	Number of errors (7), Error rate (2), Number of questions asked by the subject that could not be answered with the digital guides (2), Error occurrences (1), Number of accurate stages completed (1)
User acceptance/user satisfaction	
User acceptance (5), Satisfaction level (2), User satisfaction (2), Acceptability (1), Measurement of emotion-based impressions (1), Subjective assessment (1), Technology acceptance (1), User interaction satisfaction (1)	Interviews (1), Questionnaire (1), Questionnaire for User Interaction Satisfaction (QUIS) (1), Self-Assessment Manikin (SAM) (1), Technology Acceptance Model (TAM) (1)
Learning effectiveness/learnability	
Speed of learning (2), Effective learning experience (1), Improve knowledge (1), Learnability (1), Increase memorability (1), Learning effectiveness (1), Learning progress for increased efficiency and shorter learning times (1), Quality of learning (1)	Questionnaire (1), Semi-structured interviews based on questionnaire (1), System Usability Scale (SUS) (1)
Ergonomics/cognitive workload	
Ergonomics (2), Cognitive workload (2), Cognitive ergonomics (1), Dizziness (1), Mental workload (1), Physical comfort (1),	NASA Task Load Index (NASA-TLX) (4)

(*continued*)

Table 3. (*continued*)

Keywords used in papers (number of usage)	Methods used in papers (number of usage)
Ratings (Effort, Frustration, mental demand, performance, physical demand, temporal demand) (1), Task load (1), User movement (1)	
Costs	
Costs (3), Total production and transportation cost (1), Required mandatory standard rate (1), Minimum attractive rate of return (MAAR) (1), Return on Investment (ROI) (1)	Required mandatory standard rate (1), Minimum attractive rate of return (MAAR) (1), Return on Investment (ROI) (1)
Situation awareness	
Situation awareness (1)	Situation Awareness Rating Technique (SART) (1)

Figure 2 shows the number of criteria used for the evaluation in the upper bar (RQ1) and the number of methods used to evaluate the AR applications in the lower bar (RQ2). 29 of the publications (69% from relevant publications) define effectiveness and efficiency as an important criterion, but only two of them show the evaluation procedure as reproducible. Especially usability, user experience, user acceptance, and user satisfaction show a wide range of different standardized questionnaires.

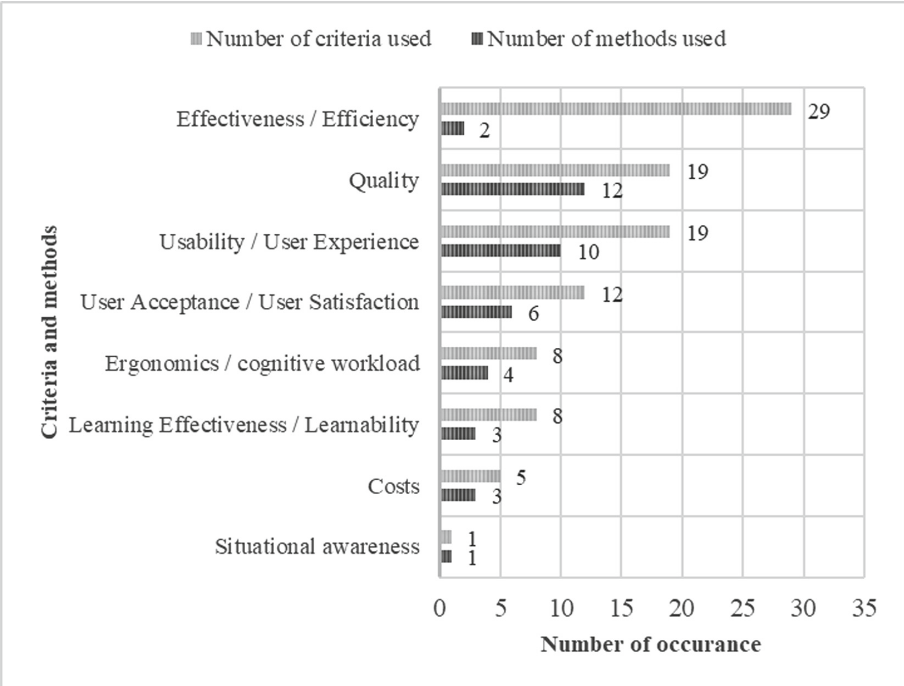

Fig. 2. Overview evaluation criteria for AR use

The number of evaluated criteria in the papers varied between one and five (RQ4). Only one publication reviewed 5 different criteria, six evaluated 4, 13 evaluated 3, 15 evaluated 2 and 8 only 1. The median is two evaluation criteria per paper.

Figure 3 displays the time of publication of the AR evaluation and which devices were used (RQ5), while some of the papers evaluate more than one device. There is an increase in evaluating AR systems since 2013 from one to 13 evaluations. Before 2013, no publications were found. Reasons might be the availability of different glasses on the market and the technological development of AR mobile and HMD devices in the last years. Especially since the launch of Microsoft HoloLens in 2015, the user studies in the papers increased clearly. Since 2017, projectors are used more commonly for spatial AR applications.

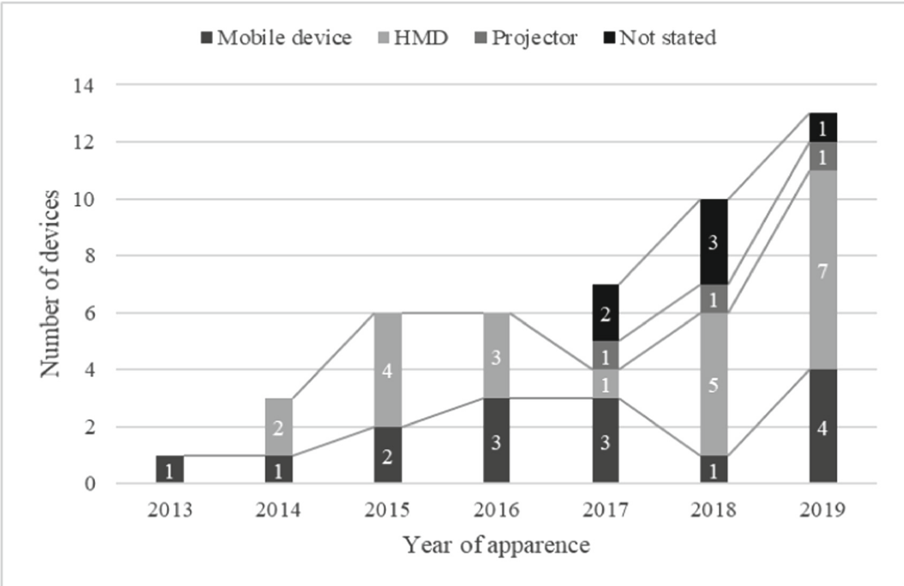

Fig. 3. Used devices in the papers over the years

4 Discussion

The literature review shows that a majority of the papers evaluate two criteria. In many cases the criteria are mentioned without a reproducible method. Mainly usability, user acceptance, and mental workload are evaluated with standardized methods. Costs are rarely considered; only one paper assessed the return of investment of the application. Efficiency and effectiveness are mentioned the most, but only some studies define how they measure the effects. The review shows a gap in AR evaluation, which will be worked on in further research. A multi-criterial evaluation is necessary to decide on an implementation of an accepted and economic AR application beyond a prototype stage. The evaluation enables an assessment of the actual benefit, an (iterative) improvement of the application, derivation of recommended actions for improved decision making during the conception and implementation phase. The literature review on the evaluation of AR applications reflects the state-of-the-art and provides a basis for a multi-criterial evaluation model in further research. The model will be tested in the research project “Mixed Reality Based Collaboration for Industry” (MRBC4I) with 21 AR and VR use cases. The project provides the opportunity to evaluate many use cases with the same evaluation method. Four areas divide the use cases into the following topics: support in production, education and training, remote support, and presentation of products [7]. Although the goal of the systematic literature research was to make this review as inclusive as practically possible, there are limitations of this research. Papers with other keywords such as “mixed reality” may were not found within the screening process. Other databases are available, but the limit for this research was set at English publications in Scopus and Web of Science.

5 Conclusion

The objective of this review was to carry out a literature analysis to answer the research questions defined above and to examine the current state-of-the-art of AR evaluation criteria. The review shows that many different criteria (e.g. efficiency, usability, user acceptance, quality, cognitive workload, costs) are used in the publications. The median of the evaluated criteria in the papers is two criteria. Often the evaluation method is not mentioned, which makes it impossible to reproduce the evaluation of the AR application. The used devices have changed over time, from mobile devices to a mix of mobiles, HMDs, and projectors. Since 2013, the evaluation of AR systems has become more relevant, seeing as that before this period no evaluations were found. This review shows a research gap for a multi-criterial evaluation model. Further research is carried out in this area based on the concept shown in [8].

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Organizational Justice: Does "IT" Matter? Empirical Analysis of the Influence of Information Technology on Employee Justice Perceptions

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Abstract. The application of technology to organizational functions has been regarded as vital in promoting organizational efficiency whiles creating a system of trust and certainty. However, the extent to which such technologies influence the perception of fairness among employees remain unknown. Adopting the theory of Sociomateriality, this study explores the relationship between the adoption of information technology (IT) and its influence on the justice perceptions of employees. Using a survey of 220 business executives, the study found that the adoption of IT was positively related to perceptions of fairness among employees. The findings of this study have theoretical implications for multi-disciplinary organizational studies as well as practical implications for 21st Century businesses as it is among the few to examine information technology with respect to its effect on behavioural outcomes at the workplace.

Keywords: Information Technology · Organizational justice · Sociomateriality

1 Introduction

Over the last couple of decades, the application of technology to organizational functions have become increasingly relevant and have been prioritized to promote organizational efficiency [1, 2]. The adoption of information technology in organizations have been associated with high market shares [3], high return on investment [4], lower cost of production [2] and overall survival of the firm [5].

Besides, the development of a work environment that promotes trust, rationality and fairness as antecedents to higher employee performance have become central to many organizations [6]. According to Jackson [6], the creation of a fair work environment has the potential of influencing citizenship behaviours, turnover intentions and organizational commitment among employees.

Amidst this dichotomic dilemma of prioritizing people or technology, there seems to be a dearth of empirical research into the people – technology nexus in terms of how the latter stimulates the perception of fairness among employees. This study therefore adopts a multi-disciplinary approach, delving into information technology and

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organizational psychology literature to provide an understanding of the nexus between information technology adoption and perceptions of justice in firms. In an era of sociomateriality, this study is opportune in promoting the understanding of the human and behavioural sides of firms' adoption of technology.

2 Theoretical Foundation and Development of Hypotheses

2.1 Information Technology in Organizations

The term Information Technology (IT) is often used in relation to the application of technologies as part of the business operations of an organization. Several studies have assessed the impact of IT on organizations as a resource for producing change, efficiency and overall superior firm performance [2, 7].

2.2 Organizational Justice

Generally, the concept of organizational justice has been used to connote perceptions of fairness at work [8]. In literature, the concept has developed as a three-dimensional concept; distributive, procedural and interactional justice. Distributive justice refers to the perception of fairness in the allocation of resources or outcomes [6]. Procedural justice refers to perceptions of fairness in formal procedures used in making decisions [6]. According to Tyler [9], it involves the procedures by which outcomes are determined and performance are measured. This third dimension of organizational justice, interactional justice, refers basically to the perception of fairness in the form of the treatment an individual receives from a decision-maker [6].

2.3 Theory of Sociomateriality

Drawing from the Sociomateriality theory, this study seeks to explain how technology adoption is integral in determining behavioural patterns such as perceptions of fairness among employees at the workplace. The Sociomateriality theory propounded by Orlikowski [10], is predicated on the assumption that "the social and the material are constitutively entangled in everyday life" and are inextricably related such that "there is no social that is not also material, and no material that is not also social" (p. 1437).

This theory therefore suggests that organizational research needs not perceive technology and its interaction with organizational life as discrete variables but rather intricately linked concepts. This assumption is supported subtly by Wickramasinghe [11] who suggests that the adoption of a technology has people consequences. Considering the social implications of technology adoption, this study proposes that the adoption of technology by firms will result in increased perception of fairness among employees and thus hypothesizes that 'there is *significant positive relationship between firm technology adoption and the composite and dimensional measures of justice perceptions among employees.*

3 Method

3.1 Participants and Procedures

The study was conducted as a cross-sectional survey. Questionnaires were self-administered to a total of 256 business executives and out of this, 220 questionnaires were among those that were completed when retrieved representing almost 86% return rate. The sample consisted of a fair representation of males (M = 55%) and females (F = 45%). More than 80% of the respondents were 40 years of age and below representing a highly youthful workforce. It was thus not surprising that majority of these respondents (53%) were single while 44% were married. In addition, more than 76% of the total respondents had not more than six years of working experience. Besides, more than 90% of the respondents had at least a bachelors degree representing a highly skilled workforce used as participants of the study. The respondents were drawn from a host of industries including academia, law, banking, insurance and public service among others.

3.2 Measures

Information Technology Adoption. To measure the adoption of technology by the firms [12], Information Technology Survey was adopted. 30 items of information technology adoption were measured on a 5-point Likert type scale where 1 = “strongly disagree”, 5 = “strongly agree”. A representative item was, “My company provides training for its employees on new information technology”. The reliability of the scale was 0.936.

Organizational Justice. A three-dimensional scale of organizational justice was adopted to measure distributive, procedural and interactional justice [13]. 20 items were measured on a 5-point Likert type scale where 1 = “strongly disagree”, 5 = “strongly agree” as a composite measure of organizational justice. 5 items measured distributive justice, 6 items measured procedural justice and the remaining 9 items measured interactional justice. A representative sample item was, “My work schedule is fair”. The reliability of the scale was 0.947.

4 Results

The descriptive statistics and correlations of the variables in this study were calculated and their means and standard deviations are reported below.

Table 1. Descriptive statistics and correlation matrix

		Mean	SD	1	2
1	Organizational justice	3.3408	.71597	1	
2	Information technology adoption	3.5211	.76424	.510***	1

***Correlation is significant at 0.000 level (1-tailed)

From Table 1 above, results from a sample of 220 business executives showed a mean score for organizational justice of 3.3408 with standard deviation of 0.71597. Also, the mean and standard deviation for the adoption of information technology by firms were 3.5211 and 0.76424 respectively.

4.1 Hypothesis for Composite Justice Perceptions

There is a significant positive relationship between firm technology adoption and perceptions of justice among employees. The results are shown below.

Table 2. Results of a simple regression for organizational justice and IT adoption

	B	Std. error	Beta
Intercept	1.658	0.198	
IT adoption	0.478	0.055	0.510***

Note: $R^2 = 0.260$, $F = 76.038$, ***$p < .000$

Table 2 shows that the regression model for the IT-organizational justice nexus was significantly fit ($F = 76.038$, $p < .000$). R square of 0.260 indicates that the adoption of IT accounted for approximately 26% of the variation in organizational justice perceptions among business executives. The results show that there is a significant positive relationship between adoption of IT and the perceptions of justice ($\beta = 0.510$, $p < .000$). The results thus support the hypothesis that there is a significant positive relationship between firm technology adoption and perceptions of justice among employees.

4.2 Hypotheses for Dimensional Interactions

There is a significant positive relationship between firm technology adoption and dimensions of organizational justice among employees.

Table 3 shows fitness of the regression models for IT adoption and distributive justice ($F = 47.339$, $p < .000$), IT adoption and procedural justice ($F = 48.400$, $p < .000$) and IT adoption and interactional justice relationship ($F = 71.079$, $p < .000$). R square of 0.178 indicates that the adoption of IT accounted for approximately 18% of the variation in distributive justice perceptions among the respondents. The results show that there is a significant positive relationship between adoption of IT and distributive justice ($\beta = 0.422$, $p < .000$). The results thus support the hypothesis that

Table 3. Results of a simple regression for justice dimensions and IT adoption

		B	SE	Beta	R^2	F value	Sig.
Distributive	Intercept	1.649	0.243		0.178	47.339	.000
	IT adoption	0.466	0.068	0.422***			
Procedural	Intercept	1.747	0.223		0.182	48.400	.000
	IT adoption	0.431	0.062	0.427***			
Interactional	Intercept	1.559	0.225		0.247	71.079	.000
	IT adoption	0.527	0.063	0.497***			

there is a significant positive relationship between firm technology adoption and perceptions of distributive justice among employees.

Also, R square value of 0.182 shows that approximately 18% of the variation in procedural justice was as a result of IT adoption by the firms. The results show that there is a significant positive relationship between adoption of IT and procedural justice ($\beta = 0.427$, $p < .000$). Thus, the hypothesis that there is a significant positive relationship between firm technology adoption and perceptions of procedural justice among employees was supported.

Finally, R square value of 0.247 shows that approximately 25% of the variation in interactional justice was as a result of IT adoption by the firms. The results show that there is a significant positive relationship between adoption of IT and interactional justice ($\beta = 0.497$, $p < .000$). Thus, the hypothesis that there is a significant positive relationship between firm technology adoption and perceptions of interactional justice among employees was supported.

5 Discussion

Adopting Sociomateriality to describe the relationship between IT adoption and organizational justice, this study sought to explain the nexus between information technology adoption and perceptions of justice in firms. The study found a significant positive relationship between the adoption of IT by firms and perceptions of organizational justice among business executives in Ghana. This means that as firms resort to the use of technology, it intricately enhances the perceptions of fairness among its employees. This finding is supported by [14] who found increased perception of fairness among employees when they use technological tools.

Furthermore, the study found a significant positive relationship between IT adoption and distributive justice. This implies that as employees perceive technological protocols are used as the basis for the allocation of resources, they develop higher perceptions of fairness about their organization. Jackson [6] provides a basis for supporting this finding explaining that individuals take cues from their context (in this case the adoption of IT by their firms) and uses that as a basis of comparison. Since technologies often result in objective and less intuitive processes for the allocation of resources, employees develop enhanced perceptions of distributive justice when such contexts are run on technology such as the use of HR information systems for distribution of rewards and bonuses.

Another finding of this study was that firms' adoption of IT was significantly related positively to procedural justice. This means that when employees perceive that technologies are used in the process of making decisions, they develop a greater sense of fairness in such procedures. Jackson [6] supports this finding offering that, individuals perceive fairness in formal procedures when they could trust the processes for making decisions and are certain of the outcomes that could be used in such occasions [6]. Technological application to organizational processes helps to build trust, predictability and certainty about decisions made [15], thus creating a increased feeling of fairness among employees.

Finally, the study found that the adoption of IT by firms was significantly related positively to interactional justice. This means that since IT influenced decisions are clear, truthful and consistent, individuals develop a sense that they are being treated with courtesy, respect and dignity thus, resulting in positive interactional justice perceptions [16]. This finding is supported by the voice-justice literature [17] which explains that employees obtain value in voice behaviour since it is a demonstration of the manager's politeness, respect and willingness to consider the employee's views.

6 Limitation, Implications and Directions for Future Research

This study did not focus on the adoption of a specific technology but as a survey, sought to understand the influence generic information technology tools used in organizations could influence perceptions of fairness among employees. It is thus recommended for future research to examine identifiable technologies adopted by companies and measure the extent to which such technologies influence justice perceptions. Furthermore, the study examined the direct relationship between IT adoption and justice perceptions without considering the processes through which such a relationship is enhanced or hindered. It is thus recommended for future studies to examine the mediation of variables such as trust in technologies in this IT adoption-fairness relationship. Nonetheless, the findings of this study serve as a baseline empirically establishing a relationship between materiality and behavioural processes – a foundation upon which future IS and organizational behaviour studies can be developed.

7 Conclusion

The study sought to examine the extent to which the adoption of IT was critical in influencing the perception of justice of employees. From the findings, it could be firmly concluded that the investment in technology, integration of IT in business processes and the use of IT in decentralizing decision making in organizations are critical in determining the extent to which employees will perceive the allocation of resources, the procedures of decision making as well as their overall treatment as fair.

It could thus be concluded that "IT" matters for firms to adopt and integrate technology in their organizational processes in their pursuit of a climate of fairness at work.

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Security and Crises Management

Design of Disaster Management Intelligent System – A Review of the Applied UCD Methods

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Abstract. THEMIS is an Intelligent System designed to support Disaster Management in the context of disaster relief operations, contributing to reduce the decision-making burden typical of these stressful operational scenarios, which is exacerbated by the big volumes of information, often affected by uncertainty. The goal of the THEMIS project was to create a distributed system that supports: the disaster scenario information gathering and updating, by reconnaissance and response teams using mobile devices; the disaster managers, through incidents analysis and response priority advice, using desktop devices; the information sharing and the flow of georeferenced data communications between system users concerning response tasking and responders' and incidents' status; and the response preparedness through simulations functionalities. Particularly regarding the support to response teams' actions, the mobile devices offer navigation aids based on maps and augmented reality.

Keywords: Disaster Management · Human factors · Human-systems integration · User Centered Design · REST architecture

1 Introduction

Disaster management is a complex activity where decision-makers are faced with the assessment and prioritization of a high quantity of conflicting courses of action for assigning a limited number of resources in response to overwhelming humanitarian incidents [1]. In fact, according to the UNISDR, Disaster Management involves the organization, planning and application of measures preparing for, responding to and recovering from disasters. Disasters encompass several families of natural (e.g., geophysical, climatological, hydrological) and anthropogenic phenomena [2].

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THEMIS (*disTributed Holistic Emergency Management Intelligent System*) was designed to support Disaster Management in the context of disaster relief operations (DRO), contributing to reduce the decision-making burden typical of these stressful operational scenarios, which is exacerbated by the big volumes of information, often affected by uncertainty [3, 4]. The goal of the THEMIS project was to create a distributed system that supports [3]: the disaster scenario information gathering and updating, by reconnaissance and response teams using mobile devices; the disaster managers, through incidents analysis and response priority advice, using desktop devices; the information sharing and the flow of georeferenced data communications between system users (*i.e.*, disaster managers and response teams) concerning response tasking and responders' and incidents' status; and the response preparedness through simulations functionalities. Particularly regarding the support to responders' actions, the mobile devices offer navigation aids based on maps and augmented reality [5, 6].

The THEMIS project, which was funded by the Portuguese Ministry of Defense, was conducted following a User Centered Design (UCD) approach [7]. This paper reviews the stages of the project implementation cycle, addressing the methodologies applied to define: the user needs and context of use; the system architectural and functional requirements; the Artificial Intelligence modeling and User Interaction prototyping; the solution implementation based on a n-tier architectural approach; and the usability testing and validation. Therefore, following the present Introduction, Sect. 2 offers a view on the concept and establishes the relation between the functional concept and the n-tier architecture. Sect. 3 revisits each the UCD cycle stages and highlights the methodologies used in the THEMIS project and their deliverables.

2 Concept and Architecture

The THEMIS solution was built in a n-tier approach, illustrated in Fig. 1, providing interoperable business services that could be easily reused and shared between applications and entities. The presentation layer is based on several client applications, namely: a simulator amenable of injecting incidents in the context of training; a desktop client to ensure situational awareness of disaster managers and decision support for assigning orders to response teams; and mobile clients, developed for the Android platform, that support response teams' information exchange with the disaster managers.

The interface among the presentation and business layers is ensured by REST web services [8]. The client applications send REST API authentication requests to server with appropriate credentials. To call REST services provided by the server, the clients include in the header of each request the token received upon authentication, which is also used when establishing a websocket communication channel with the server.

The application layer hosts an Intelligent System (IS) that combines the business rules management systems (BRMS), for prioritizing incidents, with a Multi-objective model for the allocation of resources. The operation of the IS can be summarized as follows: (1) For incidents' prioritization and task inference: (a) incidents' impact and severity analysis to identify the most critical incidents; (b) infer tasks required to tackle the type of incidents reported by response teams. (2) For resources' allocation: (a) team

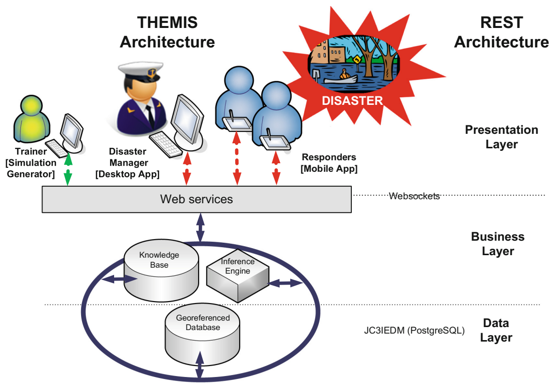

Fig. 1. Relation between the THEMIS conceptual model and the REST architecture

suitability analysis to identify teams' ability to perform pending tasks; (b) team availability analysis to check whether teams are available for pending tasks; (c) team proximity analysis (if multiple teams are available) to select the one closest to the incident. The Inference Engine allows the inference chain to be processed either in *forward chaining* (to advise: by inferring consequences) or *backward chaining* (to explain: by inferring causes). The tool incorporates information uncertainty by using fuzzy rules. The advantages of the BRMS chosen include: (a) declarative programming, which allows easier definition of rules to express solutions for complex problems; (b) perceptible rules for non-programmers that allows users to express logic easier through natural language; (c) decouple between logic (in rules) and data (contained in domain objects); (d) speed and scalability, with efficient algorithms that relate rule patterns and facts; (e) knowledge repository; (f) explain the why and when of each decision; (g) easy maintenance, since rules can be changed at runtime without modifying the source code.

The data layer infrastructure is supported by a PostgreSQL relational database implementing the JC3IEDM model [9], which was chosen to enable the interoperability among multiagency systems, that gather at the disaster scene, ensuring information sharing and coordination of efforts. The JC3IEDM model is characterized by: (a) a comprehensive structure which accommodates combined land, sea and air environments; (b) objects of interest (*e.g.*, organizations, people, equipment, facilities); (c) objects with the ability to perform a function or achieve an end; (d) geo-reference any element of the theater; (e) several aspects related to the state of the elements; (f) recurrence in object type definition is done explicitly for organizations, equipment and personnel; (g) information about what is loaded, owned or owned by another object; (h) relationships over pairs of elements; (i) past, current, and future functions of objects belonging to plans, orders, or events; and (j) validity and timestamp of the information.

3 UCD Stages. Methods Used and Outputs

As mentioned, the THEMIS project followed a typical UCD approach, considering the context of use of the system; characterized the users and identified users' needs and system requirements; designed and implemented the solution components; and iteratively tested the solution versions until one that meets the requirements is validated. The different methods used at each stage, the outputs produced and the references that addressed them in more detail are summarized in Table 1.

Table 1. Use of UCD approach on the THEMIS project. Methods and outputs overview

UCD stages	Methods	Outputs	Refs.
Context of use	Observation SME Interviews	• Reports	[1, 10, 12]
User needs & system req.s	Observation SME Interviews Literature review Technical documentation review	• Reports • Personas • Organization charts	[5, 12]
Implementation	Brainstorming, Knowledge Engineering (incl. Operations Research, Approximate Reasoning, Delphi method) Modeling and Simulation, Prototyping, App implementation	• Ontologies • UML Use-Cases • Knowledge Bases • Inference models • Prototypes (Paper, Digital & Functional), • Desktop and Mobile Apps	[3–6, 12–16]
Test and validation	Lab tests (Wizard of Oz, Cognitive Walkthrough, UEQ, SUS, Eye-tracking) Field tests (Cognitive Walkthrough, UEQ, SUS)	• Test Reports • Redesign requirements • Validated Apps	[4–6, 15]

Context of Use. The context of use was generically defined in the project proposal and was refined for the different system users at the initial stages of the project execution. The methods used for characterizing the context of use were, mainly, the Observation of DRO training exercises, and the interview of Subject Matter Experts (SME). The information gathered was compiled on reports and other documents. Papers [1, 10, 12] further detail the activity performed at this stage and the THEMIS context of use.

User Needs and System Requirements. The user needs and system requirements was a lengthy and thorough activity involving the observation of exercises and the interview of SME, the review of relevant literature and technical documentation, namely the one issued by organizations with interests in the domain (*e.g.*, UNOCHA, INSARAG, CRED). The information was compiled on reports and organization charts, and the users' characteristics, needs and expectations were represented using Personas. Papers [5, 12] present the activity performed at this stage and offer an overview of outputs.

Implementation. THEMIS design and implementation involved Brainstorming sessions engaging the project team to identify alternative solutions and decide on the approach to follow. The main activities at the early stages related with Knowledge Engineering, addressing different methods of knowledge acquisition and representation (e.g., fuzzy logics, UML Use-Cases and ontologies). The knowledge acquisition process involved a very close and frequent contact with groups of SME, to identify the techniques and procedures in use, and to capture the Disaster Management challenges that could be supported by the system. The knowledge acquired was used to populate the system's Knowledge Base. THEMIS' Intelligent System functionalities required researching and developing inference processes which involved multiple methodological approaches. The complexity of the Disaster Management decision-making posed quite demanding challenges regarding the design of the inference processes. The modeling was mainly based on Heuristic methods, involving Approximate Reasoning, Multi-objective Optimization and Delphi methods [11]. The decision-support models were the key contents of THEMIS' Inference Engine. The user interactions were first studied using paper prototypes, where the interface contents and layout were progressively improved. Subsequently, the user interactions were refined using digital prototypes which allowed to fine tune the look and feel of the apps and to study their Usability. Finally, functional prototypes were developed implementing the architecture and functionalities of THEMIS, considering the different users (*e.g.*, disaster managers, responders). The functional prototypes of the mobile apps included also simulation and Augmented Reality features. These prototypes were iteratively tested and improved until they met the requirements in a satisfactory way. Therefore, the outputs included the creation of Ontologies and UML Use-Cases characterizing the problem domain and the user interactions; Knowledge Bases; Inference models; and Prototypes (paper, digital, functional). An overview of specific activities performed at the Implementation stage is presented in [3–6, 12–16].

Test and Validation. According to their level of functionality the prototypes were assessed in laboratorial tests (paper and digital prototypes) and field tests (functional prototypes). Assessing the paper prototypes was mainly based on 'Wizard of Oz' and 'Cognitive Walkthrough' methods. Digital prototypes Usability was tested using 'Cognitive Walkthrough', UEQ [17], SUS [18], and eye-tracking methods. Functional prototypes Usability was tested using 'Cognitive Walkthrough', UEQ and SUS. The outputs of this stage were reports presenting the results of the tests and identifying the areas to improve in a new design iteration. The final output was a distributed system with validated Desktop and Mobile Apps, addressed with detail in [4–6, 15].

A new iteration of UCD process is currently being performed within the scope of the THEMIS project for the design of a Virtual Reality application developed as a Serious Game, which will support the training of disaster managers and first responders [19].

4 Conclusions

The paper offers a perspective on THEMIS architecture built according an n-tier approach. The presentation layer is implemented with several applications, which allow functionalities such as: simulation of incidents to support training sessions; situational awareness regarding the disaster scenario; decision support to disaster managers regarding the tasking of response teams; and information exchange support between response teams and disaster managers. The business layer hosts an Inference Engine that advises on task prioritizing and response teams' assignment. The data layer is supported by the JC3IEDM model, enabling the interoperability of actors cooperating for the disaster response. The interface among layers is ensured by REST web services.

Further to this, the paper offers a view on the definition of Personas, UML Use-Cases, and ontologies; describes the process and tools used for the design of prototypes, and their evolution from the paper-based up to the functional versions; describes the approach followed to develop the Intelligent System's inference processes; and presents and discusses the results obtained in the Usability and functional validation tests.

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A Programmable Coprocessor Model of Human Cognition: Implications for Human Factors, Systems Interaction, and Healthcare

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Abstract. Decades of work have explored Type 1 (intuitive) and Type 2 (logical) thinking in people. We suggest the two work together to form a programmable co-processor which guides the way people understand and act. This model has profound implications for Human Factors design and can be applied to design how to improve quality in systems. This process affects how rapidly and readily people can operate systems or devices, and whether they will interact with them as intended or make errors due to (1) erroneous pattern matching with previous learning; (2) difficulty in creating the necessary new habits because they are so difficult, novel, or contrary to familiar behavior; or (3) cognitive overload. Lack of this perspective cripples quality in healthcare. Simple improvements could make dramatic improvements in healthcare quality and reductions in cost.

Keywords: Human Factors · Human-systems integration · Healthcare · System design · Quality

1 The Evolution of Coprocessor Cognition: A Better Way to Reprogram the Program?

Observation of any species from salmon to felines to humans reveals they are born with specific behaviors and behavioral tendencies "pre-programmed" in. Newly hatched salmon swim downstream to the ocean. Newborn mammals know how to find momma's milk and some, like horses, stand within thirty minutes of birth. Children are born with their personality and that personality varies from siblings.

Other programs develop over an individual's life. Infants crawl, then wobble on two legs, and finally run (all over a much longer period than horses). Riding a bicycle is initially a novel exercise in balance and coordination, then balance becomes automatic and the rider's attention can be focused on route, pace, and traffic. Incoming medical students are flooded with technical information then, after years of study and practice, are able to instantly recognize and diagnose many medical conditions.

Clearly, some of these behaviors are pre-programmed at birth while others are taught. We leave for the neuroscientists how behaviors are actually programmed in at birth. Our questions are: (1) how is it determined which behaviors should be pre-programmed;

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(2) has this programming process evolved and how; and (3) can these learnings be applied to do better at designing human/system interaction.

Regarding what gets programmed, Darwin argued that variations which benefit an individual in its environment create survival and reproductive advantages, and those advantages "naturally select" for those variations to flourish and persist [1], either through genetic inheritance or shared learning. As described elsewhere [2], those advantages go beyond survival and reproduction and include safety and security, love and belonging, self-esteem, and self-actualization (including the psychic benefits or detriments of moral or immoral behavior) [3].

An essential part of this process is the individual recognizing and seeking the benefit in question. On the lowest level of survival, even a plant grows towards the light. Research has shown that the full array of physical and behavioral adaptations which allow man to thrive is an evolutionary continuum stretching back through time and other species [4]. Even the use of tools—once thought to distinguish humans from other species—has been observed in many other species [5].

Over long enough periods, evolution biologically programs beneficial behaviors to be expressed without instruction. They become automatic and intuitive. Over shorter time periods, they must be learned.

We focus next on the processes for learning and reprogramming behavior.

2 The Intuitive Cognitive Processor Versus the Logical Coprocessor: A Different Way to Learn

Lower level species respond to stimuli, but cannot change their responses to stimuli. An abalone cannot change its programmed response to grip tightly against a rock when prodded. That requires learning.

The ability to learn is a key advantage for higher level species. The greater the ability to learn and adapt, the more a species thrives. Crab-eating macaques use stones to crack and eat crabs which would otherwise be unavailable as food. Learning is much faster than waiting for evolution to program behavior into one's at-birth intuition.

One way to learn is by feedback and association. When a raccoon learns there are fish in my pond and that it can safely venture in to catch one, it returns when hungry. Once learned and if reliable, the feedback and association can become intuitive and automatic. Animals are trained this way. These intuitive associations can be strong and persistent without needing to parse possible causal relationships driving them. Once we know we like chocolate ice cream, we don't inquire why. We just do.

Problems arise when the situation is unfamiliar, complex, or when we cannot reliably link action and reaction. We refer to the latter as uncertainty. Then, intuition fails.

To deal with these situations, nature developed an alternate mode of reasoning to understand and predict results. Creatures great and small conduct tests where they explore what response Y is yielded by input X. If X, then only Y? Or Y and sometimes W or Z? This is logic, which is the heart of the logical coprocessor that accompanies our older and dominant intuitive cognitive processor.

Recognition and formalization of logic occurred in a number of ancient cultures, including India, China, and Greece, where Aristotle's writings launched western formal logic [6]. Logic is the basis of modern mathematics, science, and programming.

More recently, authors have described these two modes of thinking as Type 1 and Type 2 thinking [7]. Type 1 is described as fast, intuitive thinking, and Type 2 as slow, deliberative. Type 1 is the default mode, fast, and easy, but predictably fails in unfamiliar, complex, or uncertain situations. Type 2 is slower and requires more effort (including more metabolic expenditure), but can apply logical reasoning to avoid the pitfalls bedeviling Type 1 thinking. However, Type 2 thinking is subject to frame blindness: solving the wrong problem.

As described elsewhere [8], portraying these two types of thinking (Type 1 and Type 2 or intuition and logic) as mutually exclusive and in opposition to each other misapprehends nature's design. They work naturally to complement. Intuition is necessary to create the frame for logically reasoning and experiments, and to address the questions of whether something is missing or the right problem is being solved. Logic works to arrive at possible conclusions and plan of actions in situations where intuition fails. These relationships are illustrated in Fig. 1.

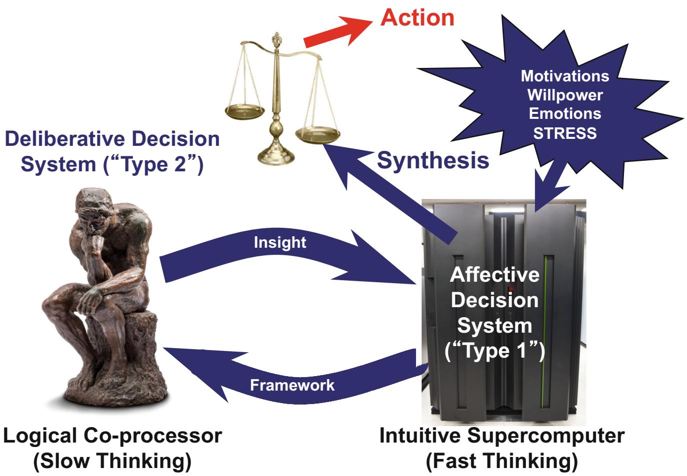

Fig. 1. The complimentary relationships of intuition and logic in decision analysis.

Type 1 thinking is fast, easy, intuitive, and works well most of the time. It uses subtle, associative reasoning that is difficult to trace. Our intuitive supercomputer governs emotions, trust, empathy and action and is specialized for understanding other people. However, it goes astray with novelty, complexity, or uncertainty.

Our logical coprocessor (Type 2 thinking) is slower and more effort to invoke, but less prone to error. It requires concentration and focus—at the risk of frame blindness. It uses transparent, logical reasoning but can be readily manipulated and does not lead to action unless trusted and qualitatively persuasive.

To be sure, intuition is in the driver's seat: it controls action and commitment to action. It works well in familiar and well-understood situations, particularly when it comes to applying long evolutionary experience to evaluating human feelings and intentions. The purpose of logic is not to replace intuition but, rather, to supplement it in unfamiliar, complex, or uncertain situations where documented failures abound.

This capability alone would make logical reasoning a formidable evolutionary advantage. However, nature designs our capabilities to work in concert with each other rather than in isolation. Perhaps the most critical advantage of this cognitive coprocessor concert is that each mode can be used to reprogram the other.

Intuition frames, informs, reviews the problem structure for logical inquiry (which then follows the internal rules of logic). What is the best problem statement? Does one believe the assumptions and the conclusions? Can one explain them qualitatively? What is missing?

Likewise, logic provides a mean of creating thought or actual experiments to test what conclusions one might arrive at other than those suggested intuitively. One intuitive sense we have (though we may override it) is a sense of unease when something is not quite right or feels wrong, or when confronted with a major decision. The natural recourse is to slow, deliberative thinking to ponder the problem.

Nature has given us one more, powerful capability of which there is little recognition at present: logic can be used to *reprogram* intuition. A few examples follow.

Swimming freestyle is a slow, deliberative process at first. Rather than intuitively inhaling and exhaling through the nose or mouth or both, one must learn to "take a bite" of air when the head is turned and then exhale slowly through both nose and mouth in the water. Difficult at first, it becomes intuitive with practice. Then swimmers can focus on other matters like tempo, body position, competitors and distance.

As mentioned above, medical students are buried in technical specifics which they must parse and absorb slowly and deliberately. Then, with years of study and practice they can leap intuitively to diagnostic and treatment decisions without needing to retrace the deliberative steps they formerly needed to reach those conclusions.

Other examples where intuition must be deliberately reprogrammed are scuba divers and pilots: which way is up? Birds intuitively know intuitively; they never accidentally fly too high or into the ground. Lacking this innate skill, people instead develop automatic recourse to instruments or watching the bubbles from exhalation. Intuition failures also plague other species. Birds fly into clear glass windows.

Skilled practitioners in many areas follow a similar trajectory: at first it requires difficult, deliberate thought and study and consciously avoiding relying on intuition to execute as desired. Then, with practice and experience, the skills needed become intuitively programmed and can be executed as easily and rapidly as taking a breath.

With this perspective on the programmable intuitive/logical programmable coprocessor nature has marvelously equipped us with, we can examine the implications for human factors and systems design.

3 Application to Human Factors and System Interaction

Human factors is the application of psychological and physiological principles to the engineering and design of products, processes, and systems. We will focus on the cognitive ease and reliability of use rather than physical stress and strain.

A common goal is making the human interface "intuitive." But what is not commonly understood is that "intuitive" depends on the preprogrammed patterns the person brings to the situation. Young people intuitively operate the interface on their cell phones. People my age are all thumbs—most of our experience predates gesture-based interfaces with small pieces of glass. The natural process people use to interact with a system intuitively is illustrated in Fig. 2.

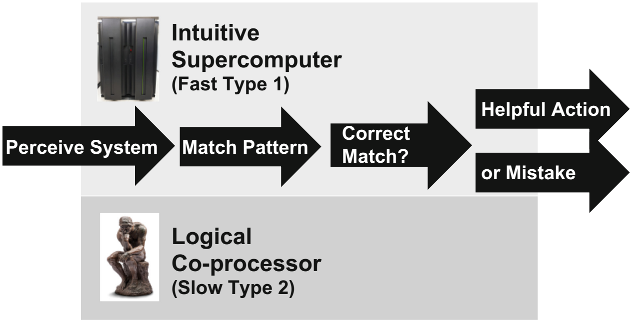

Fig. 2. Applying intuitive to match a familiar behavior to a situation.

People perceive the system, intuitively match their perception to a known behavior pattern, then act. It all happens very quickly and results in either a helpful action or a mistake (action leading to an undesired result) depending on whether the pattern match was correct for the desired result. At the time, people generally don't realize that they may be pattern matching incorrectly; they just act (a "mistake").

If instead the person realizes that the problem at hand does not match appropriately to an existing routine, the person invokes the logical coprocessor and slow thinking as illustrated in Fig. 3.

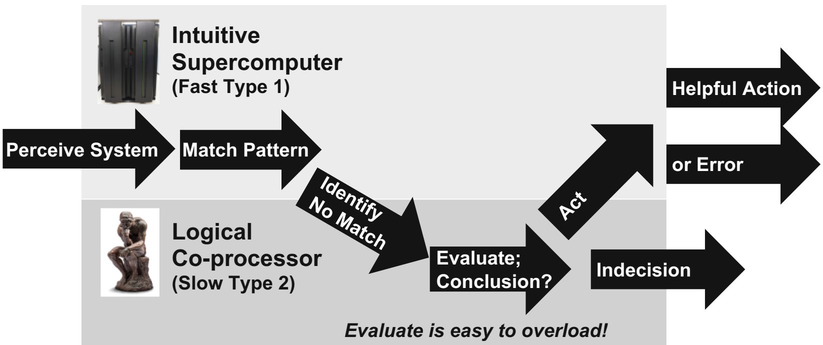

Fig. 3. Correctly identifying no appropriate pattern match in invoking slow thinking

The process of applying slower and more demanding deliberative thinking to puzzling out the correct course of action takes much longer, more energy and concentration, and is easy to overload. It can lead to correct action or an error due to the rush and pressure. With enough time and enough at stake, a confident course of action can be reached—as is routinely done in decision analysis. Alternatively, the person may be paralyzed by uncertainty and doubt and not decide or act at all.

Further, it is not practical to apply slowing thinking to every task and problem. For example, if people had to ponder each successive foot placement to walk, they would never get anywhere! People very appropriately place their feet slowly and carefully when walking on ice or rock climbing, but it's slow and easy to fall.

Where rapid and accurate selection of the right action is desirable, the alternative is to invest in reprogramming intuition as illustrated in Fig. 4.

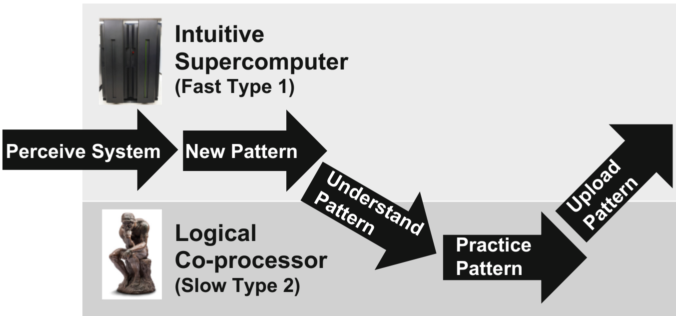

Fig. 4. Explicitly taking the time and practice necessary to learn and upload a new pattern.

With explicit identification that a new pattern is needed, time is taken to understand, learn, and practice the pattern and—with that practice—the pattern becomes automatic and is effectively uploaded to fast intuition. Thus, swimmers instinctively breathe and race car drivers instinctively manage car balance, speed, and direction.

This thinking applied to human factors and system design would add the following considerations to the process:

- Identifying the desired automatic, rapid, intuitive responses desired;
- Determining whether people interacting with the system have those patterns;
- For those patterns desired but not present in the target audience, incorporating training and practice time to make them automatic;
- Being very clear about where slow, deliberative Type 2 thinking is required and making allowances for that in the performance parameters; and
- Carefully limiting the deliberative logical coprocessor thinking required to avoid overwhelming users and errors or indecision.

Applying these considerations would result in faster, easier, more reliable user interaction with the system with better results.

4 Implications of a Programmable Coprocessor Cognitive Model to Healthcare

Much attention is placed in healthcare on quality and quality measures, and most institutions have a chief quality officer. The approach typically focuses on things to be checked to avoid preventable errors, many of which lead to patient harm. For example, when undergoing a surgery, multiple people ask the patient(!) where the surgery is to be performed and the surgeon may even initial next where the incision will be made in consultation with the patient.

However, Deming teaches that quality cannot be inspected in, and that quality needs to be built into the system to avoid unwanted variance in system results [9]. Indeed, medical errors are a major issue and believed to be the third leading cause of death in the United States (behind heart disease and cancer but ahead of respiratory disease [10]. Researchers concluded that the causes aren't bad doctors or nurses but, rather, systemic problems including poorly coordinated care, fragmented systems, and unwarranted variation in physician practices. "Unwarranted variation is endemic in health care. Developing consensus protocols that streamline the delivery of medicine and reduce variability can improve quality and lower costs in health care" [11].

Rampant unplanned variation is present in nursing, administration, and insurance as well as in physician practices. Nurses famously "hunt and peck" in the hospital wards, lurching from one unplanned interruption in their day to another, while unplanned delays derail care plans, surgeries, discharges, etc. Medical professionals from surgeons to anesthesiologists to nurses approach their tasks very differently. Even common procedures like total hip joint replacement (with an estimated 400,000 annual procedures in the U.S. [12]), are performed by surgeons using very different approaches with different postoperative protocols and drug regimes. Layout of surgical instruments is unstandardized, requiring pre- and post-operative instrument counts to avoid the known complication of a retained foreign body (something left inside).

As a result, caregivers are constantly in the situation described in Fig. 3 where, under extreme pressure, they deal with myriad unplanned and unpracticed matters required Type 2 attention rather than automatic routine. Cognitive overload and fatigue lead to errors and variance, driving up costs, patient harm and needlessly suboptimal outcomes. The constant stress and emotional toll drive caregiver stress and burnout (among both nurses and physicians).

The solutions are as old as the Industrial Revolution: design and standardize work processes to reduce complexity and variance, allowing as much as possible to be preprogrammed and processed with easy and automatic intuitive routine and freeing up Type 2 deliberative attention for problem identification and solution. The Quality Revolution provides further guidance on identifying where and how system variance should be reduced or results shifted (either up or down).

This approach has been successfully applied in another frequent-mission potentially high-risk industry: commercial aviation. The results need not be mind-numbing. Much of a pilot's work is routine, but he or she is trained, alert, ready and not already overloaded when something goes awry. A future paper will discuss why the vast potential in healthcare has not been realized.

5 Summary

The course of evolution equipped species with a programmable coprocessor model of cognition. A fast, intuitive "supercomputer" is the main controller and default mode. It works by rapidly matching inputs to known patterns to produce action. It works well most of the time, but fails predictably in novel, complex, or uncertain situations. It is complimented by a slow, deliberative coprocessor based on logic. Deliberation takes more effort and time and is less prone to error, but can be manipulated and focus on the wrong problem. Deliberative learning and practice can reprogram intuition to create new intuitive behaviors which are both fast and accurate for learned situations.

If human factors and system design take these considerations into account, large improvements in performance, results and quality are possible, accompanied by reductions in cost. Vast unrealized potential exists in healthcare.

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Developing a Serious Game to Support Disaster Management Preparedness - A Design Thinking Approach

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Abstract. Disaster management is the organization, planning and application of measures preparing for, responding to and recovering from disasters. Disaster response is a complex activity where decision-makers and responders are faced with very demanding challenges. Preparedness is key to effectiveness and efficiency of response. With the increasing technological evolution observed in recent decades gamification gained new fields of application, besides entertainment. Serious games are an example of such applications. A Serious Game is a game designed with a purpose of educating or training the user in a specific domain, namely in disaster management. This paper discusses the initial stages of the development of a serious game aimed at supporting the preparedness of responders in a context of Disaster Management.

Keywords: THEMIS project · Design thinking · Octalysis framework · Human-systems interaction · User centered design

1 Introduction

According to the United Nations International Strategy for Disaster Reduction 'Disaster management' is the organization, planning and application of measures preparing for, responding to and recovering from disasters [1]. Disaster response is a complex activity where decision-makers and responders are faced with very demanding challenges. Preparedness is key to effectiveness and efficiency of response.

With the increasing technological evolution observed in recent decades gamification gained new fields of application, besides entertainment. Serious games are an example of such applications.

A Serious Game is a game designed with a purpose of educating or training the user in a specific domain (e.g., flight simulators, defense, health care, engineering, cyber security), namely in disaster management [2]. This paper discusses the initial stages of the development of a serious game aimed at supporting the preparedness of responders in a context of Disaster Management. This work is an offspring of the THEMIS (*disTributed Holistic Emergency Management Intelligent System*) project which already developed an intelligent system, encompassing desktop apps (for disaster managers) and mobile apps (for disaster responders) [2, 3]. The purpose of the current

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research is to create a Virtual Reality (VR) environment which supports the training of disaster responders, by means of immersive disaster environments and the scoring of users performance while executing missions where they have to apply previously acquired knowledge and procedures (e.g., search of damaged buildings looking for affected victims); thus contributing to the preparedness stage of the Disaster Management Cycle.

The process used to reach this goal adopted a Design Thinking approach [4]. Design Thinking is a design methodology that provides a solution-based approach to solving problems, and encompasses a 5-stage model (i.e., empathize – define – ideate – prototype – test). Particularly interesting is the ideation stage, where ideas and solutions can be generated through a wealth of ideation techniques (e.g., Sketching, Prototyping, Brainstorming, Brainwriting, Worst Possible Idea). The gamification of the training was also inspired by the Octalysis Framework [5], which is a human-centric gamification design framework that lays out the eight core drives for humans motivation (Epic Meaning and Calling; Development and accomplishment; Empowerment of Creativity and Feedback; Ownership and Possession; Social Influence and Relatedness; Scarcity and Impatience; Unpredictability and Curiosity; Loss and Avoidance).

To develop an adequate level of skills, disaster managers and first responders need to train in the different scenarios in which they can operate. VR emerges as a technology of great potential for training (e.g., military, firefighters), due to the sensory reaction that it provokes in the user, generating sensations and reactions very close to real scenarios.

This article addresses the ongoing development process of a VR solution that allows training first responders to operate in areas affected by disasters, providing a tool that allows them to experience situations close to the real ones, with the aim of increasing their level of confidence and experience to face disaster scenarios.

This article consists of four sections. This first section aimed at introducing the main problem domains. Section 2 sets the background on techniques used in the development of VR solutions. Section 3 addresses the specific solution design process, discussing the employment of the storyboard technique. The last section presents some conclusions, summarizing the work done and the following steps.

2 Background

The design of the proposed solution, to support the training of first responders for disasters, requires a basic understanding of relevant areas of the problem, namely, Gamification, Storyboard and Virtual Reality, which will be briefly addressed in this section.

2.1 Gamification

Gamification is the process of using game elements and applying them to real life activities. Its objective is, therefore, to apply methods and techniques used in games in order to motivate and encourage the accomplishment of tasks, motivating workers and encouraging collaboration.

Deterding et al. defined gamification as the use of game elements in contexts other than games [6]. An effective gamification combines factors present in applications developed for entertainment purposes, such as design, dynamics, psychology and technology, and uses them to support the organization's current tasks. Several studies confirm that teaching-oriented gamification promotes the development of effectiveness and increased retention, by motivating students to learning [7, 8].

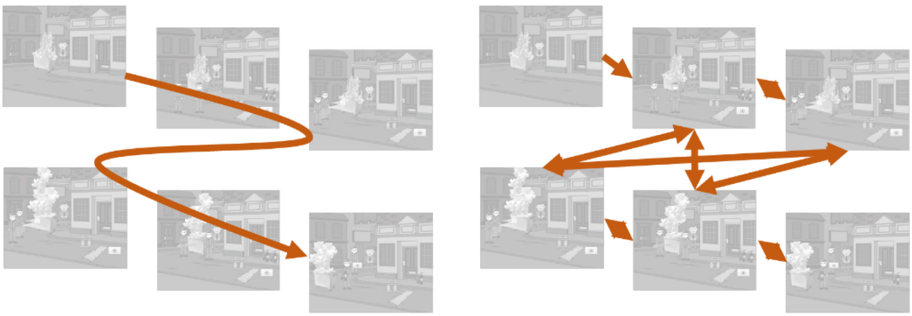
The concept of gamification was used for the first time in 1896, when a company run by Sperry and Hutchinson started a stamp business and spread it across sales outlets. The money spent by the customer allowed to accumulate stamps, later exchanged for household items [9]. Nowadays, gamification is present in applications that promote teaching and learning such as the Geography Seterra-quiz, where the user while playing can improve his knowledge in geography; or Duolingo, which offers awards for the users achievements as they learn a language. There are also some examples of the use of gamification in the context of emergency management (refer to [2]).

2.2 Storyboard

The storyboard is a predecessor of writing, having been used by ancient civilizations as a form of communication. For instance, the Egyptians used it, initially engraved on stones and later on papyrus leaves [10].

Currently, the storyboard technique is used as a first representation and visualization of a project to be developed (e.g., a movie, a game) [11]. It is prepared based on a set of sequential drawings that serve as a guide for the project [12], documented with notes of what is intended to happen. The record of its use in modern times, for this purpose, dates back to the 1930s, by the Walt Disney studios [13].

The storyboard flow can occur in two ways: linearly – as a timeline, to assist the creation of films, videos, animations (see Fig. 1a); non-linearly - for example, in the design of Graphical User Interfaces (GUI) for games and other digital products (see Fig. 1b).



a. Linear storyboard b. Non-linear storyboard

Fig. 1. Alternative storyboard flow

The storyboard is the first tool in the pre-production of any multimedia project. Through the set of images, ideas and requirements take shape and can be explained to users, anticipating problems during the execution of the project, resulting from a deficient survey of the solution requirements.

The storyboard has numerous advantages, namely:

- Helps to organize ideas - when creating a storyboard the ideas are placed in a visual way, which helps to develop the perception of what is important in the project;
- Helps Planning - with its creation the most important details of the project are highlighted;
- Helps to communicate ideas - communicating the idea in words is not always easy; therefore, the drawings of the storyboard may simplify communication;
- Simplifies the performance of tasks - with a good storyboard, important details of the project are highlighted, avoiding the loss of time due to errors that arise from deficient requirements gathering.

2.3 Virtual Reality Platform

VR is an advanced type of interface which uses a set of 3D graphic images generated by computer. In order to implement a VR-based serious game it is necessary to select an adequate platform, suited to the design requirements.

A game engine is a development environment that serves as the basis for creating game applications and similar solutions. The game engine provides a graphic environment for the creation of 2D and 3D images, animation, audio and to support programmers in the development of applications for entertainment and education.

Examples of game engines are:

- Unity - currently the most used engine in the entertainment market;
- Unreal Engine 4 - a more complex environment, used by programmers experienced in programming languages;
- Game Maker - a platform adequate for 2D modeling. When 3D modeling is required has some disadvantages in relation to the previous ones.

For the current project the game engine adopted was Unity. Unity is the software that has the best features for the intended purpose. It is the most used tool in the world gaming market and the simplest to program. It has ample support materials and simultaneously presents a set of sophisticated characteristics for the implementation work to be carried out. Due to the limitations of paper size, the Unity implementation is not addressed here.

3 Proposed Solution

Considering the Disaster Management Cycle, the Preparation phase is of crucial importance for the success of response phase, which is triggered by the onset of a disaster.

A VR simulator offers the opportunity for the agents involved in disaster response to train in quite realistic scenarios, from the sensorial standpoint.

Serious games (i.e., applications designed based on game technology) can be very effective tools since they motivate the trainees, promoting their learning and retention capacity, and exercising their mental and intellectual functions, as the psychological processes in a virtual environment are similar to the processes performed in a real training environment [14]. In fact, several studies (e.g. [15–17]) concluded that gamification is a way of developing: new thinking skills; procedural knowledge (i.e. knowing how to do something); and declarative knowledge. These studies also advocate that the teaching supported by gamification changes the behavior and psychology of the student, who participates and is motivated for learning. Therefore, it is anticipated that the creation of a VR disaster scenario to be used in the training of disaster responders helps developing their skills and become better prepared to face disasters.

The storyboard technique (illustrated in Fig. 2) was used for pre-production and structuring of ideas, aimed at creating the VR disaster scenario. This technique contributes to produce a VR app script before its implementation, obeying the following rules:

- Each relevant situation must have one or more images;
- Each image must have actors, important details and information about each element of the scene;
- The position of the camera should always be kept in mind, in order to anticipate the effect created;
- All transactions to be carried out must be identified;
- Scenes include dialogues and other important details, in order to be enlightening and awaken the imagination of those who view them;
- Actor movements and environmental conditions (for example, the wind) must be highlighted with arrows.

At a later stage, the rules, objectives, mechanics and environment of the artifact have also to be defined:

- *Rules* - help in understanding the game challenges. Thus, it is necessary to define rules so that there are no doubts from users of the artifact. According to Zimmerman [18], the rules must limit the action of users, be fixed, simple, clear and shared by all;
- *Objectives* - are intended for the user to establish their priorities. For Bates [19], objectives are important to guide the user, as the user must always know what he is doing and the reason why he does it. It is also important to establish different types of objectives: short, medium and long term;
- *Mechanics* - are the set of elements available to create a relationship between the challenge and the user. According to Sicart [20] the mechanics of the challenge are distinguished from the rules because they are applied in the space where the interaction takes place;

Fig. 2. Example of drawings created for the storyboard of a particular VR-scenario

- *Environment* - is the space where the challenge takes place and where the rules are applied, in order to allow the user to get involved in the challenge environment;
- *Artifact* - the intention is to create a set of scenarios based on a Portuguese Navy training site used for the ships' crew training in disaster response. An example is a scenario created for the training of a Search Team, whose objective is to locate and report wounded people found in street with damaged buildings. For the challenge to be successfully concluded, it is necessary for the team to follow the instructions received within an established time limit.

The analysis of the scenario structure is quite important, in order to assess its static and dynamic qualities, to verify the means available to achieve the intended ends, before proceeding to the development of the artifact in the game engine.

The artifact implementation must be evaluated regularly, in order to assess the different dimensions of its Usability and solving any detected flaws. To check for possible flaws and defects, functional and structural tests have to be carried out.

4 Conclusions and Future Work

Serious Games are increasingly being used in support of training and education, exploiting the opportunities offered by the technological evolution in computation and on the new forms of cyber-human interaction. This paper addressed the initial stages of the implementation of a training VR application for disaster managers and first responders. The main problem domains for the implementation of the artifact (gamification, storyboard and VR game platforms) were described, giving a particular emphasis to the role and advantages of creating the game scenario storyboard. The need for future analysis of the scenario structure was highlighted, in order to assess its static and dynamic qualities, and to verify the means available to achieve the intended ends. It was also stressed the need for an iterative evaluation of the artifact developed in the game engine to ensure high Usability standards.

Despite the early stage of this offspring of the THEMIS project, there is a high confidence that this VR training environment will contribute to raise the preparedness of first responders to be deal with disasters and, therefore, to the effectiveness and efficiency of Disaster Response Operations.

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Virtual Reality in Support of Maritime Rescue Training

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Abstract. One of the main missions of the maritime authorities is to provide safety for people at sea. This task often involves specialized trained professionals either lifeguards at the beaches, as well as divers assigned to search & rescue (SAR) ships and helicopters. Training professionals for rescue operations at sea is a demanding process due to the challenging requirements of the real scenarios, frequently involving harsh weather conditions. Nevertheless, such training is critical to ensure the safety of the team and ensure the success of future rescue missions. The current paper describes the process followed in the design and development of an interactive environment using virtual reality, designed for the training of maritime rescue teams. The process resorted to interdisciplinary domains, such as user experience, gamification and storytelling, for delivering a product usable, motivating, efficiency and fun. The final validation of the solution is performed through usability tests with a sample of lifeguards and divers that experienced the VR solution. The rescue professionals are submitted to a survey in order to evaluate users' effectiveness, satisfaction and ease of learn. Results are analyzed to assessing the degree of compliance of the final product with the requirements and gather requirements for the next development iteration.

Keywords: Virtual reality · Human factors · Human-systems integration · User centered design · Gamification

1 Introduction

Littoral countries, such as Portugal, with a large volume of maritime traffic and long beach coastlines, are exposed to the risk of maritime accidents, due to ships' collision or stranding, as well as incidents with bathers. According to the Portuguese maritime accident investigation office, on the first semester of 2019, there were 149 accidents in maritime Portuguese jurisdiction, which resulted in 10 fatalities and 52 injured. The number of drownings in Portugal (sea and river beaches, public and private pools, and other water courses) has skyrocketed in the past eight years. One of the missions of the Portuguese maritime authorities is the safeguard of people at the sea. This task often involves specialized trained professionals either as lifeguards at the beaches, as well as divers assigned to search & rescue (SAR) ships and helicopters. Training a professional

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lifeguard, for a rescue situation, is a difficult endeavor due to the requirements of creating realistic scenarios, including weather factors constraining the efforts of the rescue team. Nevertheless, such training is critical to ensure safety of rescue team and the success of the mission.

Serious games are games designed for a primary purpose other than pure entertainment, for instance, for a training or education purpose. Virtual reality is an example of technology that can be used to create immersive environments adequate to support the implementation of serious game.

The current paper describes the process followed in the design and development of an interactive environment using virtual reality, designed for training of maritime rescue teams. The process resorted in interdisciplinary domains, such as user experience, gamification and storytelling, for delivering a product usable, motivating, efficiency and fun. During the development process multiple training context scripts were designed and developed so that members of rescue teams could, in the future, train a set of core procedures in synthetic environments to attain proficiency on rescue operations.

Following the present Introduction, the work is organized as follow: Sect. 2 offers an overview of the problem which consist in addressing the procedures of rescue operations; Sect. 3 reviews some of the main techniques required for underpinning the proposed solution and the current developments of the solution is presented in Sect. 4; finally, some conclusions of this study and recommendations for future work are presented.

2 Background

Maritime rescue is a high-risk mission usually involving high-stress victims. Therefore, it is paramount that rescue professionals have great expertise in carrying out the procedures required for their mission. Thus, training is fundamental to the effectiveness of lifeguards' rescue actions.

As general rule, rescue procedures require three main actions:

(a) *Recognition*: the professional must be aware of the emergency, must assume the responsibility and evaluate whether the situation requires urgent response;
(b) *Planning:* the lifeguard must think before act and plan the action;
(c) *Action:* the rescue must be carry out and assistance provided until the arrival of medical aid.

There are several techniques to approach the emergency by the lifeguards, depending on the circumstances (Fig. 1). The most effective technique to be used, when the approach is made from shore, is to reach the victim with a rescue stick. Lifeguards should only use techniques that involve swimming when ground-based techniques have failed or were not appropriate, due to the distance to the castaway or because the victim is unconscious. The lifeguard must be aware that conditions can change during rescue (e.g. a conscious person may turn unconscious, the lifeguard may fail the attempt to launch a relief device, the sea condition can change). Thus, an action plan should never be considered final and may have to be adjusted during the course of the action.

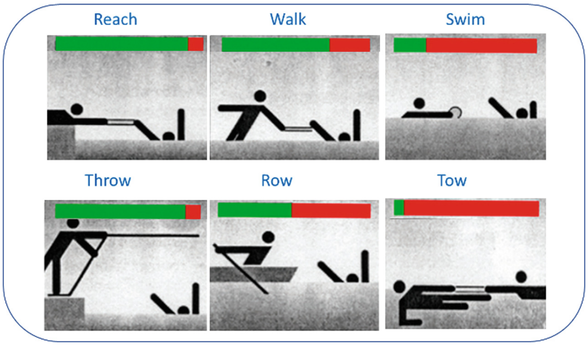

Fig. 1. Safety of the rescue procedure: green bar means the level of safety [1]

Therefore, the general algorithm for carrying on a rescue mission can be described as follows:

(a) *Recognition*:
   1. Alert emergency services; call a first-helper by other lifeguards;
   2. Undress/dress up clothing/suit to facilitate the rescue;
   3. Check the number of victims or shipwrecked;
   4. Find their position;
   5. Assess sea conditions;

(b) *Planning*:
   6. Select for the appropriate rescue method for the situation under evaluation;
   7. Reach, throw, walk, row, swim, or tow (Fig. 1);

(c) Action:
   8. Select the rescue medium according to the method defined in the planning;
   9. Enter the water if necessary, and swim without losing sight to the castaway. (The approach to the castaway should be done in rescue swimming and with great caution). As soon as the castaway is within audible range, talk to her to convey calm and confidence.
   10. Assess the castaway – in case of:
      (i) conscious castaway - speak calmly and give precise orders, instill confidence, and provide to the castaway the fluctuation device for rescue; move to a safe position, in relation to the castaway, by putting the fluctuation device between both;
      (ii) unconscious swimmer - the lifeguard should signal gesturally to the rest of the team (shaking the arm over the head) so a second-helper can call the emergency number: the quickness in reaching an unconscious castaway is vital because if he/she is not in respiratory arrest he/she will be soon; continuous observation is essential in case of the castaway to submerge; grab the castaway, bring him/her to the surface if he/she is submerged, check the airways and give 2 insufflations: priority should be firstly to stabilize the victim's condition, and only then deal with the rescue;

11. Rescue the castaway according to the rescue method used;
12. Exit the water and carry the castaway to a safe place.

3 Literature Review

Virtual Reality (VR) offers a very high potential in education by making learning more motivating and engaging. VR is based on three principles: Immersion, Interaction, and User involvement with the environment and scenario. VR has evolved in two different kinds: non-immersive and immersive. The non-immersive type is built through a computer-based environment that can simulate places in the real or imagined worlds; the immersive type takes the idea even further by giving the perception of being physically present in the non-physical world. The non-immersive VR can be based on a standard computer, while the immersive VR needs appropriate devices (e.g. HoloLens, Oculus Rift) [2]. Regarding the development of the solutions there are more than ten platforms currently available, being Unity the most widely used [3]. Besides education and training other areas in which VR may prove to be particularly valuable are planning and management, marketing, entertainment, accessibility, and heritage preservation [4].

There is relevant interest in the topic of gamification in non-gaming contexts. In fact, gamification can be used in other activities, such as education and training. Gamification can be defined as the application of game design principles to any activity in new and innovative ways. Some frameworks have been made available to instantiate gamification. Two of those frameworks that explain how gamified experiences can be created are: (1) Mechanics, Dynamics, and Emotions (MDE) [5]; (2) Octalysis [6].

Storyboarding is a design technique for demonstrating system interfaces and contexts of use. The important elements of storyboards include the use of text, people, level of detail, number of panels, and representation of the passage of time [7].

4 Proposed Solution

The VR artifact to be built will explore different scenarios in wrecks and in bathing areas where there are castaways to be saved. The elements considered for the VR artifact were the following:

1. Avatar: the lifeguard (player) will be the main persona, and he/she must feel like in a real scenario. However, more avatars could appear during the played scenario, depending on the objectives;
2. Boss: defines the mission, i.e. the challenge to be overcome by the player, which normally has to save whoever needs assistance in a beach/ship in order to successfully complete the mission;
3. Achievements: for each action/task that a lifeguard completes, a certain number of points are awarded;
4. Mission: the rescue victims to save on the beach/ship, which the lifeguard will know before starting to play;

5. Points: the system of points, aims that, for each action, the player receives a number of points, in order that, at the end of the played scenario, all points will sum allowing to evaluate either the performance of the player, by its own or in comparison with other players.

The elements, previously mentioned, are linked to following mechanics of the MDE framework [5]:

1. Cooperation and competition: this mechanics creates a feeling of victory (or defeat), based on the player's sense of responsibility, since the victims depend on the player to survive;
2. Challenges: placed in order the player can successfully complete the mission;
3. Rewards: the player will receive rewards (points) throughout the played scenario, which will contribute to the final score;
4. Victory: the mission must always be completed, with or without penalty.

Regarding the dynamics, the elements introduced in the VR artifact were:

1. Emotions: triggered by the sense of responsibility and the need to accomplish the rescue by the player;
2. Progression: the player will have the notion that is advancing in the played scenario due to the challenges that appear, the final challenge is to save the victim and return to a safe place (e.g. beach, ship);
2. Constraints: the player is obliged, in all the scenarios, to leave a safe place to meet the castaway and return to the original place after the mission.

Several scripts, such the one in Fig. 2, were designed based on a storyboarding process, executed according to the requirements gathering phase of a User Experience method [8]. In the context of each synthetic scenario of a maritime accident, a person executes a set of search and rescue procedures meant to save an endangered castaway (e.g. trapped in a sunk ship). In the specific scenario of Fig. 2, the story goes like this: a bather signals that he is in trouble; the lifeguard prepares to jump into the water; the lifeguard's jump is made with his body parallel to the water, and the eyes pointed to the man he wants to rescue; the lifeguard swims in direction of the bather, without losing him from sight; after arriving to a short distance of the bather the lifeguard plunge, circumvent the bather, and grab him from the neck to make him rotate until the chest is facing up; the lifeguard begins the transportation process towing the bather using a lateral-crawl swimming style; arriving a secure spot the lifeguard helps the endangered bather to climb up for a safe position.

The performance of each player, traversing each scenario and realizing the assigned tasks, is monitored through the gamification process previously described. The implementation of the virtual reality solution for maritime rescue training is planned to be made in the Unity platform.

The validation of the built training VR solution is performed iteratively through usability tests with a group of rescue professionals, until the VR application is deemed satisfactory. For this purpose, the usage of the VR solution is observed, and at the end of the test the users reply to a questionnaire (e.g., based on the System Usability Scale (SUS) method [10]). The observation and questionnaire results are analyzed to assess

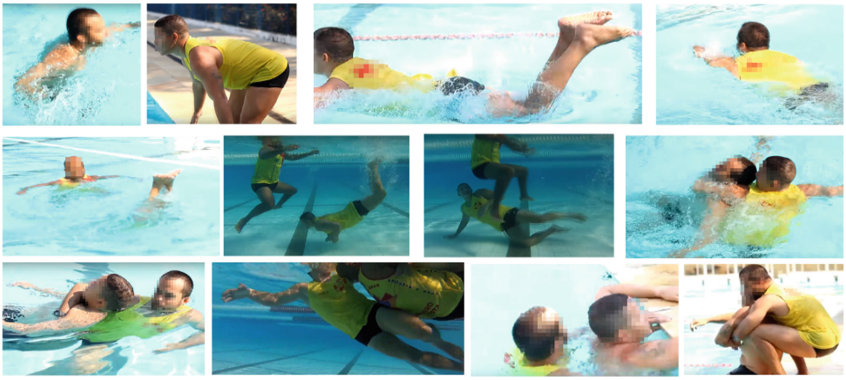

Fig. 2. Scenario demonstrating the employ of a sequence of rescue techniques [9]

the degree of compliance of the solution with the requirements and to evaluate users' effectiveness, satisfaction and ease of learn. While the assessment is not satisfactory the solution's interface content and layout are refined and improved following a User Centered Design approach.

5 Conclusions

This paper addresses the implementation of a VR solution for the training of rescue professionals. Several domains contributed to the design and construction of the solution, namely, gamification, storyboard and immersive VR. The solution is part of an iterative process, aimed to assess and improve its static and dynamic qualities, and also the compliance with required usability standards.

The system places several challenges, namely regarding the usability and human-machine interactions, which is going to be addressed, as part of the future work, in the iterative process, according to the principles and methods of User Experience.

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Automatic Classification of Incidents in Coastal Zones

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Abstract. The increase of seasonal population on coastal areas, in certain periods of the year, as well as the diversity of events to be monitored by the authorities, raise the likelihood of marine incidents. These occurrences can have a diverse nature and severity amenable to ban the access to the beaches. This work describes the development of a low-cost system based on UAV for real time detection, recognition, and classification of several types of incidents in the coastal area and inland waters in an efficient manner. The system provides, to maritime authorities, a faster and more effective capacity for intervention in controlling maritime incidents, contributing to greater protection of public health and safety of the populations and the activities developed ashore. The system implemented a machine learning algorithm and a mobile app that help human operators monitoring maritime incidents. The development of the system was based on usability principles in order to tailor the system's graphical interface to the first responder's users (e.g. lifeguards, coastguard officers).

Keywords: Maritime incidents · Human-systems integration · User centered design · Machine learning

1 Introduction

Littoral countries, such as Portugal, are responsible for the supervision of large marine areas, usually crossed by recreational and commercial routes. On those countries' coastlines, there are, usually, several agencies and civil society actors involved in relevant economic and social activities (e.g. fishing, nautical activities, bathing). The increase of seasonal population on coastal areas, in certain periods of the year, as well as the diversity of events to be monitored by the authorities, raise the likelihood of maritime incidents.

The occurrences faced by maritime population can have a diverse nature and severity amenable, for instance, to ban the access to the beaches. Some examples of those incidents are the fuel or oil spillage, polluting discharges, plastics and waste, animal corpses (e.g. dolphins, whales), cliffs' landslides, drownings, boat accidents, and other threats to bathers, such as toxic algae blooms, jellyfish and Portuguese man-of-war (*Physalia physalis*). Monitoring some of these events, such as the case of marine pollution, is currently carried out with systems supported by assets such as satellites and Unmanned Air Vehicles (UAV). These systems have sensors for detecting spills

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(pollution stains), which can assist maritime authority decision-making regarding the triggering of contingency plans. However, despite technically advanced those high-cost solutions are still prone to errors (e.g. in the distinction between pollution stains and stains caused by weather conditions or environmental phenomena) and delays in occurrences' detection.

Therefore, maritime authorities sought the development of a low-cost system for real time detection, recognition, and classification of several types of incidents, through commercial UAV, in an efficient manner in the coastal area and inland waters. The system should provide a faster and more effective capacity for intervention in controlling marine incidents, contributing to greater protection of public health and safety of the populations and the activities developed ashore.

This work, following the present Introduction, is organized as follow: Sect. 2 offers an overview of the problem and the motivation to solve it; Sect. 3 reviews remote sensing and detection methods amenable of being used by the proposed monitoring system; the architecture of the proposed solution is described in Sect. 4; finally, the conclusions of this study and recommendations for future work are presented.

2 Background

Maritime authorities are responsible for ensuring the safety in harbors and bathing areas. Their activities include procedures related to safety and support to bathers on sea and river beaches. In addition to direct assistance of bathers, maritime authorities have to implement surveillance and police measures in bathing areas, as well as measures for protection and preservation of the marine environment, and respond to marine incidents of several types. Some of the common threats that authorities have to tackle and the level of risk to bathers are described in the following paragraphs.

One of this type of marine incident is the arising of Portuguese man o' war - also known as the floating terror (Fig. 1). These sea creatures have a powerful sting that, on some occasions, can kill. Unable to move independently, the creature floats on the surface and is propelled by a balloon-like 'sail.' Its tentacles can be more than 30 meters long and they deliver a painful sting causing whip-like red welts on human skin [1].

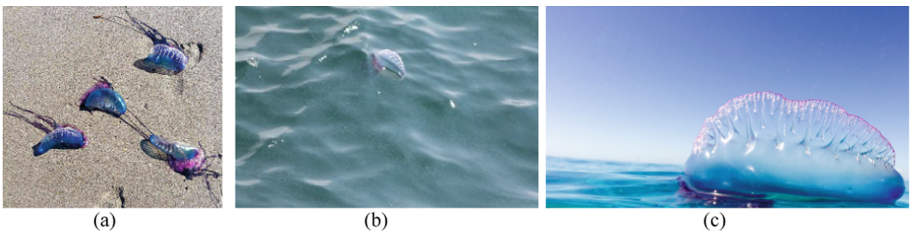

Fig. 1. Portuguese man of war from several perspectives: (a) on sands of a beach, and floating near the shore [1], (b) seen from top [2] and (c) from side [3].

Another kind of incident, which occurs in coastlines with a cliff' morphology, is their collapse (Fig. 2). When the phenomenon occurs, people sunbathing or walking along a beach, may become trapped or deathly crushed under tons of a mass of rubble and earth from the landslide. The stretches of the coastline probably crack up given the joint effects of extreme weather on cliffs, due, namely, to heavy rainfall and humidity in cold seasons, followed by periods of strong sun in hot seasons [4].

(a) (b)

Fig. 2. Cliff collapse: (a) stones falling on bathers [4]; (b) emergency services searching the rubble [5].

Oil spills include any spill of crude or distilled oil products that can pollute the surface of the land, air, and water environments (Fig. 3). The term oil spill pollution refers to the negative polluting effects that oil spills have on the environments and living organisms, including humans, due to the environmental discharge of various organic compounds that make up crude oil and distilled oil products, the majority of which include various individual hydrocarbons. The organic compounds of hydrocarbons may affect the wildlife and humans in various ways: (1) directly, by contact with the skin (e.g. irritation an absorption), through inhalation, ingestion, emitted odors; and (2) indirectly, by consuming contaminated food, disrupting professional and/or recreational activities, decreased property values from the affected areas, aesthetically alteration of the environment, and the overall economic impact [6].

One different kind of incident on rivers and sea is the emergence of plastics and waste, where it may cause harmful effects, such as damage to living resources and risks to human health, obstacle to marine activities, including fishing and other legitimate uses of the sea or rivers, and impacts on the quality of water, with regard to its use and deterioration of recreational sites. The effects on aquatic wildlife can be entanglement, death from ingestion, and transport of invasive species [7].

The Portuguese maritime authorities patrol the coastline periodically to detect incidents, such as the ones mentioned above, using terrestrial means and visual aids. The present work aims to deliver a new approach for monitoring the coastline, through specially tailored low-cost drones, in order to detect in advance imminent incidents or, at least, as early as feasible the occurrence of incidents (e.g. eroding of unstable cliffs,

(a) (b) (c)

Fig. 3. Pollution evidence: (a) patches of sheen from a spill of fuel oil [8]; (b) crude slicks dragged to the beach [9]; and (c) waterborne plastics and waste [10].

seaborne spill of fuel oil, danger creatures approaching bathing areas), triggering alerts and activating the emergency services to minimize the harmful consequences of such events.

3 Literature Review

Remote sensing has been the dominant source of geospatial information for detecting and monitoring coastline changes over time, of which the most common techniques include satellite imagery, aerial photography, airborne Light Detection And Ranging (LiDAR), terrestrial LiDAR, and UAV photogrammetry [11]. UAV-based remote sensing techniques, as well as the UAV LiDAR techniques also demonstrated great potential for monitoring rapid shoreline changes [12].

Improvements in small-scale technology have enabled the use of UAVs as an alternative remote sensing platform offering a distinctive combination of very high-resolution data capture at a significantly lower survey cost. Current research into the use of UAVs as a 3D data-capture platform includes, for instance, archaeological surveys [13], precision agriculture [14], oil spills [15], and vegetation monitoring [16–18]. These studies use image matching and photogrammetric techniques, which allow high density point clouds to be generated from the very high-resolution imagery collected by UAVs [19]. For marine debris, LiDAR technique was also proposed for the semi-automatic recognition on a beach because of its substantially more efficient role in comparison with other more laborious methods. The results revealed that LiDAR can be used for the classification of marine debris into plastic, paper, cloth and metal [20].

LiDAR data were used to verify that fine spatial scale data can provide information about wildlife not readily captured by either field work or coarser spatial scale sources. The variables extracted from the LiDAR data can successfully model activities of wildlife species using morphological beach characteristics, highlight beach changes over time and their correlations with mentioned activities. Comparisons between the LiDAR dataset and other Digital Elevation Models (DEMs) confirmed that fine spatial scale data sources provide more information than those with coarser spatial scales. The underlying principles of made research seems to be applicable for several wildlife species [21].

Given the wide range of application of LiDAR techniques for detecting the kind of incidents described in Sect. 2, UAV LiDAR technology was chosen for data collection and detection of marine incidents.

4 Proposed Solution

The architecture of the solution for detecting marine incidents is to be implemented in two layers. The first one in the UAV, through a Deep Learning Convolutional Neural Network (CNN) [22] for the capture and processing of images collected by the UAV's LiDAR sensor (Fig. 4). The output of the deep learning CNN is the likelihood of each type of incident for the image captured by the drone. The CNN algorithm is to be trained using a database with almost one thousand images for each incident. About one hundred images are used to validate the model. The deep learning framework used for training the model was Keras with Tensorflow backend.

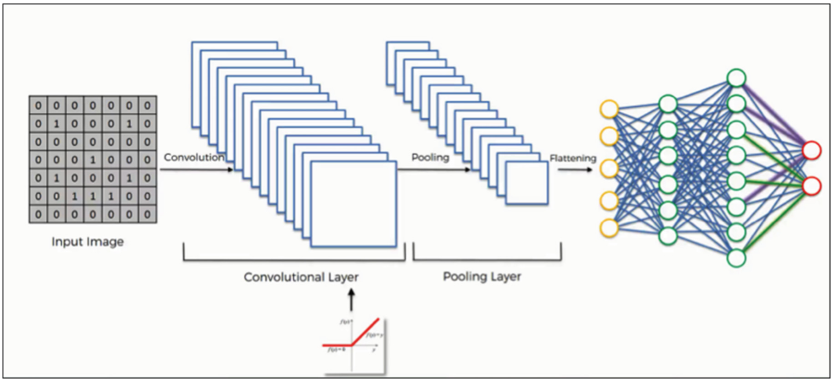

Fig. 4. Flow of the convolutional neural network [23]

The second layer of the solution is implemented as a mobile application installed on a tablet operated by a maritime officer. Through the mobile device it is possible for the user to define the UAV flight plan by setting waypoints. A communication data link allows the UAV to send alerts for the several types of incidents the CNN is trained for. After receiving the data from the UAV regarding the incidents the user can access its location on the map, and visualize the images that triggered the alert.

The user interfaces design for the mobile app are being studied using mockups built with NinjaMock [24]. The solution's interface content and layout is to be refined and improved following a User Centered Design approach, namely applying usability tests which will be assessed using methods such as the System Usability Scale (SUS) [25].

5 Conclusions

The paper describes the solution envisioned to support maritime authorities on monitoring and detecting maritime incidents, which is currently being developed by the authors. Maritime incidents may be of several types and natures, and their detection and classification places challenges to the authorities. The work here presented contributes to the detection of such incidents, adopting a two-tier system. The first layer of the system is based on UAVs carrying out a LiDAR sensor, which data is processed by a Convolutional Neural Network algorithm. The second layer is based on mobile devices whose app alert the first responder users about the potential or real incidents, allowing their validation through the access to the data and images collected by the UAV. The system places several challenges, namely regarding the usability of the human-machine interactions, which will be addressed using well known principles and methods of User Centered Design.

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Human-Systems Design

Economic Implications of Innovative Visual Guidance System for Crane Cabins

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Abstract. This paper proposes innovation through implementation of a real-time computer-aided visual guidance system (VGS) which prevents crane accidents, caused by crane operator's obstructed view, which can be the cause of collisions between load and obstacles and/or intrusions in the workspace. Proposed VGS allows predicting whether a dangerous event is going to occur and promptly alerts the crane-operator in order to let her/him taking corrective actions during the execution of crane-assisted shifting duties. VGS is equipped with interface which is designed to be simple in terms of the number of commands and easy to use in order to reduce the operators' stress. Analyses of the economic feasibility of VGS application through cost-benefit framework follows. The payback period of invested funds for the purchase and installation of VGS is 1.5 years and installing and usage of VGS represents a very low risk investment.

Keywords: Cranes · Operator · Visual guidance system · Investment

1 Introduction

Cranes are irreplaceable and very important part of the industry nowadays [1], but they also represent one of the most dangerous parts of the equipment that is used [2]. Many accidents that happen are caused due to human error. This implicates that it is necessary to identify the main reasons in human behavior that cause accidents in order to find an adequate solution to this problem [3]. In order to eliminate accidents caused by human error, it is necessary to first identify the problems faced by the crane operator, which means determination of what would be the most common cause of accidents. A crane operator is a very responsible job that requires great precision and concentration. The crane operator is exposed to high pressure which is further increased due to the high risk of crane accidents and possible injury and even death [4]. The literature [5–11] has highlighted the main needs for crane design (capability to be safely operated, easy maintenance and reduction of typical human problem factors), but up to now world-wide research has not been focused on the crane navigation system. It is essential for a

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crane operator to have adequate equipment that will help him to avoid accidents [12]. Hence, special attention needs to be given to the crane-operator's workplace, including redesign, with the aim to come closer to Industry 4.0 concept (I4.0) and prevent occupational injuries, illnesses, fatalities and undesired exposures prevention [13]. Typical crane operator interfaces actually appear to be simple in terms of the number of controls; by moving the spreader quickly and accurately, with or without a container, it requires an exceptional sense of its dynamics, including how to effectively stop the moving mass. This paper proposes the visual guidance system (VGS) that aims at simpler manipulation of a load whose direct consequence would be to reduce accidents caused by human error and gives proves of justification of its purchase and installment.

2 VGS Description and Human Factors Issues

The VGS is an innovative tool that provides the crane-operator with a safe guide in carrying tasks in manner that the system intends to solve the problem of limited vision in moving large and heavy loads within complex sites, which can be the cause of collisions between the load and obstacles and/or intrusions in the workspace. It uses stereoscopic vision imaging to capture and process images of the workspace and provide useful information for collision, as described in [14]. In order to define the optimum real-time computer-aided visual feedback, beside the development of adequate hardware and software, there are many important things that need to be considered, such as monitor size and position, selection of keyboard or touch screen, etc. These decisions will depend upon different factors including how quick and with what precision operator needs to see the information or picture on the display, does he need and how much data to entry to the device, what kind of configuration will provide him with most comfortable working postures and the least tension in his vision. As pointed out in [15] inadequate field of view can lead to decreased usage of capacity and properties of the crane, increased operators' health problems (due to awkward positions in which he operates because of the poor field of view) and, at the end, increased danger to the both operator and the crew working near the crane. Thus, ergonomic design of operators' working space regarding VGS has to take into account optimal location of displays and appropriate sized window space for the viewing of respective machine operations, as well as operator posture required to enhance task visibility while in a working position [15]. Display configuration has a strong influence on both cognition and behavior, and designers should be aware of the limitations of small desktop display configuration [16]. Larger display is less stressful and creates a better sense of confidence for user than the smaller displays. Also, display position can directly affect users' performance and subjective workload [17]. South position is the most preferable one, while the west position is the next best option, so that the display in the crane cabin should be put in those positions. Another important aspect is the size of the keys and authors in [18, 19] propose 2.27 cm per side to maintain an error rate less than 1%. Recommendations on operators' posture are given in detail in [8].

3 VGS Economic Appraisal

3.1 VGS Initial Investment Costs and Additional Operative Costs

The initial investment costs include costs of procurement of hardware (2 Wi-Fi cameras OpenNI type, 1 Remote control, 2 Portable power pack 10400 mAh, 2 MicroSDXC Memory Card 64 GB, 1 Computer, 2 Raspberry pi 3), software costs, costs of equipment installation and programme, adjusting the existing cabin costs and the initial costs of stuff training. In the economical evaluates justification model of installing an environmental detection system in an existing cabin and existing smart crane in the process industry, initial investment costs range are from EUR 5800 to EUR 8900, depending on the characteristics of the equipment. In the following estimation, the initial investment costs was taken to be EUR 7400. If the lifetime of exploitation of the crane assumed to be 17 years, then a complete replacement of hardware is planned in the eight year, which in the assessment can be seen as whole new investment cost. Additional operative costs of the installation of an environment detection system in the cabin of a smart crane for the process industry include the costs of the maintaining hardware and software, increasing labor costs, additional costs of the electricity, which implicates exploitation of new environment detection system and other dependent operating expenses. The best estimate of total annual costs is EUR 1900. This costs, both investment and operative, are shown in Table 1.

Table 1. Investment and operative costs

Investment costs	Estimate price (in Euros)
Hardware: 2 Wi-Fi cameras OpenNI type 1 Remote control 2 Portable power pack 10400 mAh 2 MicroSDXC Memory Card 64 GB 1 Computer 2 Raspberry pi 3	5900
Software	1000
Installation, testing and training of the crane operators	500
Additional operative costs	
Additional labor costs	1800
Maintaining software	100

3.2 VGS Economical Benefits (Effects)

Economic effects of the environment detection system are measured throw the savings that are consequence of installation of the environment detection system. Savings are calculated as the difference between operative costs of exploitation of the smart cranes (cranes with VGS) and conventional cranes without an environment detection system. They are realized by reducing the operation time, reducing labor costs, reduction costs for the treatment of occupational diseases and injuries at work, reducing costs of crane maintenance and repairs and reducing annual costs of crane depreciation. The Table 2 gives an overview of the effects (benefits) of installing and exploitation the VGS.

Table 2. Annual benefits of installing and exploitation the VGS

Annual benefits	EUR
Saving in the more efficient use of cranes	2494
Saving in labor costs	1440
Savings due to reducing sick leave	441
Saving in reduction of annual maintenance and repair costs	1652
Saving in reduction of annual depreciation costs	750
Total savings	**6776**

The total additional net effects (savings) resulting from the exploitation of the VGS are EUR 6776 per year.

3.3 Criteria for Assessing Economic Viability

The economic assessment was conducted through a cost benefit methodological framework. Based on investment and operating costs and total effects calculated through assumed savings, a table of net economic flows is constructed. The flow table is calculated based on the constant prices for an exploitation period of 17 years. The investment on hardware purchase costs are located in two periods. The first period is initial costs before the start of exploitation of the visual environment monitoring system. 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 VGS. The net effects of system exploitation are positive for the entire period of system exploitation except in the first and eighth year when investing in the new VGS. The annual average net effect is EUR 4876. The undiscounted difference in total cost and effects for the entire period of the exploitation is EUR 69,529.

The net present value of the installation of the system for visual and audio detection of the environment is EUR 26,828 for an exploitation period of 17 years and at a discount rate of 10%. According to this criterion and with conservative discount rate estimates, the project is economically justifiable. The internal rate of return for the project of installing a visual detection system on an existing crane's cabin is 65% and it is several times higher than the discount rate. Installation of the system is economically justified by this criterion as well.

3.4 Sensitivity Analysis

Sensitivity analysis tested the reactivity of the parameters of economic justification to change the value of the investment cost (purchase and installation of a VGS), increase of the salary of crane operators due to required higher professional qualifications (work with technically sophisticated equipment) and savings in working hours (Table 3).

Table 3. Economic justification of installation of VGS

Input values	Parameters of economic justification			
	The extent of the change (%)	NPV (€)	IRR (%)	Payback (year)
Cost of VGS	0%	26.328	64,9	1,5
	−10%	27.115	70,8	1,4
	10%	25.540	59,9	1,7
Critical value of the system price	334%	0	10%	–
Increasing labor costs	0%	26.328	64,9	1,5
	−10%	27.642	67,4	1,3
	10%	25.156	62,4	1,8

Sensitivity analysis shows the relative stability of economic justification parameters to changes in uncertain input values. Investment costs could increase more than three times and the project of installing a detection system would be on the brink of economic viability. Increasing cranes operator's hourly rate will not significantly affect on the total economic performances of installing the visual and audio detection system on an existing crane for the process industry. Sensitivity analysis shows that the project of installing the VGS on an existing crane is a project with a very low prospect for adverse economic performances. From that aspect the VGS was rated as very acceptable.

4 Conclusion

This paper assesses the economic justification of installing a real time environment detection system for an existing crane and cabin. The cost of purchase of VGS was treated as an investment. Project effects are manifested through the savings in reducing costs of crane exploitation (shortening the load transport cycle) and reducing lost working hours due to the more comfortable working environment of the crane operator. The economic feasibility indicators show a high economic justification of the installation of specified system. The net present value for the exploitation period of 17 years is EUR 26,328 and the internal rate of return (average annual profit rate of invested funds) is 65% which is several times higher than the average weighted productivity in the metal processing industry. The payback period of invested funds for the purchase and installation of VGS is 1.5 years and appraisal shows that the purchase of the specified is cost-effective and justified. Installing and of VGS represents a very low risk investment.

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Principles for Human-Centered System Design in Industry 4.0 – A Systematic Literature Review

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Abstract. Industry 4.0 seeks to combine the real and cyber worlds by implementing cyber-physical systems (CPS) within industrial processes to create a self-managing network between humans, machines, products, and other related objects. An important part of the current transformation to Industry 4.0 is the emphasis on human-centricity, allowing for a paradigm shift from independent automated and human activities towards a human-automation symbiosis. This symbiosis is characterized by the cooperation between machines and humans in work systems and is designed not to replace the skills and abilities of humans, but rather to co-exist and assist humans in being more efficient and effective. The paper presents a systematic literature review (SLR) to identify principles for the human-centered design of future CPS. The SLR follows widely accepted methodologies and introduces concepts and visions for the elicitation of operators' roles and needs in Industry 4.0.

Keywords: Operator 4.0 · Digitalization · Human factor · Human-system design

1 Introduction

The concept of Industry 4.0 has its origins in Germany at the 2011 Hanover Fair and represents a new strategy to mitigate increasing overseas competition and to differentiate German and European Union industries from other international markets [1]. Since 2011, several definitions for Industry 4.0 have been published. This paper will use Balasingham's proposed definition, which defines Industry 4.0 as "a smart way of combining the real and cyber worlds by implementing cyber-physical systems (CPS) within production and industrial processes to establish a self-managing network between humans, machines, products, and objects" [2]. A CPS is an integration of computation with physical processes. Embedded computers and networks monitor and

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control the physical processes, usually with upper and lower feedback loops where physical processes affect computations and decision making [3]. Several authors present graphical versions of the Industry 4.0 framework. For example, Stock and Seliger give a comprehensive understanding of Industry 4.0 from a macro perspective (see Fig. 1) and discuss opportunities for sustainable manufacturing in Industry 4.0 [4], focusing on the technological and organizational advantages of Industry 4.0 for increasing production performance considering the economic and environmental aspects of the product life-cycle (PLC). Humans appear only as consumers in the PLC's use and service phase. Thus, a question arises: where are the humans in Industry 4.0, especially in PLC's manufacturing phase?

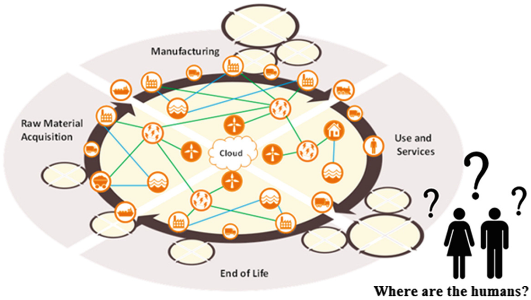

Fig. 1. Macro perspective of Industry 4.0 along the PLC, beginning with the raw material acquisition phase and ending with the end-of-life phase [4].

With the emergence of Industry 4.0, policymakers should consider current and future social impacts (e.g., job losses, employee qualification) related to the new technologies. Society at large should benefit from such industrial transformation because consumers and producers are largely connected, and both can participate in the production and consumption process [5]. Moreover, an essential part of this transformation to Industry 4.0 is the emphasis on human-centricity, allowing for a paradigm shift from independent automated and human activities towards a human-automation symbiosis characterized by the cooperation of machines with humans in workplaces, which are designed not to replace the skills and abilities of humans, but rather to co-exist and assist humans to increase human well-being and production performance [6].

However, several studies recognize that humans are ignored in Industry 4.0 concepts and methodologies. For example, Kinzel [7] criticizes these concepts and suggests a new methodology using a human-centered mediation process to involve humans in the system design for Industry 4.0 solutions. This methodology allows the humans involved to express their needs for new Industry 4.0 solutions. The methodology assumes that necessary humans and their qualifications are known and available for developing solutions. However, the author fails to designate which skills and qualifications are required to work in future production systems.

As machines become smarter, work in production lines will be enriched and unhumanized. Simple manual tasks will disappear, and workers' flexibility will be a key success factor. Workers will be deployed where help is needed, which will create greater demands in terms of managing complexity, problem-solving, and self-organization, but also allow the workforce to become more flexible [8]. Rauch, Linder, and Dallasega [9] present a systematic literature review (SLR) about the human role in production before and after the transformation to Industry 4.0. The authors discuss the research question of how and in which ways the transformation to Industry 4.0 changes the role of the operator in production.

The results show that before the transformation to Industry 4.0, the operator mainly performed physical work. Through the transformation to Industry 4.0, the share of physical work will be replaced by cognitive working tasks in future production systems, such as coordination and organization of materials and other production resources, control and monitoring tasks, and decision-making, in case of uncertainties in production [9]. In this context, several authors present their version of future operators working in Industry 4.0 environments. These new operators are unofficially named "Operator 4.0" (see, e.g. [6, 10, 11]). However, several questions emerge: Who is this Operator 4.0? What are the user requirements of Operator 4.0 working with the aid of CPS? What are the system requirements for the interaction between Operator 4.0 and CPS?

This paper presents an SLR to identify principles for the human-centered design (HCD) of future CPS to answer the defined research questions. The SLR follows a widely accepted methodology for SLRs [14], which consists of three main stages: planning, conducting, and reporting. In the planning phase, the scope and conceptual boundaries of the SLR are defined (see Sect. 2.1). Section 2.2 presents criteria for the search, selection, and analysis of studies (conducting phase) based on these boundaries. The results of the SLR are elaborated in the reporting phase and presented in Sect. 2.3. The paper ends with a conclusion in Sect. 3.

2 Outcomes of the Systematic Literature Review

The following subsections present the outcomes of the three stages of the SLR: planning, conducting, and reporting.

2.1 Scope and Conceptual Boundaries of the SLR

The main purpose triggering this research was to investigate the following questions: who is this Operator 4.0? What are the user and system requirements of Operator 4.0 working with the aid of CPS? These questions led a critical examination of the relevant literature to develop a structured view of the studies carried out in the following sections, focusing specifically on the competencies and future tasks of operators working in Industry 4.0 environments to determine user and systems requirements.

The conceptual boundaries are set by definitions for Industry 4.0 and standards for the HCD of systems. As already mentioned in the introduction, Industry 4.0 can be defined as "a smart way of combining the real and cyber worlds by implementing CPS within production and industrial processes to establish a self-managing network between humans, machines, products, and objects" [2].

The design of adequate human-system interactions is part of the Ergonomics research field. In general, Ergonomics is “the scientific discipline concerned with the understanding of the interactions among humans and other elements of a system, and the profession that applies theory, principles, data, and methods to design in order to optimize human wellbeing and overall system performance” [12]. The HCD of systems follows standards and principles for the ergonomic design of systems (see DIN EN ISO 9241-210:2010) [13], which consists of five main iterative steps (see Fig. 2). This SLR is focused on Steps 2 and 3, shown in Fig. 2, to answer the research questions for the user and systems requirements of operators working in Industry 4.0 workplaces.

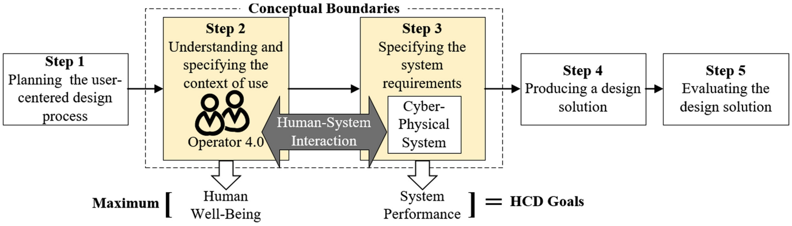

Fig. 2. Conceptual boundaries for the SLR according to common definitions and standards for Industry 4.0 [2] and HCD [13].

User needs are determined in Step 2, which involves the description of users’ competencies and tasks. The system requirements for CPS are specified in Step 3 according to the user requirements. However, according to the definition of Industry 4.0 and the framework for the HCD of systems, CPS design within production and industrial processes should maximize overall system performance, as well as the human well-being of operators involved.

2.2 Conducting the Systematic Literature Review

The basis for a systematic literature review is the definition of criteria and limitations to search and select suitable literature according to the review’s goal and conceptual boundaries. Table 1 presents the search settings for the review.

Table 1. Search settings for SLR.

Criteria/limitation	Search setting
Keywords	Operator 4.0; Human Factor 4.0; Human-centred design 4.0; Ergonomic 4.0
Database	b-on
Timeframe	January 2011–April 2019
Type of research	Journal articles, book chapters, conference articles
Language	English

A literature search was performed with the help of these limitations, and 234 articles were found. The literature found was evaluated in two steps. First, the literature was pre-analyzed by viewing the title, keywords, and abstract. Through this pre-analysis, 19 relevant scientific articles were identified. Second, the relevant articles were analyzed in a full-text review. The main criteria for the selection were that the literature was focused on the HCD of solutions. Literature focused on technologies or challenges for Industry 4.0 is not considered in this literature review.

2.3 Principles for Human-Centred Design for Cyber-Physical Systems

The section presents the results of the SLR. First, a widely accepted definition for Operators 4.0 is presented for this approach, and the tasks and competencies of operators working in Industry 4.0 are identified; second, user and system requirements are determined; and third, general design principles are defined.

Romero defines Operator 4.0 as the generation of workers which "represents the 'operator of the future', a smart and skilled operator who performs 'work aided' by machines if and as needed. It represents a new design and engineering philosophy for adaptive production systems where the focus is on treating automation as a further enhancement of the human's physical, sensorial and cognitive capabilities by means of human cyber-physical system integration [6]." This definition is widely accepted and has been used in several articles, e.g., [10, 11, 14, 15]. From the author's perspective, the definition is focused on human integration in CPS to improve system performance, but neglects the human aspect, e.g., well-being, qualification.

Table 2 summarizes competencies and tasks extracted from the literature for future operators according to the definition. Social skills are still essential. However, additional technical and digital skills are required to interact with modern technical and digital assisting technologies.

Table 2. Prospective operators' competencies and tasks identified in the SLR.

Tasks and competencies of the Operator 4.0	References
- Execution of digital and sensorial guided physical work procedures, e.g., assembly, maintenance, inventory, quality control	[6, 14–17]
- Execution of complex cognitive tasks focused on decision-making, implementation, and innovation using visual tools	[6, 14, 16–21]
- Analytical, creative, and innovative skills to implement new tools and strategies for production systems	[6, 22, 23]
- Social skills for teamwork and collaboration, including communication skills and intercultural competences	[20–22]
- Technical skills to interact and collaborate with modern assisting technologies, e.g., human-machine interfaces, augmented and virtual reality, cobots	[14, 15, 18, 20, 22, 24]
- Digital skills to handle the increasing amount of data and information to support decision-making in management processes	[15, 20, 22, 24]

User and system requirements based on the extracted tasks and competencies are presented in Table 3. Due to changing required competencies and skills performing new technical and digital tasks, user and system requirements are changing too for more data privacy, security in automated workplaces, and possibilities for job training.

Table 3. Summary and relationships of user and system requirements extracted from the revised literature.

User Requirements	System requirements
- Privacy of the operator's personal data [24] - Compensation of individual (human) limitations because of, for example, aging or handicaps, to increase well-being and performance [6, 25] - Safe working environments in automated and isolated workplaces [15, 23] - Possibilities for training on the job or using digital tools, for example, simulations, virtual realities [11, 24, 28]	- Database to control operator's qualification status [24] - Individualization and personalization of working environments using adaptive workplaces and production environments [6, 11, 21, 23, 25, 26] - Security and safety measures to avoid accidents, especially in automated/isolated workplaces [6, 11, 23, 25] - Sensors to control operators' well-being, performance, and work experience [15, 27] - Information and resource support of operators at the right time and format depending on the work context and level of expertise [21, 25, 29]

With the aid of the identified tasks and competencies as well as extracted user and system requirements, general design principles can be defined. Several technical and digital approaches exist (e.g., cobots, digital assistant tools), which seeks to simplify the future jobs of operators. However, operators are faced with complex tasks, which requires an increasing number of technical and digital skills. HCD procedures can be used to develop assistant systems and workplaces, which minimize the required technical and digital skills of future jobs. Therefore, the involvement of operators with different experience levels and capabilities is crucial for the design process. Workplaces and assistant systems should be easily adaptable according to the operator's roles, experiences, skills, and capabilities, as well as the production situation, to provide information, resources, tools, and support needed under specific conditions. The adaptation must support both individual machine user interfaces and a system view of the machine entity. The general HCD aim should be a smooth, clear user experience that minimizes required technical and digital skills for operators working in the factory of the future and to increase the operator's well-being and performance.

3 Conclusion

The transformation to Industry 4.0 changes how enterprises produce new products, which requires a redefinition of the role of operators and modification of current work designs in unknown ways. The paper first presents a widely used definition for Operator 4.0, which is focused on the improvement of the system performance. Future definitions should also consider social aspects for Operator 4.0. Second, tasks, competencies, user, and system requirements are extracted with the aid of an SLR. Social skills are still necessary, but technical and digital skills to interact with new assistant technologies becoming essential too. Third, two generally applicable design principles have been defined based on the SLR results: Operator engagement is crucial for developing new solutions for Industry 4.0, and highly adaptable workplaces are required according to the requirements of operators.

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Employees Perception of the Implementation of Information Technology Systems in the Ghanaian Public Sector

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Abstract. This paper explored the consequences of employees' perception on the digitization of financial management system in a Ghanaian public organization. Guided by the systemic-structural theory of activity, quantitative data was collected from 123 employees and analyzed morphologically to understand how employees perceived the implementation of the digitized system. The results show that while majority of employees perceived the digitization of the financial management system as useful towards improving the organization's operational efficiency and effectiveness, a minority were skeptical. Such skepticism was cognitively translated into negative employees' attitude towards the system's digitization process, which negatively impacted on the successfulness of its implementation. It is concluded that the digitization of financial management systems in Ghanaian public institutions are constrained by minority employees' skepticism, since such skepticism have cognitive implications that translates into employee's negative perceptions of digitized systems, and which perceptions can have an impeding consequential effect on the system's implementation process.

Keywords: Information technology system · Manual work system · Digitized work system · Employee perception · Public sector organization · Ghana

1 Introduction

The pace at which information technology has developed over the past two decades and the impact it has, and continue to have, on the socioeconomic development of most countries is a clear manifestation of the increasing positive impact of the global technological revolution that has been trending over the past two decades. In this regard, the effective use of information technology is now considered by several countries, especially those that are developing economies, as a critical factor for rapid economic growth. In cue with this, Ghana has developed a comprehensive integrated information technology-led socio-economic development policies, strategies and plans, referred to as Ghana's 2003 ICT4AD Policy. This policy acknowledges that for the country to make a desirable and appreciable impact on developmental process, it must also aim at addressing the country's developmental challenges defined in terms of key

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socio-economic indicators. In this vein, The Ghana Integrated Financial Management Information System (GIFMIS), which is a major public financial management reform in Ghana was implemented by the country's Controller and Accountant General Department (CAGD). The GIFMIS is an integrated computerized financial management system used in budget preparation and execution, accounting and financial reporting, as well as cash management and assets management [1]. Additionally, it serves as the official system for recording Government of Ghana's budget, disbursements, financial accounting and reporting, internal control, and auditing [1]. The GIFMIS system, as outlined by [1] is aimed at establishing an integrated information technology-based public finance management (PFM) information system in Ghana to improve efficiency in public financial management [1]. The GIFMIS, according to [1], seeks to address specific PFM problems including lack of integration or interface between various PFM Systems. It also seeks to address inadequate budgetary controls over public expenditure, lack of transparency in budget execution, poor record keeping on public financial transactions [1]. According to [1], other problems the GIFMIS sought to address include; undue delays in processing transactions due to cumbersome manual processes, lack of reliable data for effective fiscal planning due to weak accounting and fiscal reporting system, and delays in financial reporting, especially at the National level [1].

According to [1], implementation of the GIFMIS follow eight stages (as illustrated in Fig. 1 below); putting up a system implementation team (user driven project); securing network infrastructure (countrywide if necessary); developing application software based on user requirement; choosing servers, data storage and backup units depending on software; developing system and network management tools; installing technical maintenance and support systems; providing system safety/security and business sustainability/continuity solutions; and ensuring user involvement in system design, configuration, testing and acceptance.

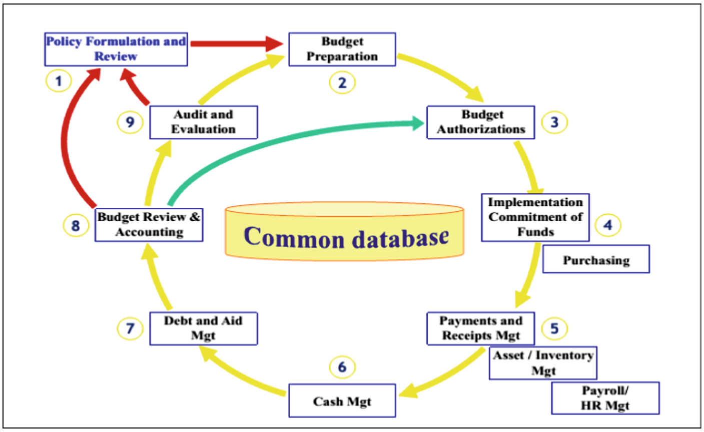

Fig. 1. Cycle for implementing GIFMIS by the organization [1].

According to [1], the development of the core treasury system is an important milestone for the execution of a countrywide public financial management system (PFMS) which enables integration and exchange of information available in various systems developed by different agencies. The financial management system for public finance is based on centrally available information gathered from all important components of the PFMS [1]. Finally, after evaluating the system over a given period, the CAGD can decide to update the system as highlighted in the cycle illustrated in Fig. 1 above. Thus, for the information provided by the GIFMIS to be valued by users, it must meet the following five criteria; (i) accuracy, (ii) significance and relevance, (iii) comprehensiveness, (iv) readability and visual impact, and (v) consistency of format. In spite of the few challenges in terms of network availability and stability, the GIFMIS project gained prominence in both public and private sector organizations in Ghana and also attracted international attention, since the implementation started early 2012 [1]. Yet, despite the successful deployment and roll out of the GIFMIS in Ghana, it appears that the CAGD is still facing some implementation challenges emanating from some key actors associated with the implementation process. This study, therefore, investigated why some actors in the organizations find it difficult to relate positively with the digitized characteristics of the GIFMIS project and the consequences of their negative perceptions on the implementation process of the digitized system.

2 Literature Review

The digitization of organizational systems has now gained currency to the extent many organizations are viewing the design of future organization life to be centered on full automation. In this vein, the incorporation of information technology in organizational system has now gained currency as a key attribute of organizational design. The introduction of information technology in organizational system can thus be viewed as so important [2]. This can be attribute to its recognition as an important integrator of organizational goals and other organizational subsystems at different levels. In this vein, extant literature on the implementation of information technology abounds with much focus on understanding the internal dynamics associated with the implementation process. Thus, most researchers on information technology implementation view the process as intricately intertwined with organizational design and culture [3, 4]. In this context, it is important to have an alignment between information technology development and organizational goals after the implementation goals have been met [4]. It is also important to note that in the implementation process, resistance is a key factor in achieving effectiveness [5]. Such resistance, according to [5], guides the behaviour as well as influences the actions taken by those who develop the technology and those who manage its implementation in the organization. Arguments in the extant literature on information technology implementation suggest three types of resistance to implementation [6, 7]. The resistances, in this wise, are behaviours that are intended to prevent the effective implementation of the information technology system in organizations [6]. In the opinion of [8], some form of users' resistances may just be applied-behaviours which do not manifest behavioral intentions of preventing the technological system's effective implementation. As it clarified by [5], when the interaction between a person and an information technology system is not critical to an organization's overall system operation, then the person's choice not to use the technological system cannot be considered resistance [5]. This behaviour, according to [5], may be a manifestation of personal fear of technology, ignorance of the system, or lack of training. Thus, the first argument is that, the resistance by individuals is influenced by internal factors that are specific to such individuals. The second argument is that, such resistance may be technically-oriented, based on factors that are inherent in the technology being implemented or in the organizational system as a whole. Arguing from the perspectives of [6] and [7], these two forms of resistance are divergent. While the first form of resistance sees individual behaviour as internally determined, the second form of resistance sees individual behaviour as technologically determined [6, 7].

Based on the notion professed by [6] and [7] that behaviour is determined both internally and externally, it is imperative to consider the influences of both resistances simultaneously in the process of technology implementation. This is encapsulated by [5] and [8] observations that individuals will tend to resist regardless of the system, despite the likelihood that such resistance will be lessened when the technology is well designed. The third argument is that, resistance to information technology implementation evolves from the interaction between users' personal-characteristics and characteristics of the technological system [6]. Therefore, it is important to investigate how the introduction and implementation of the system is perceived. According to [9], whereas user-satisfaction is based on attitudes and beliefs, system-usage on the other hand is based on perceived behaviour of employees. As such, a combination of user-satisfaction and system-usage will provide a more complete picture of user's acceptance of technology-based system, than if either measure is applied in isolation [9]. In this respect, the acceptance or otherwise of technology-based system is measured by the system-usage and user-satisfaction [9].

3 Methodology

There are several approaches of assessing the success of implementing an information technology system in public sector organizations. These include the "system-usage" and "user-satisfaction" approaches [9, 10]. The system-usage approach is a measure of the extent to which the implemented technology system is used, while the user-satisfaction approach is a measure of the level to which the implemented technological system is perceived to be of value and easy to use by users [11, 12]. Thus, the methodological approach for this study was underlined by both approaches. It was professed by [13]'s notion that, for practice in a digitized work environment to be understood, it is important to penetrate the situated and localized nature of practice in the environment's context. Underlined by this notion, the perceptions of workers on the implementation of the GIFMS in the organization was studied.

3.1 Data Collection

Data were collected in a public organization engaged in the implementation of the GIFMS) in Ghana. Thus, guided by the systemic-structural theory of activity approach outlined by [14] and [15], which brings together systems-structural approaches and methods from human factors and cognitive psychology, quantitative data was collected using self-administered questionnaire from 123 employees who were involved in the GIFMS project implementation project in the organization.

3.2 Data Analysis

The morphological approach outlined by [13] and [15] was used as the basic paradigm for analyzing the perceptions of workers who were engaged in the GIFMIS project implementation project. In this analysis, the elements of the GIFMIS that are deemed relevant and the way they are dynamically perceived by actors in the work context are extracted. These included an appraisal of the workers' experiences before and during the GIFMIS project implementation. The workers' subjective perceptions on the standards of successful result and admissible failure for the implementation GIFMIS project were also appraised.

4 Results and Discussion

Demographic analysis of the 123 respondents in this study showed that they were highly educated, with majority (75.6%) of them holding university degrees, and 10% holding Higher National Diplomas and Professional Certificates. Eleven (8.9%) of them have Training College Certificates with the remaining 6(4.9%) have Secondary School Certificates. n view of this, it could be deduced that the study was dominated by university degree holders. Furthermore, majority (65%) of the respondents have been with the organization for more than 5 years with the remaining 35% being with the organization between 1 and 4 years. This implies almost all the respondents were familiar with issues relative to the GIFMIS project implementation in the organization and as such, possessed the requisite knowledge of the phenomenon under study. The comparative measure of the respondents' perceptions on the GIFMIS project implementation in the organizations are shown in Fig. 2 below.

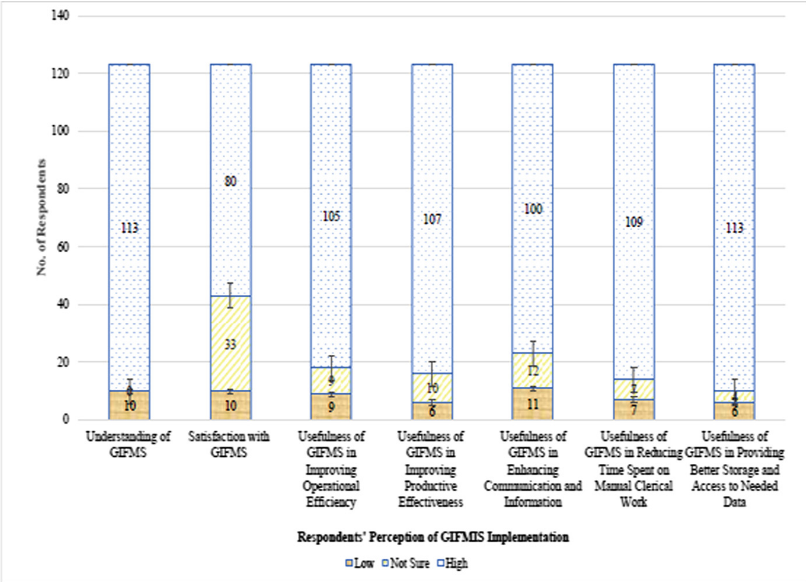

Fig. 2. Comparative measure of respondents' perceptions of GIFMIS project implementation.

As it is highlighted in Fig. 2 above, a comparative analysis of the respondents' understanding of information technology systems as incorporated in the organization's GIMFIS project, shows that 113 (91.87%) of them were knowledgeable of such a system, with a minority of only 10 (8.13%) indicating their lack of such knowledge. A comparison of the respondents' measure of their satisfaction with the GIFMIS project implementation showed that 80 (65.04%) of them were satisfied with a minority of 10 (8.13%) indicating their absolute dissatisfaction. Further comparative analysis of the respondents' perceptions on the GIMFIS project implementation shows that; (i) a majority of 105 (85.36%) as against a minority of 9 (7.32%) respondents perceived it as useful towards improving the organization's operational efficiency, (ii) a majority of 107 (86.99%) as against a minority of 9 (4.88%) respondents perceived it as useful towards improving the organization's productive effectiveness; (iii) a majority of 100 (81.30%) as against a minority of 11 (8.94%) respondents perceived it as useful towards enhancing communication and information in the organization, (iv) a majority of 109 (88.62%) as against a minority of 7 (5.69%) respondents perceived it as useful towards reducing time spent on manual clerical work in the organization's; (v) a majority of 113 (91.87%) as against a minority of 7 (4.88%) respondents perceived it as useful in providing better storage and access to needed data in the organization's

The results above show that majority of the respondents had adequate knowledge and understanding of the GDFMIS project implemented in the organization, and perceived it as useful towards improving operational efficiency and productive effectiveness, in terms of service delivery to clients, as well as enhancing communication and reducing time spent on manual clerical work. Yet, there were a minority of respondents who were doubtful of the IT systems capability to improve the efficiency and effectiveness of the organization's operations and its services delivery to clients. The consequences of the minority's perceptions, as perceived by most respondents was that it generated negative employee attitude towards the GIFMIS project, thus making its implementation in the organization problematic. Thus, arguing from the perspective of [16], it is inferred that the implementation of an effective technology system, such as the GIFMIS can be enhanced by understanding and learning from workers perceptions, especially those with negative attitudes on the introduction and implementation of the technological system. This is because, organizations that seek to digitize their organizational systems as a means of enhancing productive efficiency and effectiveness must encourage the practice of procedural knowledge sharing [16] among all stakeholders in the digitization process, including employees who interact with the digitized systems. Such practice of knowledge sharing, as argued by [16] will help enhance the practice of learning from individuals' perceptual leanings as well as knowledge transfer and competence development when technological systems, such as the GIFMIS, are introduced and implemented in organizations.

5 Conclusion

This study has shown that the perception of workers who are to be engaged in technology-oriented work systems is an important learning medium for designers of the work environment and management process for such systems. Based on the findings, it is concluded that the digitization of work systems can be constrained irrespective of the number of employees who do not perceive it as useful, since system-based work activities entails several operational activities that are interrelated, and the malfunction of even one operational activity can have a consequential effect on the systems functionality. An argument is therefore made on the need for understanding the cognitive dynamics behind employees' reluctance to accept the digitization of manual work activities, especially in the Ghanaian public sector organization.

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Research on Eye Movement Parameters of Command and Control System Operator Based on Emma Model

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Abstract. Eye movements and movements of attention (EMMA) model divides eye movement behavior into two parts: eye movement preparation and eye movement execution. The time of eye movement preparation tends to be fixed for special groups, while the time of eye movement execution depends on the saccade speed and saccade distance of human eyes, and the saccade speed tends to be fixed for special groups. EMMA's previous research did not involve operators of command and control system, so this paper carried out experiments on the acquisition and analysis of eye-movement preparation and eye-movement execution data for 20 people. The results of the experiment showed that the average eye movement preparation time of the command and control system operators was 136.15 ms and the average saccade speed was 1.3 ms/deg. The above research not only improves EMMA model in the field of command and control system, but also lays a foundation for later cognitive behavior modeling of operators.

Keywords: EMMA model · Eye movement · Command and control system · Human-computer interaction design · Cognitive behavior modeling

1 Introduction

Eye movement and attention are the focus of visual cognition and human-computer interaction design [1, 2]. The eye movements and movements of attention (EMMA) model is a classical model in the field of eye movement modeling. It solves the two unreasonable hypothesis problems in the description of the relationship between eye movements and visual attention, and greatly promotes the application of eye movement data in cognitive modeling and visual understanding modeling [3]. EMMA model divides eye movement behavior into two parts: eye movement preparation and eye movement execution. The time of eye movement preparation (T_{prep}) tends to be fixed for specific groups. The time of eye movement execution depends on the saccadic speed and distance of the eye, where saccadic speed tends to be fixed for specific

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groups [4]. Eye movement behavior modeling is an important part of cognitive behavior modeling of command and control system operators, which affects the integrity and accuracy of modeling and affects the design of human-computer interaction interface of the system. Moreover, operators in this field also belong to a fixed group. EMMA's previous research did not involve operators of command and control system, so it is urgent to carry out basic experiments related to eye movement preparation and eye movement execution, measure the time of eye movement preparation and the time required for each (degree) degree of eye movement transfer, collect relevant experimental data, and provide support for subsequent design and modeling.

2 Experiment Equipment

Experimental equipment includes: PC, monitor, simulation software, mouse, keyboard and eye movement measurement equipment. The eye movement measuring equipment is the Tobii Pro Spectrum 600 eye movement instrument. It is a screen eye tracker with a sample rate of 600 Hz that allows for a wide range of head compensation with high precision and accuracy without the need for any bondage devices [5] The display resolution of the interface was 1920 × 1080, the screen size was 30 × 53 cm, and the distance from the screen was 0.65 meters.

3 Experimental Subjects

The subjects were 20 command and control system operators, all male, aged between 20 and 40. The subjects showed no color weakness or color blindness.

4 Eye Movement Preparation Time Measurement Experiment

4.1 Experimental Process

1. before the experiment, subjects will be informed of the specific content of the experiment task: a series of "×" ICONS displayed on the monitor, as shown in Fig. 1.
2. this experiment is divided into the control group and the experimental group, in order to eliminate the uncertainty of time and space.

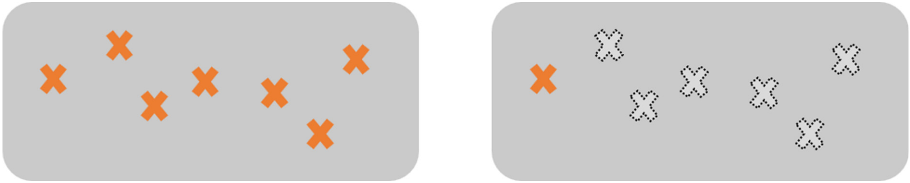

Fig. 1. Left is the control group and right is the experimental group **1**

For the control group, the monitor will display 7 target ICONS "×" simultaneously. The subjects had to look at each icon as quickly as possible, from left to right.

For the experimental group, an initial icon "×" will appear on the left at the beginning of the display. The next icon will not appear until the subject has looked at the icon and recorded the successful gaze on the eye tracker of the main test machine. Participants were told in advance that seven ICONS would appear in the experimental group. In some cases, one of the target ICONS has a delay of varying times (set to 50 ms or 150 ms for this experiment). The delay target is randomly selected with the only constraint that the delay target cannot be the first or last icon in any experiment.

3. in addition to the control experiment of 50 groups, the subjects also need to accept the experiment of target delay of 50 ms in 25 groups and 150 ms in 25 groups. During the whole process, the experiment type was randomly determined. The whole experiment lasted from 30 to 45 min, and participants were allowed to rest at any time.

4.2 Experimental Results

The eye tracker measured the fixation time on each icon "×" during rapid saccades in the control group. The measured results are the sum of the EMMA model parameter eye movement preparation time (T_{prep}) and the fixed time of the executive part of eye movement (70 ms). The 70 ms includes 50 ms for non-unstable programming and 20 ms for saccades (Fuchs, 1971). Therefore, the eye movement preparation time can be measured.

The comparison between the control group and the experimental group can eliminate the uncertainty of space and time. The experimental results are shown in Table 1.

As can be seen from Table 1, the mean fixation time was 206.15 ms. In the measurement results, the maximum mean value of the 20 subjects was 263 ms, the minimum mean value was 162 ms, and the standard deviation of the mean value of the 7 measurements of each subject was 32.2. Taking into account the measurement results of whether the subjects' eye muscles were tired on that day and other factors, the standard deviation of 32.2 was within the acceptable range of our experiment. Based on the above measurement results, we can estimate that the preparation time (Tprep) in this EMMA model is 136.15 ms (that is, the fixation time measured minus the fixed time of eye movement execution is 70 ms).

Table 1. Summary of Fixation Time Measurement Results of Subjects on Each Icon (Unit: ms)

Number of subjects	Fixation time							Mean value
1	240	200	280	286	279	281	276	263
2	120	261	280	241	279	247	320	249
3	200	150	240	241	200	248	240	217
4	161	161	201	238	200	160	240	194
5	200	203	173	264	160	213	162	196
6	238	278	238	240	278	199	162	233
7	280	275	231	201	274	281	269	258
8	200	281	160	121	125	88	159	162
9	159	240	121	199	160	123	240	177
10	118	147	167	157	240	265	163	179
11	162	119	117	203	200	161	273	176
12	279	280	200	282	280	252	211	254
13	160	161	240	200	160	159	202	183
14	160	227	280	278	281	210	165	228
15	160	160	161	173	213	239	241	192
16	201	161	118	281	200	119	200	182
17	198	280	201	239	161	238	199	216
18	169	228	201	248	200	240	240	218
19	200	199	240	161	152	121	125	171
20	210	162	201	218	131	108	197	175
Mean value								206.15

5 Eye Movement and Saccade Speed Measurement Experiment

5.1 Experimental Process

1. The subjects were informed of the specific task before the experiment.
2. After adjusting to a comfortable sitting position, fix the subject's head. Make sure you can't use head movement to compensate for eye movements.
3. Under the experimental display, the subjects were required to look at three very dark light spots with their faces facing the display, back and forth alternately at angles of −30°, 0° and 30°.
4. When the subjects determined the correct range, the lights were turned off. The graph continues to perform actions at different angles (30°, 60°, 90°) without the target. The essence of eye movement in the dark is a pronounced saccade, but it has a longer duration and lower peak speed than a target saccade in good lighting.
5. Experiments from different angles appear randomly. Each subject was required to perform 50 experiments under each condition.
6. The eye tracker records the time and amplitude of saccade under dark conditions after the correct amplitude has been formed.

5.2 Experimental Results

The results of saccade time at different angles were recorded under dark conditions, as shown in the table below. Table 2 shows the experimental results of 20 subjects at viewing angles of 30°, 60° and 90°. Each value of the results of the 20 subjects in Table 2 is the average value (in milliseconds) of the results of the 50 saccades of each subject under different conditions. The average value of the last row in Table 2 is the average result of the subjects' scanning time under each condition.

Figure 2 is the fitting of the experimental results. According to the fitting results, there is a linear relationship between angle (deg) and saccade time (ms). In this interface experiment, the linear relationship is as follows:

$$y = 1.3x - 2.2. \quad (1)$$

Table 2. Experimental Measurement Data Of Saccade Time At Different Angles (Unit: ms)

Number of subjects	30°	60°	90°
1	35.4	71.9	108.1
2	37.8	68.5	114.4
3	36.1	76.7	110.1
4	33.9	73	106.8
5	31.6	75.3	108.7
6	37.2	74.4	107.9
7	29.6	72.9	109.6
8	37.5	73.3	115
9	31.5	77.7	102.2
10	45.2	67.2	114.1
11	36.8	81.5	107.3
12	37	76.2	104.3
13	37.4	73	108.3
14	38	76.2	107.6
15	33.5	70.3	113.2
16	33.3	71.5	108
17	40.2	74.4	114.3
18	25.5	71	109.2
19	28.3	79.3	117
20	31.6	72.3	113.8
Mean value	34.87	73.83	109.995

Where x is the saccade Angle and y is the saccade time.

By matlab fitness analysis index of the fitting function error analysis. In this fitting, SSE (sum of error squares) is 1.302, and the sum of error squares is small. For the determination coefficient r-square [6] it is 0.9995 in this experiment and the value of

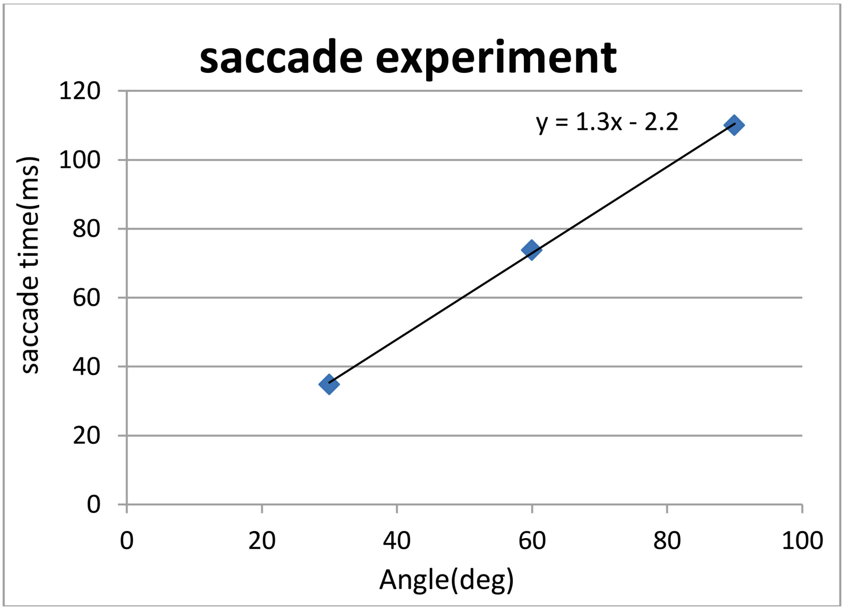

Fig. 2. Experimental fitting results.

adjusted fitting function is 0.9991, which is close to 1. The fitting effect is better. The standard deviation RMSE (root-mean-square error) of this experiment is 1.1411, indicating that the actual experimental results and the fitting function are less discrete. Therefore, based on the above indicators, it can be considered that the fitting degree is relatively high. The fitting function can accurately reflect the actual value.

6 The Experimental Conclusion

In this paper, the preparation time of eye movement preparation behavior and eye movement saccade speed were measured experimentally. Firstly, the experimental task was designed to measure the eye movement preparation time for a group of 20 people. The average eye movement preparation time of the group was 136.15 ms. The combined experiment of the control group and the experimental group eliminated the spatial uncertainty and temporal uncertainty of this experiment. Secondly, the experimental task was designed to measure the eye movement and saccade speed of a group of 20 people, and the saccade time of each degree of the group was 1.3 ms/deg. The above experimental results not only extend the research field of EMMA model to the field of command and control system design, but also provide accurate data support for quantifiable cognitive behavior modeling.

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Green Work Environments and Workforce Productivity Among Energy Organizations in Ghana

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Abstract. The current work aims at exploring green workplace practices that trigger environmentally friendly changes, leading to an increase in workforces' productivity among energy organizations. Green work settings globally, are environmentally sensitive, resource efficient and socially responsible. Green work strategies, when well deployed, can make office practices more sustainable, efficient and well suited to the complex, ever-changing world of business. Indeed, evidence abound that, modern organizations enhance business profitability and long-run marketability, while reducing costs and increasing productivity through greener practices. Research overwhelmingly shows that eco-friendly offices and green environmental practices among energy organizations translate to a happier, healthier and more efficient employees. Drawing on a qualitative, multiple-case study approach, primary data were collected from selected energy organizations in Ghana, using interviews and document archival sources. The paper showed green work environmental awareness initiatives being embarked by the energy organizations. The results further showed how the energy organizations are adopting environmentally friendly practices, resource-efficient initiatives and socially responsible actions to enhance productivity. The results also point to the various energy organizations embarking on environmental audits to understand their initial situations and using such audit results to create workplace environmental policies and procedures for sustainability that is geared towards minimizing negative impact of their activities on the environment. The paper has practical implications for clean energy, competitive and sustainable energy operations as well as a more productive workforce. The paper recommends an adoption of holistic green work environment practices as a priority to leverage lean energy production, transmission and distribution across the various energy organizations in Ghana.

Keywords: Green environments · Cost-effective energy production · Sustainable development · Energy organizations · Healthier · Productive employee

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1 Introduction

This chapter explores green workplace practices that trigger environmentally friendly changes, leading to an increase in workforces' productivity among energy organizations in Ghana. A green workplace is one that is environmentally sensitive, resource efficient, and socially responsible [1]. In other words, green work environment is one that results in improved human well-being and social equity while significantly reducing work risks and waste [2]. Thus, a green workplace requires taking a holistic and integrated approach to enhancing work culture, improving place of work and reducing environmental impacts. Green strategies do exist, and are based on concrete and cost-effective changes such as working from home, ways to cut commuting costs, video conferencing to cut down on travel and increasing access to natural light to save energy [3].

Literature has emphasized that, adoption of green workplace practice is a key objective of organizational smooth functioning [4, p. 25]. Haden, Oyler, and Humphrey argued that the integration of green objectives and green strategies along with strategic development goals of a company results in effective environmental management system. Daily and Huang proposed that organizations need to balance industrial growth with preservation of the environment because it has been confirmed that by endorsing green practices, companies may profit [5]. It is identified that the greater the strength of green human resource policies, the greater the intensity of adoption of environmental management systems and policies [6]. Several workers argue that in order to implement effective corporate green management system, it is important to promote a great deal of technical and management skills among all employees of the organization [7, 8], whereas, others propose that organizations look at development of innovative tools and initiatives of environmental management which will significantly impact sustainability of the firm and promote a competitive advantage [9]. Clem [10] posits that going green reflects a social consciousness around saving and advancing the Earth's natural resources, preserving and protecting them for the sake of sustainability. Going green does foster positive feelings from customers. Employees feel safer working for green businesses. Involving workers in company-wide green initiatives boosts morale. Employees feel that their health is cared for and they are not simply expendable commodities. This is also a good way to reduce turnover, because employees do not want to leave a place that makes them feel as if they are a part of a work community that cares. When it comes down to it the benefits of going green for a business, the benefits far outweigh any negatives. The time and money it takes to establish new environmentally green protocols pay back in dividends over the years, not only in money but also in feeling good that the company is kind to the planet.

The story of green work environment and employee's productivity is fundamentally a story about technology adoption. Beginning in the late 1960s, modern organizations have introduced a number of digital platforms to overcome the challenge of waste, demotivation and underperformance. The energy organizations are not exception, and their huge infrastructure investment profiles make adoption of green work environments a priority. Globalization and community pressures are pushing businesses to go green. There is also pressure for work environmental sustainability, which requires strategies to be put in place to reduce the environmental impacts caused by the products and services being offered by the businesses.

2 Energy Organization

Energy organizations in this context are limited to the power suppliers in terms of policy making, regulations, generation, transmission and distribution of power in Ghana. The minister of energy is the head of the ministry and directly accountable to the president of Ghana. The position is politically appointed and approved by parliament of Ghana. The ministry of energy in collaboration with relevant agencies like the energy commission, develop and ensures a reliable high-quality energy service at the minimum cost to all sectors of the economy through the formulation, implementation, monitoring and evaluation of energy sector policies. Within the context of energy sector vision, the goal of the energy sector is to make energy services universally accessible and readily available in an environmentally friendly and sustainable manner. The Ministry also work closely with relevant agencies to create an enabling legal and regulatory regime aim at ensuring transparent, accountable and prudent management of Ghana's energy resources. Critical Legislation in place include: Income Tax Act 2015 (Act 896), Local Content and Local Participation Regulations 2013 (Ll 2204) among others [11].

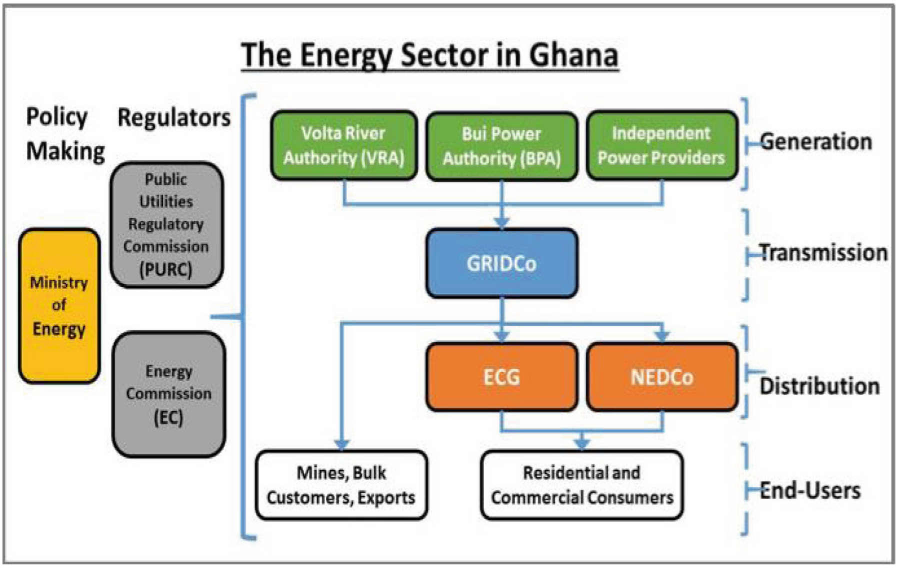
Main regulator is the Energy commission of Ghana. As part of its regulatory functions as mandated by the Energy Commission Act, 1997 (Act 541), the commission has responsibility for matters relating to development of regulations and codes for the electricity and natural gas supply in Ghana. The Energy Commission among other things regulates the technical operations of service providers in the electricity and natural gas supply industries. The Commission performs these regulatory functions through elaboration and enforcement of technical rules. The Commission has developed the National Electricity Grid Code as part of its regulatory functions. The purpose of the Distribution Code is to ensure that the distribution network provides fair, transparent, nondiscriminatory, safe, reliable, secure and cost-efficient delivery of electrical energy [11].

Generation is the first arm of power value chain in Ghana. Organizations performing the generation functions are VRA, Bui Power and Independent private power producers. These organizations combine hydro, thermal and solar generation of power for both local consumption and export. The total installed capacity for existing plants in Ghana is 4,132 MW consisting of Hydro 38%, Thermal 61% and Solar less than 1% [12].

The second arm of power value chain is the transmission. This process transports power from generating plants to local service areas such as cities, towns, communities and neighbourhoods. Here, electricity is routed into network of high voltage transmission lines [12]. The Ghana Grid Company (GRIDCo) owns and operate the transmission grid. GRIDCo further steps down power to lower voltage for onward distribution by major bulk customers such as Electricity Company of Ghana (ECG), Northern Electricity Company (NEDCo) and Enclave Power Company (EPC).

Distribution is the final process to deliver power to homes and businesses. Distribution equipment include; transformers, meters and poles. At this stage, the voltage is lowered further by a distribution transformer and channel through electric meter into homes and businesses. The ECG is the major distributor of power with over 70% market share [12], mainly in the southern part of Ghana. The NED is responsible for distributions in the Northern regions of Ghana. While Enclave Power Company, the only privately-owned power distribution company is responsible for distributions to the industries in the Free Zone Enclave in Tema (Table 1).

Table 1. Energy sector organization



[Adapted from 2, 2019]

3 Green Practices and Productivity Among Energy Organizations

Work environment of the Ghanaian energy organizations were assessed qualitatively to gain understanding of their green environment commitments, and how this affect quality service delivery. Several perspectives of their green practices were explored, including green technology adoptions, health and well-being of employees, resource-efficiency, housing, training and development as well as sustainability and social inclusion. In other to be effective in operation, most of the energy organizations have established data centers. Their data centers are centralized locations installed with computing resources and crucial telecommunications. The installations include servers, storage systems, databases, devices, access networks, software and applications. These installations are controlled by highly trained personnel within the organizations and used to control their operations. The energy organizations use these data centers for data backups and recoveries, networking, hosting of websites, manage e-mails, and instant messaging services. They also use it to support cloud storage applications and e-commerce transactions. According to them, greater levels of security, flexibility and accessibility to data and information around the world is obtained via the data centers. Through data centers of the various energy organizations, electricity corporation of Ghana for instance, now has online customer portal for self-services such as online application for new services, a digital payment systems and automatic meter reading services. There is also Supervisory Control and Data Acquisition (SCADA) device for remote switching and field supervision. Their smart pre-paid meter systems, payment platforms and point of sales terminals (i.e. systems localized in the office making it possible for banks to connect and make payments). Remote Desktop Software used for remotely working on end users' computers and providing IT support to all directorates of the end users as well as a 24/7 call centers to attend to customers. The ECG Mobile App is another innovation with full featured App to buy power anywhere anytime instantly. The App is also used to check consumption both daily and monthly on periodic chart. It is used to pay ECG bills, check balance on ECG account and many others. The study further found that, these self-service models have drastically reduced human interface in the operations of the energy organizations. The benefits according to some customers being that transactions are done in real time, coupled with a cut in cost of transporting oneself to points of services. Benefits to the organizations being effective checks and balances on cashiers, an increased productivity as well as effective revenue mobilization.

In the area of psychosocial and employee well-being, the study found that, designated clinics were contracted by the energy organizations to cater for health needs and well-being of their workforce. In this regard, a pre-finance model also exists, and allowed workers to attend facilities of their choices and subsequently receipts for reimbursement. Their health scheme covers all manner of medical conditions except gynae cases. The organizations also house their workers by either providing bungalows and flats or payment of rent allowances to workers. Also, a bereavement scheme is available for bereaved members. A local pension scheme does exist together with an educational grant for members in every month of August. Training and development among the staff. Both internal and external training programs do exist. A training center do exist, where personnel from VRA, GRIDCo & Bui receive periodic training. The external training often exists outside the country. Countries involved are the USA, Canada, Dubai, China, UK among others. The training center doubles as income generation point. The facility is often rented out for training and other similar ventures to other organizations outside energy production. Other income generation ventures include supply of power to neighboring countries such as Ivory coast, Togo, Benin and Burkina Faso.

Benefits associated with the psychosocial and health well-being of the staff, according to the study include enhanced self-esteem of staff, stress reduction among workers, improved morale of staff, increased productivity of the workers and increased job satisfaction. The study further found that the employer-assisted housing program helps build employee loyalty and increase productivity through improved morale. Enhanced employee work/life balance and a decrease in employee absenteeism was also found. The training schemes put in place by the energy organizations help their staff gain job security, job satisfaction and increased productivity. Training also improves both quantity and quality performance.

The study equally found that, the Gender and Social Inclusion Unit of the Millennium Development Authority, Ghana is in collaboration with the energy organizations in mobilizing of women in energy-Ghana. It is composed of women employed in the Ghanaian energy industry, such as the VRA Ladies Associations, the ECG Power Queens, GRIDCo Ladies, and NEDCo Ladies Association. Indeed, being in a male-dominated setting, the women acknowledge the fact that their strength lies in numbers, hence the women felt their purposes, values, and orientations could best be served by mobilizing their own selves and resources. The women in energy institute and promote 'barrier breaking' and 'boundary crossings' and championing moves such as educational, scientific, advocacy, career development, energy conservation campaigns and outreach programs. It also fosters gender awareness and tries to ensure gender equality and social inclusion among energy organizations. The women act collectively in sharing common values and orientations that are opposed to the status quo of women in the energy jobs of Ghana. The women emerged at the right time in response to the latent dissatisfaction with the longstanding masculine dominant cultures in the energy sector, with its associated gender inequalities. The women are advocating for change – in terms of recruitment policies and practices that are gender balanced. The women in energy serves as a vanguard, which works to bring many voices on table to proffer solutions to energy problems. Inclusive representation in energy will lead to productive use of energy in Ghana.

MiDA is training and mentoring 800 women in practical skills and help them to pursue professional careers in the energy sector. They comprise 600 interns from second cycle institutions and 200 National Service Persons. The beneficiaries are placed in energy sector organizations, both private and public, so that they would gain practical experience and leadership skills to build their capacity in the power sector. Under the mentorship program, interns are assigned supervisors who take them through orientation and practical lessons at the workplace to become familiar with the equipment and machinery applicable in the energy sector. Benefits of the gender equality and social inclusion plan include an increase in employment opportunities for women and disadvantaged groups in the energy sector, a reduction in electricity costs to legal rate payers through lower cost reflective tariffs and a more safe and secure work environments for both men and women in the energy organizations.

4 Conclusion

Results from the study suggest an adoption of some green workplace practices among the energy organizations in Ghana. Their green workplace practices include data centers and associated self-service portal regimes, employee well-being schemes as well as Gender Equality and Social Inclusion working groups. The energy organizations' subscription to self-service portals strengthens their brand reputation by creating positive client interactions. Also, intuitive self-service portals save time and cost, and help clients locate information speedily. The self-service portals imply customized knowledge base of the portals act as useful tools for bringing in more website traffic, and marks the energy organizations as information source and authorities in their fields. Portals also expand energy organizations clients' knowledge and skills, and give them the tools they require for solving other similar issues in the future. Adoption of portal regimes among the energy organizations further imply an increase in productivity and better customer care. The self-service portals above all, help customers personalize their self-service accounts. The study also showed, the energy organizations subscribe to psychosocial and employee well-being programs. This suggest a complement to workplace safety systems. It also implies a reduction in energy workers absenteeism, improve in their productivity, a reduction in health care cost, improve recruitment and retention as well as build and help sustain a high employee morale.

The formation of Women in Energy Ghana, alongside the Gender and Energy Working Group in collaboration with the Gender and Social Inclusion Directorate of the Millennium Development Authority (MiDA), deploy modern organizational models, aimed at dismantling self-seeking interests in the pursuance of collective values and orientations in the form of a progressive but slow move towards achieving gender equality in the energy sector of Ghana. The Women in Energy-Ghana act collectively as well as separately, sharing common values and orientations that are opposed to the status quo of dominant masculinity cultures in the energy jobs of Ghana. The women group emerged at the right time, giving change voices to the women in terms of recruitment policies and practices that are gender balanced in the world of Ghanaian energy jobs. The Women in Energy-Ghana explore available platforms enthusiastically, deploying networks of civil society, offices of Energy Commission and the Ministry of Energy Ghana, for advocating, lobbying and exchanging ideas to achieve a gender- neutral energy sector in Ghana.

Finally, it is crucial to emphasize that masculinity in itself is anti-social and the very culture of masculinity dominance in energy workspaces in Ghana constitute a bane to organizational and national social inclusion commitments and probably socio- sustainably too expensive to ignore. To make the Ghanaian energy organizations sustainable and more relevant, women can never be cut out of the value chain equation. Therefore, a conscious national effort is recommended to encourage more female enrolments into science and engineering-based education. Green movements in the energy sector is equally recommended for the promotion of green workplaces in the energy sector of Ghana. Indeed, the move for green energy workplaces, employee well-being, sustainability and social inclusion will engender poverty eradication, work towards achieving energy organizational growth and development, their global competitiveness and an assurance for innovative energy sector in Ghana.

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Assistive Technologies, Affordance and Accessibility

Using High Fidelity Interactive Prototypes for Effective Communication to Create an Enterprise Mobile Application

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Abstract. This paper describes use of high fidelity prototypes and their benefits in the design process of a native iOS enterprise mobile app that provides employees with internal and external news on industry and business-related topics. As designers have various touch points including users, developers, stakeholders, and other designers, we built and used interactive, high-fidelity prototypes to enhance communication between all parties. In this paper, we use three project case studies to demonstrate the unique and beneficial role that interactive, high-fidelity prototyping plays in the design.

Keywords: UX · Prototyping · Mobile app · Usability testing · High fidelity · Interaction design · Design communication

1 Introduction

During the design and development cycle of a product, what matters most for designers is communication: designers continuously communicate with stakeholders, potential users, and project team members such as developers, the product owner, and other designers. Designers are responsible not only for a good design but also for delivering the design precisely to those who will consume and use it and those who will implement it.

Anything that users cannot directly perceive is left to explanation and imagination. In turn, our imagination heavily-impacts our perceptions [1]. To accurately convey ideas to others, designers should express them as closely as possible, in a tangible way, to the final, planned outcomes. This also helps those others to use less imagination to understand what they see.

Fidelity can vary in the areas of visual design, content, and interactivity [2]. While low fidelity prototyping is useful to receive early feedback, there are certain times that level of fidelity affects user research results, especially when a product is being developed and designers are working more on detailed user interaction and visual design. Low fidelity prototyping can help to make early decisions or project directions but makes a huge gap when detecting subtle usability issues. High fidelity prototyping is an essential part of a good communication method. It helps to reduce loss in translation between designers to others.

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From UX designers' perspective, not only the user interface layer but the whole system should be considered in the design process. For UX designers, pixel-perfect color drawings are not enough to be high-fidelity mockups since there is no ability to interact with them [3].

This paper will present three case studies revealing the importance and effectiveness of high fidelity prototyping for both - finalizing design decisions and effectively communicating with users, stakeholders, and team members. The paper will also discuss high fidelity prototyping methodology.

2 Background

At IBM, we wanted to create a new native iOS app called "w3." Employees want to receive fast, high-quality information that helps their productivity and business communication. Our mission was to create an easy-to-view application that provides 350,000 IBMers with the internal and external news and information they need to be effective at their jobs and informed representatives of the company.

From preliminary internal research[1] to validate the level of interest of IBM employees in a mobile news app, we found that 79% of the respondents said they are very or somewhat likely to use an IBM news app if exists. They wanted to know the topics that interest them personally, how things can impact their business goals, the latest news, processes, and future goals of their business units. In addition to the internal sources and topics, they also wanted news from external sources.

During the design process, we worked on various ideas and built prototypes in different levels of fidelity accordingly: we used paper sketches, low fidelity wireframes, and sometimes just verbally delivered ideas using other mobile apps in the market. As our project evolved and incorporated more content and features, we found benefits and effectiveness from high fidelity prototyping to communicate with users, developers, stakeholders, and other designers.

3 Objectives of High Fidelity Prototyping

The goal of our project, "w3" is to create an effective enterprise mobile application to provide values for IBM employees. The app contains internal news, industry news, and internal websites and blogs. Since we are introducing a new app that did not exist in the IBM internal ecosystem previously, it is critical to deliver user value with a familiar, yet modern and innovative interface. It is also important to receive early feedback from users by conducting frequent usability and preference testing.

Designers need to interpret stakeholders' requirements, deliver benefits and key messages to users, and help the team align on and deliver design ideas. As such, we defined objectives of high fidelity prototypes from four major touchpoints of designers:

[1] 36,000 invitations were sent to full and part-time IBM employees across all locations and 14,529 completed surveys returned (40% response rate). The survey was done between May 14 and June 4, 2018. +/−2% points of margin error.

- To interpret stakeholders' business requirements and abstract ideas into tangible form
- To deliver detailed interaction between static screens effectively to developers
- To communicate among designers in different disciplines working on different stages of the process (e.g., Visual/UI design, UX design)
- To receive quality feedback from users by using prototypes closest to the live app, allowing them to rely less on imagination

4 Case Studies

Since our goal was not to enhance an experience of an existing app but to create a new concept for internal IBM employees, we need a vehicle for detailed communication with users, stakeholders, and our team members. In this section, we address challenges, problem solving processes, and benefits of high fidelity prototyping through three case studies.

4.1 Demonstrate Complex Structure on Mobile to Developers and Stakeholders

One challenge that w3 had was to make a decision on whether to implement a native viewer for IBM internal websites or use an in-app browser to show a responsive mode of the webpages. We researched whether a native viewer can deliver better usability in terms of site navigation. The internal websites are built with a pre-defined platform, therefore they have similar structure across the websites: 1) first level navigation items have their own landing pages, 2) up to three levels of navigations are allowed, 3) no limitation on the number of navigation items, and 4) the desktop version of the websites have horizontal navigation, whereas on the mobile responsive view the websites surface the hamburger menus[2]. Also if we proceed, the native viewer would be nested inside the main app, which also has its own navigation system.

Developers and stakeholders presented some competitors' mobile apps that use a horizontal navigation system. Designers objected to the suggestion since the navigation structure of the internal systems was differently structured from the competitors' apps. To give visual evidence of potential usability issues with the horizontal navigation system in our app, we created an interactive design prototype with real data from one of the internal websites, to show horizontal structure is not appropriate for the websites. With the interactive prototype, we demonstrated to the stakeholders and developers how users would interact with multi-level horizontal navigation, what kinds of usability issues users would face when the horizontal navigation is placed in our app, and how it is different from competitors' apps.

[2] The hamburger menu is the button in websites and mobile apps that usually hides the navigation items.

4.2 Test Animated Images Before Implement

The content of w3 app is comprised of industry news, company news and internal content, which could make the app monotonous. Stakeholders desired to make this app look modern, playful and delightful. As a part of the effort to overcome the potential weaknesses, we decided to add animated elements to highlight featured sections. The biggest benefit of animation is that it attracts user attention, reinforcing content hierarchy [4]. On the other hand, users are sensitive and prone to be distracted by any type of motion [5].

We added a zooming in and out movement to the static article images and made the video thumbnails play automatically to spotlight the article carousel section that contains top three news headlines. To receive more accurate feedback from users, we built a high fidelity prototype using an advanced interactive prototyping tool that allows building prototypes with dynamic and delicate interaction.

We initially researched animated features of competitors' products and asked other designers for feedback by verbally explaining the animated features. However, we wanted to validate how the features work in our app to gain more confidence in the interactions. We built a set of high fidelity, interactive prototypes and decided to conduct in-person usability testing.

The usability testing was conducted in-person with 10 users, asking them to interact with the prototype on a mobile device. Surprisingly, the usability testing results were completely opposite to the expectation. While the animated images successfully drew attention from the users as they said the animated images made content look very important and gave them little surprises, 6 users said the animated images are distracting and unnecessary, and 2 users pointed out accessibility issues. Ironically, two users indicated that the animated images in the carousel interrupted them and prevented them from paying attention to other articles below the carousel.

4.3 Observe How Users Interact with a Product on a Device

During usability testing, conductors can ask questions to participants and participants may think aloud, but the underlying value is observing their actions [6]. Therefore, how accurate and how close to the live app the testing prototype is unquestionably affects user interaction and their feedback. Unlike large screen computers that are mostly controlled by keyboards and mousepads, mobile devices have touch screens, supporting direct interaction with users' fingers allowing various interactions including scrolling, tapping, swiping, long-pressing, etc. Therefore, observing is an important part of usability testing especially for mobile user interfaces. High fidelity prototyping can help to narrow the experience gap between design prototypes and live apps.

w3 has a feature that users are able to select topics to follow and read articles about the topics collectively. The feature supports multiple interactions, such as card movement and transition to new screens. The goals of the usability testing were to determine 1) whether users understand the values of the screen quickly and easily 2) whether those interactions hurt or enhance usability, and 3) whether the design is visually appealing and enhances user experience.

Rather than simply displaying screens and explaining interactions verbally, we built a fully functional prototype with all possible interactions. During the usability testing sessions, the conductor observed user behaviors while users fully experienced the interactions. As seen in Fig. 1, one screen contains multiple interactions, movement, and transition. Without asking questions, we could observe how users interacted with the cards, whether they discovered all capabilities, and if they found them useful. After initial observation, we asked participants to attempt to complete a series of tasks, asked questions, and requested their opinions on the interactions.

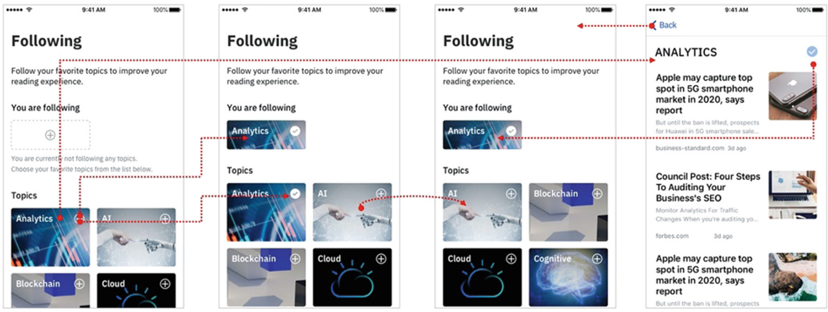

Fig. 1. The image depicts possible interactions and flows occurring on one screen. In addition to the illustrated interactions, the movement of each element can also affect usability.

5 Methodology to Build High Fidelity Prototypes

Choose the Right Tool. Interactivity is a key part of high fidelity prototyping to user experience designers. When choosing a tool, choose one that easily imports 2-dimensional design screens from your graphic design tool to the prototyping tool to fully transfer user interface design, and that equips functional interactions, such as animated transitions, micro-interactions, various commands.

For User Testing Purpose, Make Prototypes Nearly Fully Interactive. When creating a prototype for user testing purposes, prototypes should include not only interactions that are necessary for predefined scenarios but also all possible interactions users might make. Limited interactions on a prototype lead users to follow the pre-constructed flow, hindering them from giving quality feedback.

Utilize Various Transition and Motion Effects. High fidelity means more than simple transitioning between two screens. If there is an animated effect when transitioning two screens, apply it into the prototype rather than instantly changing the first screen to the second screen. It is important to express the transitions and behaviors of interfaces as close as the real app.

6 Conclusion

In the design and development process of a new enterprise mobile app, we made prototyping as an essential step of the process. We used high fidelity prototypes as a communication tool with the team, stakeholders, and users. High fidelity interactive prototyping is a big part of work processes when designers need to create new concepts, messages, and interfaces. It plays a crucial role in the success of the project in that high fidelity prototyping allows designers to full-test concepts and refine before asking the development team to build the app. It is design-intensive but helps avoid waste in implementation. As stated in the case studies, it benefits various touchpoints around designers. We could receive quality feedback from users to validate our ideas, convey design flow and concepts efficiently to developers, and express business requirements effectively.

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No, We're Driving! Steer or Be Steered. How to Keep UX Front and Center During a Vendor's Demo

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Abstract. In enterprise companies, vendor products used in the workplace are often selected by a procurement team through a Request for Proposal (RFP). Driven by vendor claims, pricing, and show-and-tells, the process historically undervalued usability and design. This lack of attention to user experience (UX) often results in friction for users interacting with these products. We transformed the show-and-tell into a test drive, allowing us to take control of the UX our company wants for its employees. We mobilized a cross-disciplinary team to uncover solution truths and heuristic violations as they experienced the products for the first time. This paper describes our vetted methodology for supporting a UX evaluation during a vendor demo.

Keywords: Usability evaluation · User experience comparison · Expert review

1 Introduction

The selection of procured products in enterprise companies is not trivial. Poor products can cause unnecessary friction for users; leading to frustration, poor experiences, and productivity loss on a large scale. Vendors and their products are often selected based on their Request for Proposal (RFP) claims, pricing, and product show-and-tells. Technology, price, and service are often prioritized over user experience (UX) and design.

During the product sourcing process, rather than oblige as passive observers, we transformed vendor demos into a test drive, allowing our company to take control of the user experience we want for our employees. Byrne and Gingras suggest that "demos serve as a kind of bridge between a narrative proposal and hands-on prototyping, taking an abstract process and making it more real." [1] Instead of allowing vendors to demonstrate their solution in the context of our user stories as Byrne and Gingras suggest, we experienced the solution ourselves in the context of foundational tasks, without vendor intervention. We took the steering wheel by mobilizing a cross-disciplinary team, including product Subject Matter Experts (SMEs), management, and procurement professionals, to uncover solution truths and heuristic violations as we experienced the proposed solutions for the first time. The goals of our demo evaluation included:

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- Evaluating ease of use and quality by experiencing the print solution firsthand
- Validating the functionality that vendors shared in their written RFP proposals
- Detecting meaningful differences across vendors in technology, reporting, and partnering

2 Method

We applied a task-based heuristic approach to the user experience evaluation of a global print solution during vendor demos. Our approach was a blend of heuristic review and usability test adapted to fit within a procurement environment. We outline the framework of our evaluation process, followed by a detailed explanation of the framework.

1. Task development and planning: Converted a product feature checklist into a series of user tasks. Tasks, procedures, and test materials were refined repeatedly
2. Task assignment: Team members were assigned to tasks and dyads
3. Ratings development: Aligned "Minimum acceptable ratings" to RFP requirements
4. Vendor instructions: Addressed scope, held Q&As, and scheduled the demos
5. Team workshop: Conducted the demo preparation with the co-located team
6. Demo: Completed product usability ratings in real-time at vendors' offices
7. Debrief: The team gathered after the demo to discuss ratings and observations
8. Analysis: Task ratings were tallied and strengths and gaps compared across vendors
9. Ranking: A UX score per vendor was included in the procurement evaluation criteria

Task Development and Planning. While seemingly simple, print is a complex domain comprised of various user touch points such as physical hardware, computer software, mobile apps, networking, etc. Informed by a variety of sources such as help desk metrics, usage analytics, usability testing, surveys, and SME and stakeholder input, we were equipped with insights and deep knowledge of our user's needs and pain points to develop the tasks. Our first step was to deconstruct a lengthy 200 + feature list, initially scoped for the RFP, and consolidate it into 60+ user tasks. Tasks were qualified by the number of users they impacted and were prioritized and classified by baseline functionality, desired enhancement, or known pain point.

Tasks were grouped into 14 categories across the full arc of the user experience journey. The subset of the UX categories tested included:

1. Software installation
2. File transmission (computer, mobile)
3. Walk-up experience
4. Authentication
5. Print/copy/fax/scan
6. Troubleshooting
7. Hardware/Accessibility
8. Performance
9. Reporting

To demonstrate our methodology, we'll explore the UX category of authentication in more detail. Authentication is the process of securely signing in, by which a device recognizes the user, their preferred settings, and the documents they print. Currently, users authenticate with a personal ID or with their proximity card, and in the future, biometric options are possible. Since authentication is an important high-frequency event for all employees, we prioritized each mode of authentication as three separate tasks.

We iteratively tested and refined task content and wording, sequencing, assignments, ratings and test materials until we felt confident that we would be able to perform all tasks across all vendors in the allotted time.

Task Assignment. Tasks were assigned according to a SME's domain expertise. By staggering tasks among SMEs, critical aspects of the user experience could be investigated in a small amount of time. Team members without domain expertise were generally assigned to user tasks related to core functionality. All team members were paired into user/observer dyads so that one person could perform the task while another observed, wrote notes, and captured photos or videos. There were two observers, but only one was assigned to each task. Assignment to dyads and tasks was standardized across vendor demos.

Ratings. Two sets of ratings were required for this evaluation: minimum acceptable ratings and ease of task completion ratings. As part of the procurement process, the team was required to set and finalize minimum acceptable ratings for each RFP requirement prior to the demo evaluation. This was done before experiencing any solution to ensure fairness across vendors and to prevent bias in task ratings. As minimum acceptable ratings are beyond the purview of user research, we describe the process at a high level. Essentially, the team rated each requirement against its availability in the proposed solution based on the vendor's written RFP response. Each vendor was also asked to self-rate the availability of the requirements in their proposed solution. This helped the team understand the vendor's view of their capabilities. Paraphrased for this paper, here is a reference scale of the ratings (Table 1):

Table 1. Minimum acceptable ratings

Rating	Description
0	The requirement is not met and is not planned
1	The requirement is not met in the proposed offering but is planned with no committed development date or development is more than 6 months away
2	The requirement is not met in the proposed offering, but there is a committed date to be available within 6 months of the day of proposal submission
3	The requirement is fully met and is available now

Aligned with the 4-point procurement scale, the team rated ease of task completion in real-time as they experienced each solution. On the day of the demo evaluation, tasks were rated as described below (Table 2):

Table 2. Task completion usability ratings

Rating	Description
0	Unacceptable. The task could not be completed, or the option was unavailable
1	Poor. The task was successfully completed but with great difficulty
2	Acceptable. The task was completed successfully, possibly with minor errors or deviations which were easily overcome. Standard execution
3	Excellent. The task was completed successfully with no issues Flawless execution

Vendor Instructions. It was critically important to communicate our expectations to all vendors. We stipulated early-on that the demo was a test drive for our company, unlike a traditional demo where vendors showcase their product. We also insisted that our team complete all tasks at the printers independently, without instructions or help from the vendor, unless asked. We communicated specific requirements about computers, operating systems, mobile devices, and functionality to be tested, and also requested their consent to record or take photos of our interactions with their devices. To dedicate the demo purely to the user experience evaluation, we gave vendors the opportunity to showcase their solutions via an online presentation, in the days following the demo.

Team Workshop (In-person). First, the team was refocused on our users. Empathy and adopting a different point of view was encouraged through the use of vivid persona and user stories. Second, to level-set ratings the team was trained in affordances [2] and heuristic design principles [3]. Sample ratings with qualitative comments were provided as a guide. Third, we tactically prepared for the many unknowns involved in experiencing a new solution. Fourth, a social protocol was established on how to interact with each other and vendors during each visit. Fifth, a timed dress rehearsal was conducted using the current solution for comparison.

Demo Day. Each evaluation took place at a different vendor location and lasted approximately two hours after introductions and set-up. Upon arrival, each team member received a personalized folder with test materials and task rating sheets for easy markup. Each task description listed the user/observer pairings as well as step-by-step instructions. Assignees were standardized across vendors. Users moved in step through the evaluation with their observer. Tasks were staggered to accommodate the limited evaluation time. Test files of varying sizes and types were created beforehand and dispatched from a public box folder during the evaluation.

Debrief. Since team conversations were limited during the evaluation, it was important to debrief immediately afterwards at a private location to compare our ratings and candidly exchange thoughts and opinions. Our ratings were consolidated into a master procurement spreadsheet for scoring. Observations and follow-up questions to vendors were recorded. Photos and videos taken during the day's demo were uploaded into a file sharing system for later reference and comparison.

3 Analysis and Ranking

Data available for analysis included task ratings, observer comments, debriefing notes, photos, and videos. Data preparation included keyword tagging of photos and videos, tallying of scores, and synthesizing usability issues and suggested improvements. By requesting permission from vendors to capture photos and videos, we were able to reflect and analyze results with better clarity. Without this courtesy, it would have been difficult to retain the information across all the user tasks completed at each printer.

As we are not at liberty to discuss specific findings, we can only reveal how we synthesized the data for upward executive decision making. We compiled the following as part of our analysis:

- Ratings for each task were color-coded in a comparative table format for at-a-glance comparisons and standings. Colors included red for 0 or Unacceptable, yellow for 1 or Poor, light green for 2 or Acceptable, and green for 3 or Excellent.
- We gave separate focus to tasks that were aimed at meeting core functionality, overcoming current pain points, and implementing desired enhancements.
- Tasks that did not perform well or that fell below our minimum acceptable response were examined closely as to why, and modifications required of vendors to make the UX successful for our employees were noted. This part is critically important for clarifying requirements in later stages of the procurement process. Usability issues were grouped into categories such as feedback, attributes of the physical printer, or screen layout.
- Tasks were collapsed into their user experience category for a summary view of vendor comparisons. Vendor commonalities and differentiators were called out.
- An individualized assessment of each vendor was developed based on the unique strengths and weaknesses of their solution along with our impressions of best fit.
- A UX score was calculated by summing the ratings across all tasks for a given vendor. The higher the score, the better the UX. Vendors were ranked by their UX score and the score was entered into the overall procurement equation.

4 Discussion

Our approach had several advantages. It enabled us to cover a lot of ground while alerting the team to solution gaps very early in the procurement process, essentially facilitating the negotiation of changes ahead of a contract. In preparing our analysis, we discovered a study on user-centered procurement by Larson, Hocko, and Bye. Our approach supports their assertion that UX researchers need "low overhead methods that address genuine concerns and help procurement teams make informed decisions." [4] Equipping the product team with heuristic and usability training supercharged their attachment to user experience. All team members played a valuable role in the evaluation; no one was sidelined. By taking control of the demo, we were able to uncover which vendors could provide the best match to our company culture and employee needs. This approach is easy to repurpose for other vendor products, ultimately helping to keep costs low and usability high.

The findings of this evaluation will lead the team to confidently down-select contenders for the proof of concept phase of the RFP. The next phase will involve bringing the proposed solutions into our company's infrastructure, giving us plenty of time to look under the hood. We will explore including methodologies such as PURE [5] in our next phase of evaluation.

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What Am I Looking for? Improving User Sentiment by Enhancing Search and the Overall End User Experience in the Mobile Environment

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Abstract. Search is a popular method for mobile users to quickly find information. Thus, when search is poorly designed, it can make locating the right content a frustrating and inefficient experience that reduces user engagement. In this presentation, we will review several design changes, such as integrating cognitive capabilities directly into search to improve discoverability, which led to a significant increase in user sentiment. We will compare this approach to more traditional search methods through user testing and survey results.

Keywords: UX · Search · Intercept · Watson · Mobile app

1 Introduction

The popularity of search is evidenced by its wide adoption in many contexts. We may go to Google to search for information, or within an application such as Excel or Word to find specific data or words. Search helps make our work easier and increases our productivity.

Users have come to depend on search in the mobile environment. Not all apps, however, have an efficient search. As the amount of available information grows, finding the right information becomes increasingly more difficult; there may be too many results, and there may not be a good match for the user's specific query. While it is important to provide accurate search results, it is also important to make the process as simple and fast as possible.

In this paper, we review the mobile adaptation of the IBM Help website and the design decisions that helped significantly increase its user sentiment score over a relatively short period of time. We also discuss why our approach to cognitive integration is superior to a separate chatbot.

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https://doi.org/10.1007/978-3-030-51369-6_25

2 Background

With approximately 350,000 employees worldwide, there are several thousand IBMers in need of technical support each day. The majority of support requests come via our internal web site; however, there are many use cases when mobile-enabled IBMers also require support, so we have developed an internal enterprise iOS application, “Help@IBM mobile,” that facilitates locating appropriate technical information across over 6,000 documents related to troubleshooting employees’ computers and mobile devices.

The goal was to provide a “search centric” experience and create a user interface that leverages iOS 12 capabilities with the latest design patterns from Apple’s human interface guidelines [1]. Using the app, one can view alerts, outages, open tickets, and resolve various issues, including passwords, connectivity, mail, telephony, and more.

3 Objectives

Our objective is to design the app to provide a best of breed support experience on the mobile platform by:

- Providing fast and easy search with autocomplete and word suggestion features.
- Eliminating as many unnecessary steps in the search process as possible to minimize the time and effort in support activities.
- Guiding users to find best answers to their questions with simple and user-friendly flows to address their issue.
- Being consistent with the Help@IBM website in functionality and appearance.

4 Original Design of Help@IBM Mobile App

4.1 Mirrored the Browse Categories from the Internal Support Site

The original design of Help@IBM Mobile displayed the appropriate browse navigation found on the Help@IBM website as clickable icons in the content area of the Help@IBM mobile home screen.

4.2 Supported Filtering Content by Platform

When users browsed to a category with support content, they would be prompted about which platform to select so that the results they received would be relevant to their situation. If the user went directly to search, they could modify a platform selector widget, which displayed at the top of the results section, to limit the content to the relevant platform.

4.3 Supported Traditional Search Methodology

Search was supported by displaying a search bar at the top of the mobile home page to give the user a mechanism to directly ask their question without browsing. Keywords entered would bring up relevant articles in a list sorted by relevance (Fig. 1).

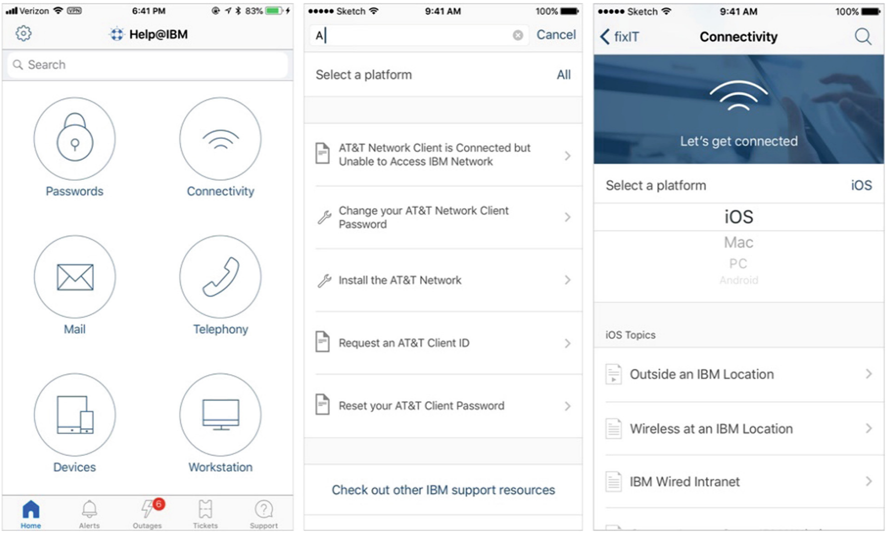

Fig. 1. Original design of the Help@IBM mobile app

5 Updated Design of Help@IBM Mobile App

5.1 Supported a Modernized 'Search First' Interface

By reducing the prominence of the category icons and placing them lower on the home screen, the new interface encourages searching as the primary action in the app. As long as your search is able to provide relevant answers to your users, this is the most efficient way for users to find the information they are seeking. Another design point as part of the updated effort was to always make a search option visible to the user. It is important to keep in mind that proper indexing contributes to any successful search model which will be discussed further in Sect. 5.3.

Supporting Research. Roughly 75% of the tasks users were seeking to address through the application were most efficiently driven through 'Searching' rather than browsing (43% seeking 'How to' guidance, 22% seeking connectivity assistance, 8% seeking password related help). With this updated interface over 70% of users were successful at finding the answer they needed suggesting that search was able to help bring users to the answers they were seeking.

5.2 Improved Filtering by Platform

One of the most effective ways to help users find what they are looking for is to only show users content that could be related to their issue. In the case of Help@IBM Mobile that is supported by having the content filtered to only show results for the platform of interest. In the latest design, the platform is defaulted to iOS and is prominent. By making a selection in the filter one time, all content and search results are filtered for the entirety of the session.

Supporting Research. Users rated the importance of filtering content by a platform as their most important function (5.9/7) over modern look and feel (5.6/7) and having intelligent workflows integrated into the search results (5.5/7).

5.3 Search-Related Enhancements

An effective search is often the key component in whether or not a user has a delightful or an unsatisfactory experience. If you can successfully aid the user in predicting their issue based on their search and help them achieve their goal, the user will walk away with a positive experience and promote that good experience to others. Accordingly, the Help@IBM team enhanced the mobile search as follows:

Cognitive-Enhanced Search. Cognitive functionality was integrated directly into search to improve the discoverability of key information. These cognitive capabilities made it possible to intelligently boost key search results, disambiguate questions that may have led to erroneous search results, and provide self-service capabilities so that some issues could be directly resolved by the user in minutes.

Chatbot technology was integrated into search using a design approach called "cognitive intercept" [2], where the chatbot capabilities lay dormant until needed, When the query strongly matches with an answer (a "cognitive intent"), the chatbot capabilities respond with either an answer or additional questions to disambiguate the input. When multiple suggestions are returned, the user may select between them for the best match. This process gives the user the feeling that they are having a short conversation with a chatbot without the cognitive overhead of learning how to interact with a chatbot. Users don't need to choose between search or chatbots; both technologies are blended to provide the best features of each. Together, these improvements made it easier to find and navigate to the right content, thereby improving user engagement.

Show Related Searches. When the user begins to search by typing characters into the search bar, the app will automatically show related search results before the user finishes typing the full word or sentence. This saves the user time by eliminating the need to type complete words or sentences. It also is useful when the user has a problem but doesn't know exactly what to search for; the user just needs to type in a single word related to the problem, and it will bring up the search results, allowing the user to select the one that best fits the problem.

Show Trending Topics when the Search Tab is Selected. A list of topics are displayed based on their search frequency (i.e., topics most commonly sought). These trending topics are typically ones that of general interest to most users in that time period. Users can simply scan the list of trending topics for fast results (Fig. 2).

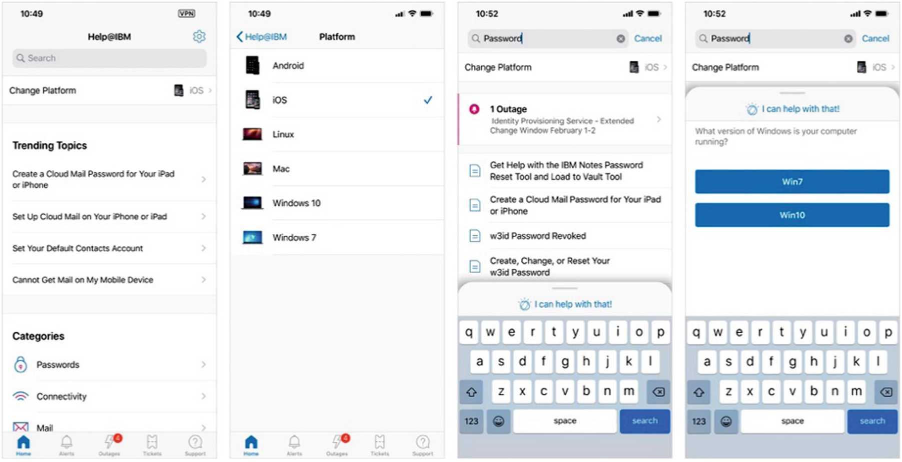

Fig. 2. The redesigned Help@IBM mobile app

6 Usability Session and Survey

6.1 Usability Session

To validate that these UX improvements were effective, we conducted usability tests to obtain feedback on the functionality and design of the current app, comparing it with the new cognitively-enhanced app, and also asked our participants about which design approach they preferred.

Participants. Eight usability test participants were recruited through an internal UX Volunteer Participants List. They took part in a 45-min usability test session. They were from the US, Brazil, India, Canada, New Zealand, Germany and the UK. They were from different IBM Business Units, and have different job roles.

Materials. The participants and the moderator communicated via screensharing for the entire session. The moderator shared the screen of an iPhone running the Help@IBM mobile app and an InVision Prototype of the proposed new design. Screensharing has some limitations for mobile solutions but has nonetheless proven useful for remote testing with a global audience.

Procedure. Participants completed three tasks in a fixed order. Afterwards, the participants reviewed each screen of the app, provided their feedback about the flows, ease of use, preferences, and provided comparisons between the two design approaches.

Results and Discussion. During testing, several issues were identified with the old design, including:

- There were too many steps to get to the right information using the search bar.
- Some of the users were confused that how to open the ticket using the app.
- Some of the users didn't understand that all of the platforms were displayed at the same time.

Seven out of eight participants preferred the new search-centric design, including the prominent placement of search on the home screen, popular topics, and platform selection screen. They preferred the new, modern design to the original design. And all participants liked the new cognitive chat intercept experience.

6.2 Pilot Survey

We surveyed 700 employees on their overall satisfaction using the redesigned app and to obtain feedback on the efficacy of cognitive-enhanced search in a mobile context. We sent the survey in April 2019 to a mix of IBMers that have downloaded the Help@IBM pilot app and volunteers from CIO Design Insights Group. The survey's estimated time was 5 min. We had a 41.14% response rate, and 288 people completed the survey. The participants were from different business units in IBM, and various countries, including Brazil, Canada, France, India, Germany, Japan, the UK, and half of them were from the US.

40.5% of people tried to resolve their problem by using the Help@IBM mobile app. The majority of people answered they attempted to resolve their problems by first searching for a solution and then browsing/navigating through the help options. 71.1% of people who attempted to solve their problem using the app were able to resolve it.

6.3 NPS

NPS for Help@IBM mobile was collected in two independent surveys to IBMers globally. One was collected prior to the enhancements discussed (July 2019) and one was collected after the changes were implemented (January 2020). Users indicated they used the application at least a few times per month surveyed (Table 1).

Table 1. NPS survey results

Survey	Help@IBM Mobile NPS
July 2019 (pre)	8.9
Jan 2020 (post)	28.0

NPS climbed 19.1 points after the redesign. Based on a margin of error (MoE) test, these values were significantly different. The MoE for the difference was 6.1.

7 Conclusion

Search is a natural fit to the mobile platform, allowing users to find solutions quickly while minimizing excessive navigation. Enhancements such as showing related and trending searches helped surface top issues, and together with predictive typing, helps to minimize the need to type, a common pain point on mobile devices. The integration of cognitive capabilities directly into search, as opposed to creating a separate chatbot, simplified navigation and lowered the learning curve. The net result was a search that was even more effective at helping users locate the correct solutions than before, and without any additional cognitive overhead, included advanced capabilities such as question refinement and ability to understand natural language as needed. Together, our search-centric design improvements helped users find and solve their problems more effectively, and provided a significant improvement in user sentiment.

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Evaluation of Open Source Mobile Phone Weather Applications

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Abstract. The quality of our everyday lives undoubtedly depends on our alertness for upcoming weather conditions, particularly, extreme meteorological parameters. Sudden heat or cold waves, floods, thunderstorms, among others, are crucial events affecting human health and safety, that can even cause substantial economic losses. At present day, the technological advances offer practical and fast ways to access this information, such as consulting the internet and even more conveniently through weather applications. However, not all the open access applications offer the same quality of information or are presented in an intuitive manner. Therefore, in this study, selected open source mobile phone weather applications, available for Android and iOS systems, were evaluated, specifically focusing on the usability functions of these tools.

Keywords: Evaluation · Mobile applications · Weather

1 Introduction

The quality of our lives often depends on our preparedness for upcoming weather conditions. This is especially important for health and safety implications of extreme meteorological events, such as heat or cold waves, floods, thunderstorms, hurricanes, among others [1]. For example, extreme cold or hot weather may cause an increased prevalence in respiratory diseases, cardiovascular complications, or even premature deaths [2]. With the changing climate, extreme events, such as heat waves, are becoming more of a concern due to an increase in incidences all over the world [3], and are now considered as the most fatal natural disaster [4]. In addition to the health implications, weather can cause serious economic damages, not just due to the loss of lives, but also public (including environmental quality, biodiversity, etc.) and private

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property losses. Based on AON 2018 report, only the top ten global economic loss events accounted for annual monetary damage of 225 billion dollars [1]. This strongly advocates for the importance of current and future weather awareness.

While before we would consult local weather conditions through television and radio news, nowadays, due to the great advance of technology, there is a more practical and faster way to access this information: the mobile phone applications [5–8]. A wide variety of weather applications updates human population on current and even future weather conditions. However, the information provided by mobile phone weather applications is very diverse, from the most basic, such as temperature and the probability of rain, to more complete, such as the warning of allergenic agents or air pollution. They can alert the user about the dangerous conditions more efficiently compared to the more limited weather television programs. In addition, the information provided, and the way it is displayed, varies from one application to another.

This work aims to evaluate the usability of selected open source mobile phone weather applications for Android and iOS systems, in order to identify the most common functionalities, including their weaknesses, either in the interface or for lack of valuable information.

2 Methodology

A vast amount of smart phone weather applications exists for free and for a fee for Android and Apple operating systems (OS). A thorough research was performed to identify the most used whether applications, and as a result, eight open source applications were downloaded on Android (Samsung Galaxy J7, OS 6.0.1) and Apple (i-Phone 7, iOS 12.1.2) cellular phones for evaluation. The selected applications were: AccuWeather, The Weather Channel, Today Weather, WeatherBug, Wunderground, Yahoo Weather, Windy and 1Weather. Features, such as Temperature, Thermal sensation, Chance of precipitation, Wind information, UV index, Humidity, Cloud cover, Pressure, Hourly forecast, Daily forecast, Allergen agent information, Notifications and Alert severe weather, Visibility, Sunrise/sunset, Air Quality Index (AQI), Air Pollution information, Radar and maps and News, were considered. Most of the analyzed applications contain the same features. However, three out of the eight applications (with a higher number of features) were selected to perform a deeper evaluation. This evaluation process focused on the complexity of access to a specific feature by mean three interaction criteria, in more detail explained in [7].

3 Results and Discussion

The completeness of the eight selected mobile phone applications for weather are presented for Android (A) and Apple (I) in Fig. 1. The most complete, in terms of parameters, are Wunderground (18(A)/17(I) features). The Weather Channel (17 features), AccuWeather (16 features) and WeatherBug (17(A)/13(I) features) (see Fig. 1). The first two applications are very similar; thus it was decided to further review the more complete Wunderground application, in addition to AccuWeather and WeatherBug.

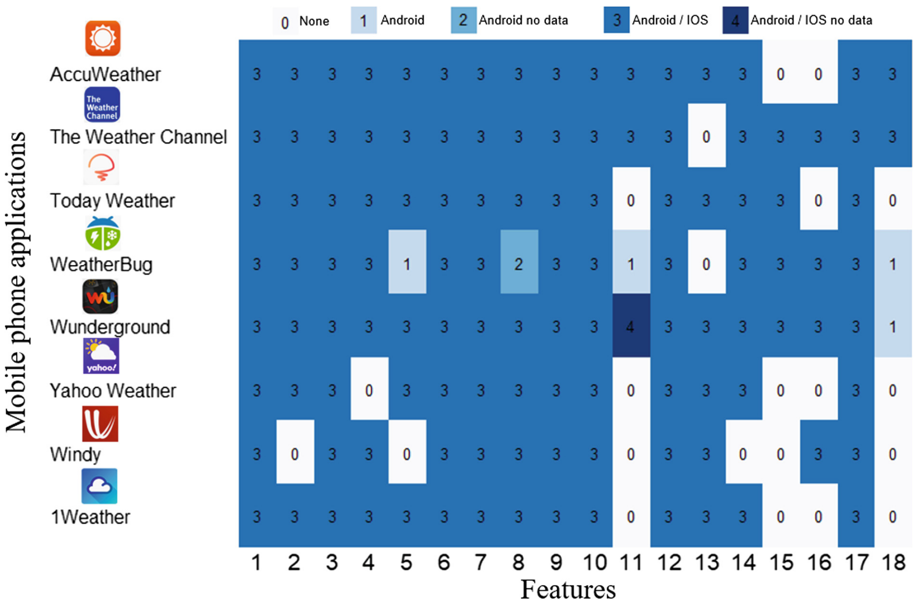

Fig. 1. Features evaluated for availability in 8 mobile phone applications: for Android and iOS operating systems (OS): (1) Temperature; (2) Thermal sensation; (3) Chance of precipitation; (4) Wind information; (5) UV index; (6) Humidity; (7) Cloud cover; (8) Pressure; (9) Hourly forecast; (10) Daily forecast; (11) Allergen agent information; (12) Notifications and Alert severe weather; (13) Visibility; (14) Sunrise and sunset; (15) AQI; (16) Air Pollution information; (17) Radar and maps; (18) News. None (0) - there is no feature in any OS; Android (1) - the feature is only available for Android; Android no data (2) - the feature is available only for Android, but there is no data; Android/IOS (3) – the feature is available for both OS; Android/iOS no data (4) – the feature is available for both OS, but no data exists for iOS.

3.1 AccuWeather

AccuWeather mobile phone application is accessible for both the Android and iOS platforms and is a second most comprehensive in number of features (16). The interface of Accuweather application is not very intuitive. The information of deeper interest has to be searched. On the first screen, of both OS, the main meteorological parameters are displayed: temperature, thermal sensation, cloudiness, humidity and wind speed (Fig. 2a). Clicking on this section, more information, such as wind gusts, cloud cover and visibility, is provided. If scrolled from the main screen down, a brief weather forecast and alergenic conditions are also displayed in both OS (Fig. 2b). It was detected that there are some interface and information differences between the OS. For instance, on iOS, the information of hourly and daily forecast, news and maps, can be obtained by scrolling down or by selecting the option on the main page. On the other hand, in the Android OS, this information is offered only from the main page. The information shown in the hourly and daily forecast sections is different when comparing the Android with the iOS. For example, although in the hourly forecast the minimum and maximum temperatures and the cloudiness parameter are displayed in both OS (Figs. 2c, d), in the iOS more information is given on the same page (real feel, probability of precipitation, humidity, etc.), while in the Android OS, it is necessary to click on the arrow to get to this information. Also, an orange icon on the upper right corner can be selected in the iOS to view more detailed information on temperature, real feel, and precipitation. On the other hand, if selected daily forecast, a very general information can be accessed up to two weeks ahead in both OS (Figs. 2e, f). However, in the Android OS, day and nighttime information is provided unlike the iOS. If swiped to left or right, the pages change for the next or previous day of the daily forecast. Finally, in maps option, world satellite, temperature contour (Fig. 2g), dangerous thunderstorm allerts, Accucast, tropical storms (path, rainfall, risk, maximum winds, storm surge, etc.) and current weather, can be selected to display in the global map in both OS.

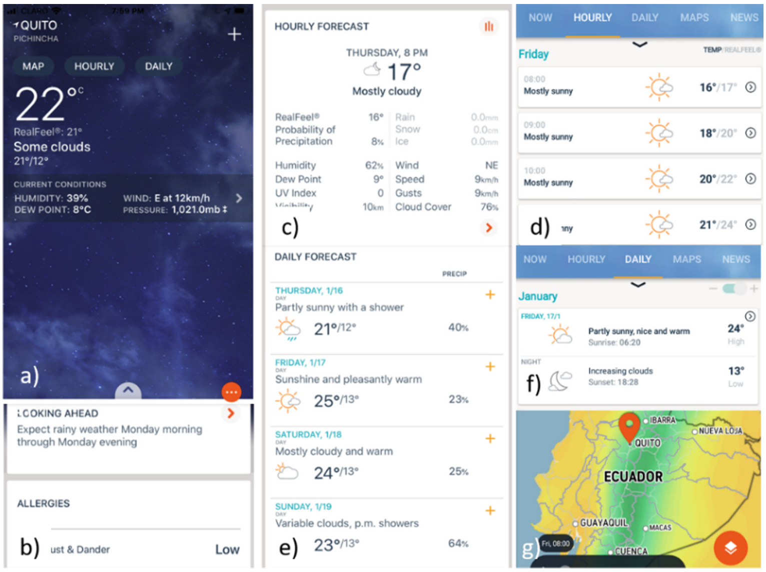

Fig. 2. Screenviews of AccuWeather: a) main page with the main meteorological parameters; b) scrolling takes user to a brief weather forecast and allergy risk evaluation, c) hourly forecast for iOS; d) hourly forecast for Android OS; e) daily forecast for iOS; f) daily forecast for Android OS; (g) global map centered on a user location.

3.2 Wunderground

Wunderground application is an adaptation of an existing popular webpage by the same name that reports weather conditions and forecast. The interface of this application is identical for the two OS with a very few differences (Fig. 3). On the main screen, temperature, thermal sensation, cloudiness, wind direction and speed (and wind gusts), and the chance of precipitation are displayed (Fig. 3a). If clicked on the section of the temperature, the user can see more complete information (precipitation estimate for the next 24-hrs, dew point, visibility, pressure, UV, and a brief forecast) (Fig. 3b). If the precipitation icon is selected, information of the conditions of cloudiness and the intensity of precipitation (up to 6 h ahead) appears. In addition, a map centered on the location of the user, is displayed in the main screen (Fig. 3a). If map option is selected, the global information can be seen (as heat maps) on radar, temperature, satellite layers (cumulative info of all the above). Then, if scrolled down from the main page, the user is directed to the forecast (daily, hourly and summary), and the moon/sun phase and air quality index (Fig. 3c–f).

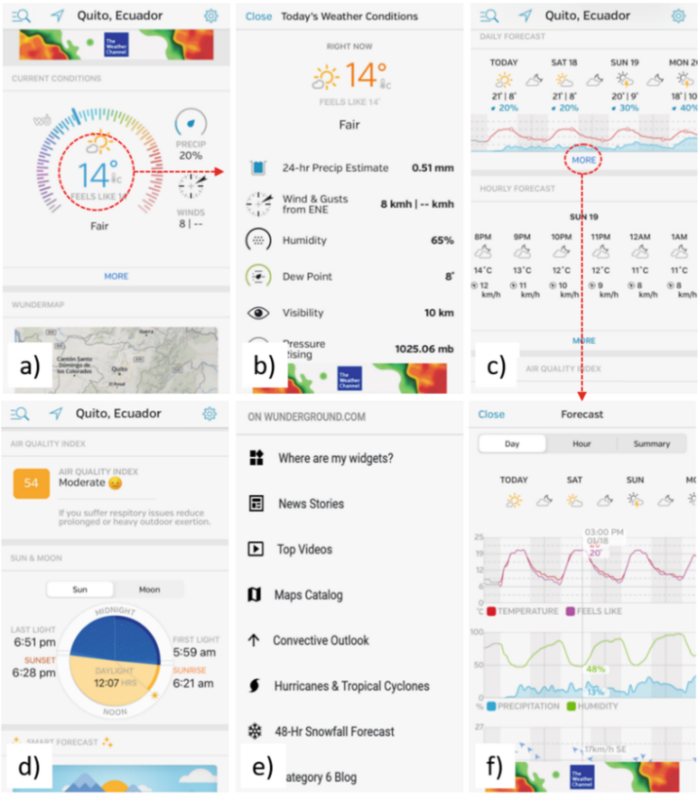

Fig. 3. Screenviews of Wunderground: a) the main screen; b) complete weather information if clicked on temperature; c) scrolling takes user to daily/hourly forecast; d) scrolling takes user to air quality conditions and sun/moon phases details; e) more data appears for Android OS; f) graphical representation of forecast information.

There are a very few differences in the interfaces of this application in the two OS. For example, in iOS interface, a more detailed information on the AQI of all criteria pollutants is available. If selected of an icon “i”, an explanation of each pollutant and corresponding health problems are offered and recommendations are given. On the other hand, in the Android OS, ranges of acceptable and ideal conditions of temperature, wind speed, chance of precipitation, etc. can be configurated, in order to define outdoor activities, such as running, walking, photography, etc., for extra payment. This configuration can be made for different times of the day or week. This shows that this application is an ideal option for outdoor activity planning.

3.3 WeatherBug

The interface of this application is also identical for the two OS (Fig. 4). On the main screen, temperature, thermal sensation, minimum and maximum temperature, cloudiness, wind direction and speed for current day are displayed (Fig. 4a). In addition, on the main screen, a map centered on the location of the user is presented. If map option is selected, the global information can be seen (as heat maps) on radar, temperature, satellite, storm tracker, air quality, etc. (Figure 4b). Then, if scrolled down from the main page, the user is directed to the air quality, lighting, fire center, wind, sunrise/sunset information (Fig. 4c–d). The air quality, fire and lighting options can be further explored in a visualization of risks displayed on the map. Air quality page offers more detailed information. In addition, on the main page, the hourly, 10day forecast and map buttons exist (Fig. 4e–f). Hourly forecast offers minimum and maximum temperature, precipitation and cloudiness, however, if clicked on, more detailed information appears (humidity, thermal sensation, wind and dew point temperature).

Fig. 4. Screenviews of WeatherBug: a) the main page; b) detailed information appears if clicked on the map; c–d) scrolling takes user to air quality, lightning, fire activity, etc.; e–f) hourly/daily weather forecast appears if chosen corresponding buttons.

Daily forecast displays the same general information, and, if selected, presents a differentiated information for daytime and nighttime in words (Fig. 4f).

4 Conclusions

A thorough review of a vast number of available smart phone weather applications was performed. At the end, eight most used weather applications were reviewed for available weather features for Android and Apple operating systems. While all open access weather applications offer a wide range of features, only three most complete (Wunderground, AccuWeather and WeatherBug) were analyzed in more detail for usability. The three applications ranged in their intuitiveness, however, all of them are highly advanced in terms of providing a user with relevant information, such as temperature, thermal sensation, chance of precipitation, wind information, UV index, humidity, cloud cover, atmospheric pressure, hourly and daily forecast, allergen agent and air pollution information, notifications and alert about severe weather, visibility, sunrise and sunset, maps and news. It was detected that there are some interface and information differences between the operating systems, meanwhile some applications are very similar in both operating systems. Finally, most weather application offer a comprehensive information on environmental risks and can be programmed to personalized user requirements. This study serves as a base to help improve the interactions of these applications.

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Accessibility Assessment of Mobile Meteorological Applications for Users with Low Vision

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Abstract. The World Health Organization indicates that more than one billion people worldwide live with some form of disability; almost 200 million people experience considerable difficulties in their physical functioning. In the future, disability will be a significant concern, as it tends to increase because the population is aging, and the risk of disability is higher among older adults, such as their decreasing vision known as presbyopia. On the other hand, technology has become an essential tool that brings support in daily life, such as mobile applications, with information that helps to know the weather conditions in any part of the world. However, not all meet accessibility standards for mobile applications. In this study, we took a random sample of mobile meteorological applications to assess whether they comply with the mobile accessibility considerations related primarily to the perceptible, operable, understandable and robust principles proposed in WCAG 2.1.

Keywords: Accessibility · Assessment · Application · Low vision · Mobile application · Weather

1 Introduction

The development of accessible mobile applications has become a great challenge for accessibility experts; with the advancing age, users suffer from changes. Among them, the most frequent is that of visual impairment, specifically low vision. Currently, many mobile applications facilitate our daily activities, but not all of them are accessible, which means that a large number of users cannot easily access and interact with mobile applications. To test accessibility in mobile applications, Google has an Accessibility Scanner for Android, which is a tool that helps in some way in the revision of the

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https://doi.org/10.1007/978-3-030-51369-6_27

accessibility guidelines proposed by the WCAG 2.1 [1]. The accessibility guidelines include four principles that are perceptible, operable, understandable and robust, the same one that includes three levels of accessibility, depending on the policies and legislation of each country in most cases is accepted up to the average level corresponding to the "AA." To solve this problem, we suggest applying accessibility standards in mobile applications throughout the development cycle of the application.

The results of the evaluation of accessibility in mobile meteorological applications show that these applications are not accessible and inclusive because they do not meet the minimum accessibility requirements. We recommend applying the accessibility principles for mobile applications based on the WCAG 2.1 principles throughout the development cycle of these applications. Besides, we suggest to include 1) A mobile application configuration option that allows managing the contrast and color mode of the image, 2) An alternative to managing three natural and synthetic color modes, 3) An option to use in environments with low light, activating flash, 4) A map to zoom, 5) An audio wizard to guide the user. This research can serve as a reference for programmers and developers of mobile applications in the creation of more accessible and inclusive applications.

The rest of the article is structured as follows: in section two we show the background, in section three we depict the methodology and, therefore, the case study, in section four we show the results and, the discussion, and finally, in section five, we tend to incorporate our conclusions and propose future analyzes.

2 Background and Related Work

Currently, there are a variety of mobile applications; in our daily life, they are valuable when ordering a taxi, finding out about traffic conditions in any city in real-time, ordering food from home, as well as taking and editing photographs. We also enjoy games and can check and write our email while searching the dictionary to clear our doubts about grammar. Thus, an "app" or mobile application is a tool that supports the organization of our activities. In this study, we consider the evaluation of accessibility in mobile applications for weather, which allows managing the live forecast of meteorological parameters. Also, we can find out about the extreme weather alerts, live alerts, weather trends, daily temperature, and wind speed, so that we can better plan if we need a winter coat or an umbrella.

The Web Accessibility Initiative [2] states that "mobile accessibility" refers to making websites and applications more accessible for people with disabilities when using mobile phones and other devices.

Jabangwe et al. [3] indicate that a mobile application is a program, according to the technologies involved, which can be native, web, or hybrid. Mobile applications have a design for use in smart mobile devices or tablets.

There are many weather mobile applications available for download and use. In this study, we have randomly chosen five weather applications in order to analyze if these tools have been built applying accessibility standards, optimizing for the most significant number of people, especially people with disabilities. In this work, we analyze the applications for users with low vision, who, with the advance of age, are losing visual ability.

Acosta-Vargas et al. [4] argue that the lack of adequate methods to test the accessibility of a mobile application has become a great challenge for accessibility experts. In this previous study, ten mobile applications, the most popular, according to PCMAG, were analyzed by performing the automatic review with Accessibility Scanner from Google Play Store. The evaluation results indicated that they do not meet the minimum required level proposed by WCAG 2.1. The research proposed suggestions to raise awareness among mobile application designers.

Furthermore, Acosta-Vargas et al. [5] evaluated the accessibility of mobile applications for air quality with the Accessibility Scanner tool. No doubt, there are a lot of free applications for mobile devices, but not all of those mobile applications are accessible. The study proposes to use Google accessibility scanner, applying the Web Content Accessibility Guidelines 2.1. In this investigation, ten mobile applications were evaluated; the results propose to develop inclusive mobile applications.

3 Method and Case Study

As a case study, we have evaluated five mobile weather applications; the evaluated mobile applications are summarized in Table 1.

Table 1. Summary of the WCAG 2.1

Id	Tool	Logo	Updated	Current version	Android Requires	Offered by	Download
A	AccuWeather		January 18, 2020	Varies with device	Varies with device	AccuWeather	50,000,000+
B	The Weather Channel		January 1, 2020	Varies with device	Varies with device	The Weather Channel	100,000,000+
C	Today Weather		December 24, 2019	1.4.4-12.221219	4.2 and up	todayweather.co	1,000,000+
D	WeatherBug		January 22, 2020	Varies with device	Varies with device	WeatherBug	10,000,000+
E	Weather Underground		January 20, 2020	6.1.2	6.0 and up	Weather Underground	5,000,000+

We use a combined method of automatic and manual review for the Android operating system because it is the most used in the world; it consists of eight stages summarized in Fig. 1.

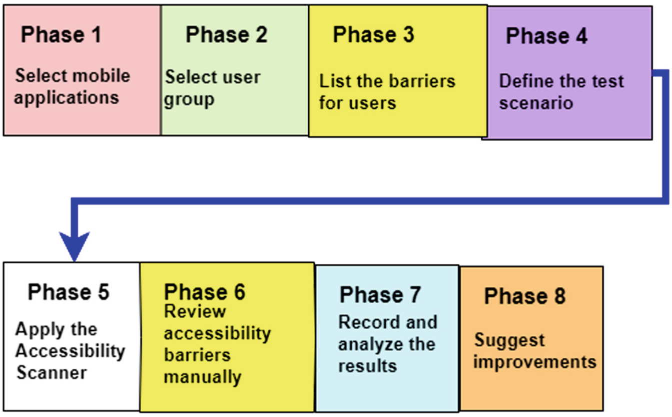

Fig. 1. Method to evaluate accessibility in a mobile application.

Phase 1: Select mobile applications; in this phase, we randomly select five applications that are detailed in Table 1. The applications were selected from the Google Play Store, taking as reference the number of downloads, the most current and the most controlled version.
Phase 2: Select user group, in this phase we define the type of users who use the application, in this case, users with low vision, which includes the condition in which a person's vision cannot be corrected with glasses. It interferes with daily activities such as reading and driving. Low vision is more common among the elderly, but it can result in people of any age as a result of diseases such as macular degeneration, glaucoma, diabetic retinopathy, or cataracts. Five users with average ages of 42 years participated in this study.
Phase 3: List the barriers for users with low vision, defining the barriers for the group of users selected in phase 2. In this phase, the present principle is the "Perceptible" because it cannot perceive the content and not enough contrast.
Phase 4: Define the test scenario, select the activities that users must perform during the execution process with the Google Accessibility Scanner tool. In this case, the tasks were to enter the main screen and display the options menu.
Phase 5: Apply the Accessibility Scanner validator, evaluate each of the mobile applications (see Table 1) with the Accessibility Scanner tool.
Phase 6: Review the accessibility barriers manually, in this phase, we review the results issued by the accessibility scanner manually, although it is expensive, it is the best way to identify errors. For low vision users, we focus on the "Perceptible" principle with the criteria of "Small screen size," "Zoom/Enlargement," and "Contrast."
Phase 7: Record and analyze the results; the results are recorded in a spreadsheet to analyze the results.
Phase 8: Suggest improvements, in this phase, some suggestions will be executed to improve the application.

4 Results and Discussion

Table 2 summarizes the mobile accessibility considerations, contains the ID of the analyzed parameters, # Elements, Touch target, Text contrast, Element label, Image contrast, and Clickable items.

Table 2. Summary of the WCAG 2.1

ID	# Elements	Touch target	Text contrast	Item label	Image contrast	Clickable items
A	17		15		2	
B	13	1	6	2	4	
C	4	1		2	1	
D	14	8	1	3	1	1
E	29	7	12	6	4	
	77	17	34	13	12	1

Figure 2 shows that the most significant number of barriers corresponds to "text contrast" with a value of 34 correspondings to 44.2%; followed by "Touch target" with 17 errors and represents 22.1%; thirdly "Item label" with 13 errors representing 16.9%; "Image contrast" with 12 errors corresponding to 15.6%, and finally, "Clickable items" with one value that representing 1.3%.

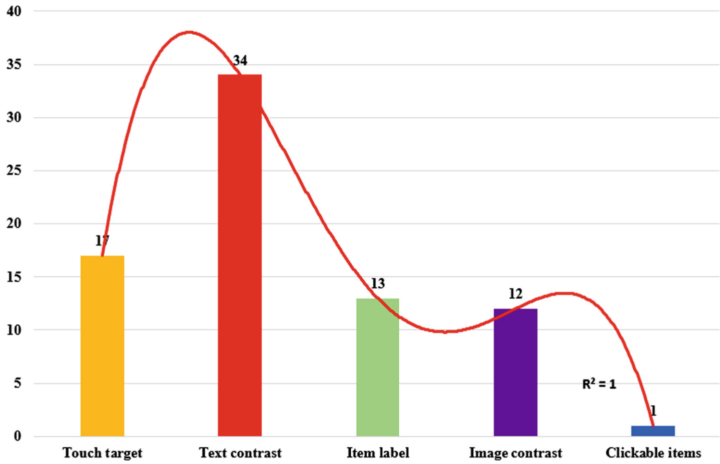

Fig. 2. Barriers detected with Accessibility Scanner.

Figure 3 shows that the most accessible application is Today Weather, followed by The Weather Channel and Weather Bug.

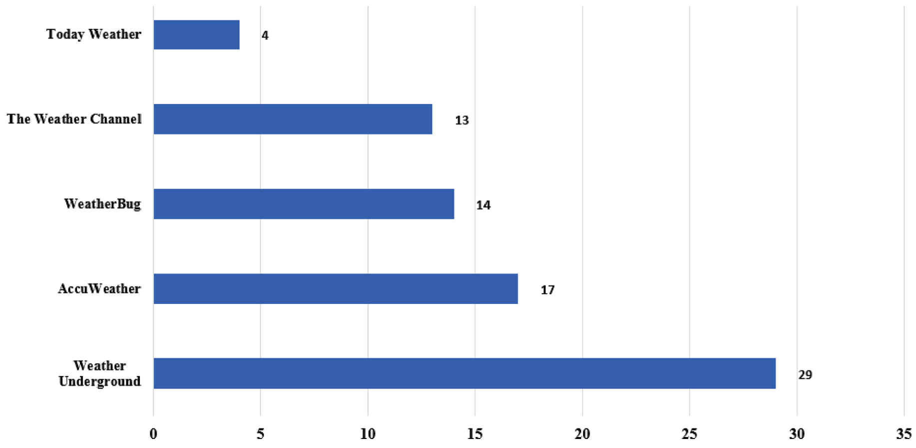

Fig. 3. Mobile accessibility detail of the applications evaluated.

During the analysis of mobile applications for weather, we identify the criterion "1.1 Small screen size" that is solved by minimizing the amount of information. The "1.2 Zoom/Enlargement" parameter, which is resolved at the operating system level that can set the default text size, enlarges the entire screen and expands the view of the lens under the user's finger. Concerning the browser can set the default text size of the text represented in the browser view. It is required to change the text size without assistive technology up to 200 percent. Furthermore, the "Contrast 1.3" that is resolved requires a contrast of at least 4.5: 1. When analyzing the web platform, it was identified that the principle that has the most significant frequency to apply in users with low vision corresponds to "Perceptible" with the success criteria "1.4.4 Change text size", "1.4.3 Contrast " (Minimum) and "1.4.6 Contrast (enhanced)".

5 Conclusions and Future Works

The method applied in this study has its limitations; it takes too much time and, therefore, is too costly to solve accessibility problems. This research can serve as a reference for future studies related to accessibility methods for mobile applications to achieve more inclusive applications. The method can be replicated for other types of users, considering the several accessibility barriers.

We suggest applying this web accessibility review method throughout the application development cycle.

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The Portable Document Format: An Analysis of PDF Accessibility

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Abstract. Today, PDFs are frequently used as part of the preservation of historical documents in libraries, and they are also one of the most used formats on the web when sharing information. Unfortunately, most shared documents are not accessible, especially for users with disabilities. To solve this problem, we propose to relate accessibility techniques for PDF documents in accordance with the Web Content Accessibility Guidelines (WCAG) 2.1. As a case study, we have selected a random sample of 10 documents related to the modern architectural heritage of Quito. The authors applied a combined method to check accessibility in PDFs with the help of the PDF Accessibility Checker version 3.0,

The results revealed that the accessibility barriers that are repeated in most documents are related to the content and the natural language of the analyzed PDFs. The analysis applied in this investigation can contribute to future works to generate more inclusive PDF documents.

Keywords: Accessibility · Digital documents · Portable document · PDF techniques · WCAG 2.1

1 Introduction

Presently, portable document formats (PDF) are an essential element of information excellence. PDF documents are increasingly used as part of the preservation of historical documents in libraries and are often shared on the web. Nevertheless, not all PDFs offer universal access. To solve this problem, we apply the PDF techniques of the Web Content Accessibility Guidelines (WCAG) 2.1 [1]. In this study, we take as a case study a random sample of 10 documents in PDF format that refers to the modern architectural heritage of Quito and is stored in a digital format. In the evaluation of the documents, we use the PDF Accessibility Checker version 3.0, which showed that libraries had not been concerned about providing accessible documents under

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https://doi.org/10.1007/978-3-030-51369-6_28

minimum accessibility standards. The PDFs became the first digital format to distribute the documentation on the Internet; PDF files enable the whole integration combination of various kinds of content, like text, images, videos, and forms.

The rest of the article is structured as follows: in Sect. 2 we show the background, in Sect. 3 we depict the methodology and, therefore, the case study, in Sect. 4 we to 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

Accessibility refers to how users can communicate, interact, and navigate the web with ease. To better the level of accessibility, the Web Content Accessibility Guidelines 2.1 (WCAG 2.1) proposes 4 principles of accessibility, 13 guidelines and 78 compliance criteria, and some sufficient techniques and advisory techniques. The four principles of web accessibility are 1) perceptible, 2) operable, 3) understandable and 4) robust [1].

Uebelbacher et al. [2] indicate that the research presents the PDF Accessibility Checker 2.0 tool that allows for automatic testing of those 108 test conditions that can be thoroughly tested automatically. The tool promotes PDF accessibility among a full group of users and has the potential to increase compliance of PDF documents with the respective accessibility standard.

Furthermore, Ahmetovic et al. [3] argue that accessing mathematical formulas inside digital documents is a challenge for blind people; in specific, the formats of documents designed for printing, such as PDF, structure the mathematical content for visual access only. While there are accessibility characteristics for presenting non-visual PDF content, formula support is limited to supporting alternative text that can be read on a screen reader or shown in a braille bar. Nevertheless, the procedure of introducing replacement text is left to document creators who infrequently deliver such content. Besides, at most excellent, descriptions of formulas are supplied, which consequently makes it almost impossible to transmit a detailed understanding of the complex formula.

The authors [4] suggest that in order for documents to be accessible, navigation aids, such as bookmarks, may be included, which are particularly useful for longer documents. The key to creating accessible PDF documents is to design the source document taking into account accessibility; they suggest applying the standard ISO 32000-1: 2008.

In their previous studies, Acosta-Vargas et al. [5, 6] depict that PDF documents are universally accessible, and Web Content Accessibility (WCAG) 2.0 must be applied. The authors took as a case study the repositories of Latin American universities with the most excellent university reputation corresponding to the Webometrics. In the assessment of the PDFs, they showed that academies have not been worried about supporting creating accessible documents.

Following the techniques proposed in WCAG 2.1, we have 23 techniques to make a PDF accessible [7], Table 1 presents a summary of the success criteria associated with PDF techniques. With the techniques recommended by WCAG 2.1, it is probable to examine the scanning order of the labels, of how the manuscript is read aloud. To

Table 1. Summary of the success criteria associated with PDF techniques [7].

Success criteria	Level	PDF general techniques
1.1.1 Non-textual content	A	PDF1, PDF4
1.2.1 Audio-only and video-only	A	General techniques
1.2.2 Subtitles	A	General techniques
1.2.3 Audio description or alternative media	A	General techniques
1.2.4 Subtitles	AA	General techniques
1.2.5 Audio description	AA	General techniques
1.3.1 Information and relationships	A	[7] PDF6, PDF9, PDF10, PDF11, PDF12, PDF17, PDF20, PDF21
1.3.2 Significant sequence	A	PDF3 [7]
1.3.3 Sensory characteristics	A	General techniques
1.4.1 Use of color	A	General techniques
1.4.2 Audio control	A	General techniques
1.4.3 Contrast	AA	General techniques
1.4.4 Change text size	AA	G142 [7]
1.4.5 Text images	AA	PDF7, General techniques
1.4.9 Text images	AAA	PDF7
2.1.1 Keyboard	A	PDF3, PDF11, PDF23
2.1.2 No traps for keyboard focus	A	G21
2.1.3 Keyboard	AAA	PDF3, PDF11, PDF23
2.2.1 Adjustable time	A	PDF3, G133
2.2.2 Pause, stop, hide	A	General techniques
2.3.1 Threshold of three flashes or less	A	General techniques
2.4.1 Avoid blocks	A	PDF9, General techniques
2.4.2 Titling pages	A	PDF18
2.4.3 Focus order	A	PDF3
2.4.4 Purpose of the links	A	PDF11, PDF13
2.4.5 Multiple ways	AA	PDF2, General techniques
2.4.6 Headings and labels	AA	General techniques
2.4.7 Visible focus	AA	G149, G165, G195
2.4.8 Location	AAA	PDF14, PDF17
2.4.9 Purpose of the links	AAA	PDF11, PDF13
3.1.1 Page language	A	PDF16, PDF19 [7]
3.1.2 Language of the parties	AA	PDF19 [7]
3.1.4 Abbreviations	AAA	PDF8
3.2.1 Upon receiving the focus	A	General techniques
3.2.2 When receiving tickets	A	PDF15 [7]
3.2.3 Consistent navigation	AA	PDF14, PDF17, G61 [7]

(*continued*)

Table 1. (*continued*)

Success criteria	Level	PDF general techniques
3.2.4 Consistent identification	AA	General techniques
3.3.1 Error identification	A	PDF5, PDF22 [7]
3.3.2 Labels or instructions	A	PDF5, PDF10 [7]
3.3.3 Error suggestions	AA	PDF5, PDF22 [7]
3.3.4 Error prevention	AA	General techniques
4.1.1 Processing	A	Not Applicable: PDF
4.1.2 Name, function, value	A	PDF10, PDF12 [7]

review accessibility in PDFs, there are some validators, which allows us to assess the accessibility of PDFs corresponding to the WCAG 2.0 and the PDF/UA standard.

An additional tool is PDF Accessibility Checker 3.0, which is free and validates meta information, labeling, safety, bookmarks, scanning order, and text contrast. This investigation applied the PDF Accessibility Checker 3.0[1] because it permits validating the PDFs under ISO 32000-1 (PDF/UA-1) [8] and the WCAG 2.1 [4], it offers a quick way to test the accessibility of PDFs, it supports both experts and end-users who perform accessibility valuations.

3 Method and Case Study

The case study is applied to a random sample of 10 documents in PDF format related to the modern architectural heritage of Quito; Table 2 contains the detail of the documents evaluated.

Table 2. PDF documents used in accessibility evaluation.

Id	File	Size (kB)	Title	Language	Tags	Pages
A	prueba_1.pdf	453	no title	no language	no tags	23
B	prueba_2.pdf	3158	no title	no language	no tags	23
C	prueba_3.pdf	2795	no title	no language	no tags	23
D	prueba_4.pdf	4981	no title	no language	no tags	23
E	prueba_5.pdf	2137	no title	no language	no tags	23
F	prueba_6.pdf	355	no title	es-ES	525	12
G	prueba_7.pdf	16670	no title	no language	no tags	92
H	prueba_8.pdf	671	no title	no language	no tags	8
I	prueba_9.pdf	11328	Yes	es-ES	5519	130
J	prueba_10.pdf	2910	no title	es-ES	50	16

[1] https://www.access-for-all.ch/en/pdf-lab/pdf-accessibility-checker-pac.html.

The method applied to evaluate accessibility in PDFs comprises of five phases, as presented in Fig. 1.

Fig. 1. Method to assess accessibility in PDFs.

Phase 1: Select the random sample of PDF documents, in this phase we randomly selected ten documents in PDF format that contain information related to the modern architectural heritage of Quito, the evaluated documents are detailed in Table 2.

Phase 2: Review with PDF Accessibility Checker, we review each document with PDF Accessibility Checker 3.0, version 3.0.7.0. The tests performed are available in a data set located in the Mendeley repository[2].

Phase 3: Record the results, in Table 3, we record the evaluation data; the tests are available for the reproduction of the experiment in the Mendeley repository. Table 3 contains the number of barriers presented by the PDF documents evaluated, the errors presented by each PDF document is detailed according to the errors presented.

Table 3. PDF documents failed.

PDF (failed)	A	B	C	D	E	F	G	H	I	J	Total
Embedded files	0	0	0	0	0	0	0	0	0	0	**0**
Metadata	4	4	4	4	4	6	0	4	4	0	**34**
Document settings	4	4	4	4	4	2	2	2	14	4	**44**
Fonts	0	0	0	0	0	6	0	24	32	0	**62**
Structure elements	0	0	0	0	0	0	0	0	332	4	**336**
PDF syntax	22	0	22	22	0	0	186	18	5791	86	**6147**
Structure tree	0	0	0	0	0	0	0	0	9998	4	**10002**
Role mapping	0	0	0	0	0	0	0	0	10752	196	**10948**
Alternative Descriptions	0	0	0	0	0	0	0	0	21608	198	**21806**
Natural language	916	10724	920	926	10296	0	0	0	109872	36	**133690**
Content	918	11368	922	928	10770	0	0	4692	246230	138	**275966**

[2] https://data.mendeley.com/datasets/83n9xvgfcr/2.

Phase 4: Analyze the results; in this phase, we analyze the outcomes of the PDFs; in Fig. 2, we present a summary of the analyzed PDF documents. The parameters that fail and represent an accessibility barrier for the users are shown, we observe that a substantial number of failures corresponds to the *Content* followed by *Natural language* and *Alternative descriptions*.

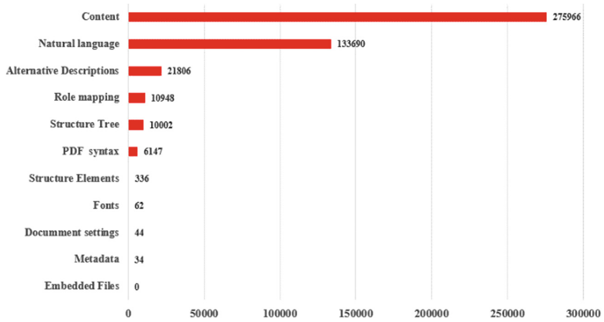

Fig. 2. Parameters of failed PDF documents.

Table 4 shows the parameters that pass the accessibility verification test; there are zero (0) errors related to Embedded files, followed by Metadata.

Table 4. PDF documents passed.

PDF (passed)	A	B	C	D	E	F	G	H	I	J	Total
Embedded files	0	0	0	0	0	0	0	0	0	0	**0**
Metadata	2	2	2	2	2	0	0	4	4	0	**18**
Document settings	2	2	2	2	2	4	2	2	14	4	**36**
Structure elements	0	0	0	0	0	4	0	0	332	4	**340**
Fonts	0	380	0	0	0	14	0	24	32	0	**450**
PDF syntax	26	48	26	26	26	553	186	18	5791	86	**6786**
Structure tree	0	0	0	0	0	1048	0	0	9998	4	**11050**
Role mapping	0	0	0	0	0	1146	0	0	10752	196	**12094**
Alternative Descriptions	0	0	0	0	0	0	0	0	21608	198	**21806**
Natural language	0	0	0	0	0	24524	0	0	109872	36	**134432**
Content	916	10724	920	926	926	49768	0	4692	246230	138	**315240**

Phase 5: Suggest improvements, to ensure that PDF documents achieve an acceptable degree of accessibility, we suggest the following: 1) Apply the same criteria as on the web, that is, only images that are not decorative should have

alternative text; 2) create the PDF so that bookmarks are automatically generated, hence, it is necessary to structure the source document well; 3) label the tables correctly with the labels TABLE, TR, TH, and TD; 4) define the links before labeling the document; and 5) include relevant information in headers and footers consistently throughout the entire document.

4 Results and Discussion

In Fig. 2, we observe that PDF documents are not compatible with PDF/UA; 60% contain errors related to *Content*, 29% with the *Natural language,* and 5% with *Alternative descriptions*. Natural language is the most frequent error; it is present when it is impossible to identify the language of the content of a document; this is the reason why voice synthesizers and braille devices cannot automatically switch to a new language. Also, the authors suggest considering the requirements for multimedia and image resources to be accessible to the most significant number of users and, therefore, suggest reviewing the studies [9]. Finally, they suggest considering the application of heuristic methods [10] related to web accessibility and the type of disability of end-users.

Figure 3, we observe that the documents that present a more significant number of failures correspond to those of identifiers B, E, and I.

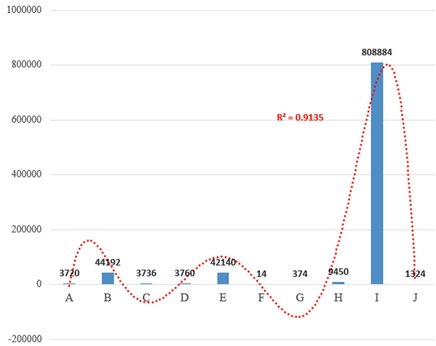

Fig. 3. Parameters of failed PDF documents.

Figure 4 presents a summary of the documents analyzed with PDF Accessibility Checker 3.0; the most common errors are related to *Content* and *Natural language*.

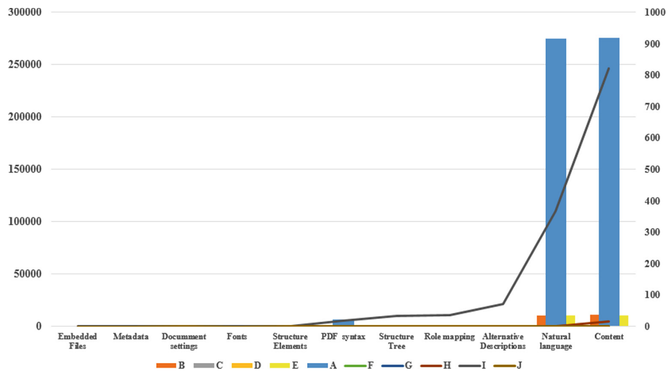

Fig. 4. Detail of the documents analyzed.

5 Conclusions and Future Works

The study carried out recommends creating accessible PDFs by applying the techniques for PDFs, according to WCAG 2.1. To generate more inclusive documents we propose to use PDF Accessibility Checker 3.0, version 3.0.7.0. The study carried out can promote as a beginning point the future work to produce more accessible PDFs. On the other hand, we suggest conducting accessibility tests and correcting errors in PDF documents before sharing in digital repositories. Furthermore, the authors suggest applying accessibility tools for PDFs in the design of architectural plans which will allow innovating this area and to get better access to a large number of users with disabilities. Finally, we recommend libraries to develop access to digital papers so that they can raise accessibility from an international communication viewpoint by employing the criteria related to WCAG 2.1.

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Web Accessibility Analysis of a Tele-Rehabilitation Platform: The Physiotherapist Perspective

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Abstract. Today, according to the World Health Organization's disability reports, they indicate that more than 15% of people worldwide have some disability. This research presents an analysis of the evaluation of accessibility made using ePHoRt, a web-based platform that aims to improve the rehabilitation of patients after hip arthroplasty. To achieve this parameter, so that it is accessible to all, we apply Web Content Accessibility Guidelines (WCAG) 2.1. This study presents an evaluation of the accessibility of the platform from the physiotherapist's perspective to achieve an accessible and inclusive site. The results of this research can serve as lessons learned to motivate the developers of the ePHoRt platform towards universal access through the application of WCAG 2.1 throughout the application development cycle.

Keywords: Accessibility · Analysis · Physiotherapist · Platform · Tele-rehabilitation · WCAG 2.1

1 Introduction

Currently, the use of the Internet is substantially more than the possibility of communication. It has become a necessity due to globalization. The United Nations states that access should be universal; many websites do not meet minimum accessibility requirements.

According, the World Health Organization, between 2015 and 2050, the number of people aged over 60 years will double. Due to the aging of the population, preoccupying disability reports indicate that more than 15% of people worldwide live with some disability [1].

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For the above reasons, our research presents an analysis of the accessibility assessment made with ePHoRt, a web-based platform that aims to improve the rehabilitation of patients after hip arthroplasty. To achieve this parameter, in such a way that it is accessible to all, we apply the Web Content Accessibility Guidelines (WCAG) 2.1 and the Website Accessibility Conformance Evaluation Methodology (WCAG-EM) 1.0. We considered the four principles of accessibility that are perceptible, operable, understandable, and robust.

This study presents an evaluation of the accessibility of the website from the perspective of the physiotherapist in order to achieve an accessible and inclusive website. An accessible web platform is essential to allow that physiotherapists can access and interact with the site. In evaluating the accessibility of the ePHoRt platform, we apply the following method: 1) Select a sample of the site. 2) Explore the site for the physiotherapist. 3) Determine a scenario in which the sample will be tested. 4) Select a user group. 5) Apply an automatic tool. 6) Review manually. 7) Record and analyze the results. 8) Generate a suggestion report. The results of this research can serve as lessons learned to motivate the developers and designers of the ePHoRt platform towards universal access by applying WCAG 2.1 throughout the application development cycle.

The rest of the article is structured as follows: in Sect. 2 we show the background, in Sect. 3 we depict the methodology and, therefore, 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, the topic of telemedicine has attracted much interest in the use of web platforms that help the speedy recovery of the patient as well as cost reduction. Rybarczyk et al. [2] indicate that the ePHoRt project helps in tele-rehabilitation therapies in patients with hip operations.

Previous studies by Acosta-Vargas et al. [3] propose that the model applied in ePHoRt includes fuzzy logic, which allows real-time identification if a patient is making a correct or incorrect movement, assisted by a 3D avatar. The proposed method includes an inspection method with protocols and instruments. It also proposes accessibility standards for the content of educational resources in video and PDF format on the tele-rehabilitation platform, following the Web Content Accessibility Guidelines (WCAG).

Furthermore, the accessibility parameter in web applications is essential so that the most significant number of users can access previous studies by Acosta-Vargas [4] indicate that to access a website easily, it is essential to apply the WCAG-EM methodology that considers specific situations for WCAG 2.0 [5]. The reason why it is necessary to apply best practices.

Undoubtedly, applying new methods will improve accessibility in web applications, previous studies [6] indicate that checking accessibility is a challenge for accessibility experts where users suffer changes related to age and cause problems to access the services offered by the web.

Therefore, in this investigation, we will apply WCAG 2.1 [7], with the four accessibility principles that include 13 guidelines and 78 compliance criteria. The principles are noticeable, operable, understandable and robust.

3 Method and Case Study

3.1 Case Study

The case study was applied in ePHoRt [2], which is a web-based project for tele-rehabilitation exercises in patients who have undergone hip replacement surgery. The evaluation was applied to the pages related to the management from the physiotherapist; we analyze four main screens taken randomly.

3.2 Method

This study applies an adaptation of WCAG-EM 1.0 [8] and the Web Content Accessibility Guidelines (WCAG) 2.1. The study proposes the evaluation of the platform using the automatic WAVE[1] review tool with the Google Chrome plug-in component that supports authentication problems; this case study includes four screens summarized in Table 1.

This method consists of eight phases described in Fig. 1.

Phase 1: We randomly select the screens to evaluate with WAVE; in this case, we select four screens described in the Table.
Phase 2: In this phase, we explore each option of the screens related to the physiotherapist.
Phase 3: In this phase, we define the activities to be performed on each screen to test functionality.
Phase 4: In this phase, we select a group of three expert users in web accessibility to evaluate the interfaces.
Phase 5: In this phase, the accessibility experts evaluate the interfaces detailed in Table 1.
Phase 6: In this phase, we manually review the errors detected with WAVE.
Phase 7: In this phase, the data is recorded in a spreadsheet shown in Table 2, contains the ID, Errors, alerts, structural elements, contrast errors, features, and ARIA.
After detecting the errors, the type of errors was reviewed in detail concerning the lack of form label, very low contrast, empty button, empty table header and lack of document language, shown in Table 3.
Phase 8: In this phase, the errors found are listed, and the possible solutions for the interfaces are applied in Table 1.

[1] https://wave.webaim.org/.

Table 1. Summary of the WCAG 2.1

ID	Screen	Description
A	LOGIN	The physiotherapist can authenticate through a username and a password
B	PHYSIOTHERAPIST MENU	The physiotherapist can choose any of the following options: doctor management, patient management, learning resource management, exercise management, program management, suspended program management, and messages
C	THERAPEUTIC PROGRAM LIST	The physiotherapist can see the therapeutic program list, can create/edit/delete a new program, can print a program, manage their stages, suspend an active program, see the patient's performance and search a program
D	THERAPEUTIC PROGRAM FORM	The physiotherapist can create a program by assigning a name, a description, a patient, and a time. By default, the period is around three months. He can always return to the therapeutic program list and cancel the current operation

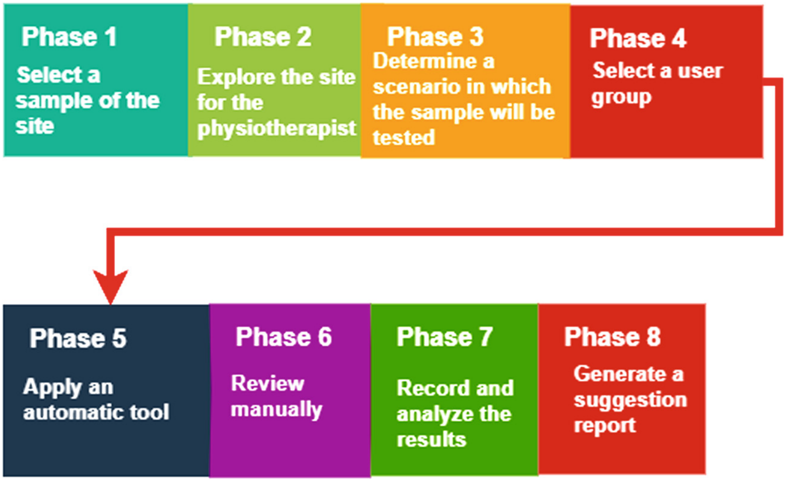

Fig. 1. Method to assess accessibility in the tele-rehabilitation platform.

Table 2. Errors detected with WAVE

ID	Errors	Alerts	Structural elements	Contrast errors	Features	ARIA
A	2	2	1	1	3	0
B	0	7	10	9	9	19
C	24	3	30	53	1	10
D	5	2	7	3	1	8

Table 3. Error detail

Missing form label	Very low contrast	Empty button	Empty table header	Document language missing
1	1	0	0	1
0	9	0	0	0
7	53	2	15	0
5	3	0	0	0

4 Results and Discussion

In Fig. 2 it is observed that the greatest number of errors corresponds to "Contrast errors", followed by "Structural elements" and "ARIA".

Fig. 2. Screen capture of errors detected with WAVE.

Figure 3 shows that the highest number of errors is related to "Very Low Contrast," followed by "Empty table header" and thirdly "Missing form label."

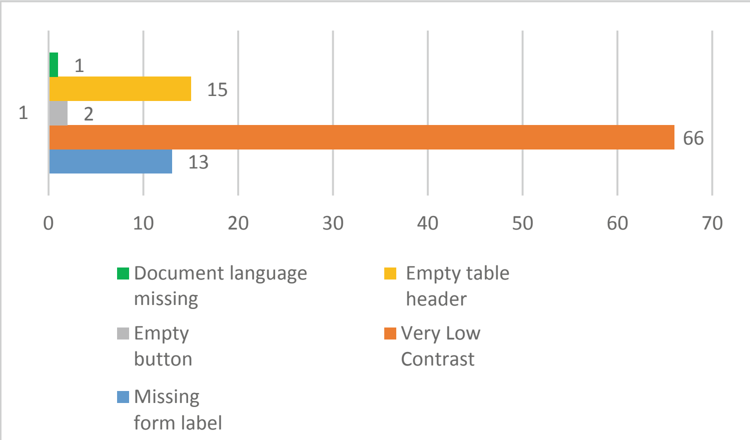

Fig. 3. More errors are related to "Very Low Contrast"

ePHoRt includes the compiled CSS and JS of the Bootstrap 4.0 open-source toolkit. Therefore, to solve the problem the styles were overwritten in a custom class called "ephort.css" with other sizes for the header tags and another foreground color # 0000FF at the suggestion of the WAVE, the style code details in Fig. 4.

```
h1 {
   font-size: 1.6rem !important;
}
h2 {
   font-size: 1.4rem !important;
}
h3 {
   font-size: 1.3rem !important;
}
 .btn-info {
   background-color: #0000FF !important;
   border-color:  #0000FF !important;
}
.btn-outline-info {
   color: #0000FF !important;
  border-color: #0000FF !important;
}
.bg-info {
   background-color: #0000FF !important;
}
.alert-light {
   color: #0000FF !important;
   background-color: #ffffff !important;
   border-color: #0000FF !important;
}
```

Fig. 4. Custom class "ephort.css"

5 Conclusions and Future Works

The most frequent errors were related to associate a label with each form control, include alternative text for images, use the aria-label and aria-Labelby attribute to identify form controls, associate the data cells with the appropriate headers to the tables, add a subtitle to the tables. Automated review tools are useful for the evaluation of accessibility on websites. However, they do not guarantee a high level of accessibility. It is essential to consider the inclusion of all types of people to talk about innovation. By applying the four principles of web accessibility through WCAG 2.1, we can count on more inclusive applications.

In future work, we suggest looking for new methods and strategies to evaluate and improve web accessibility in the tele-rehabilitation platform.

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Interactive Storytelling Books for Fostering Inclusion of Children with Special Needs

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Abstract. Children with Special Needs may have difficulty understanding the content of a book or associating words and sentences with their meaning. Teachers use the storytelling as a powerful literacy tool which engage children in making connections between academic content and pedagogy. This strategy is also useful to integrate the diversity of the classroom. Increasing or varying the types of materials available to children is another way to make the classroom more inclusive. This paper proposes a new approach for fostering interaction and inclusion development during shared reading. We sought to increase the interactivity of traditional tale books by incorporating elements of technology and storytelling. To develop prototypes we recruited 30 teachers divided into six groups. Each group worked with two challenges: (1) to incorporate technology into a traditional storybook and (2) create an interactive storytelling book for left-handed children. During five work sessions each group developed two proposals: The first proposal was designed with QR codes and the second with NFC tags and augmented reality patterns to facilitate left-handed activities among teachers and children. The proposals were evaluated in the classroom and with experts' reviews, finding interesting results.

Keywords: Interactive storytelling books · Inclusion · Children with special needs · Left-handed children

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1 Introduction

There are many challenges and issues to be solved regarding the inclusion and development of social and academic skills of Children with Special Educational Needs and Disabilities (SEND). Among them, education and training of teachers, the participation of parents in the learning process, educative resources adaptation or physical environment adjustments in classrooms, for instance, many students need classroom reading material to be adapted for their individual needs [1]. In the current study, we propose a new approach for fostering interaction and inclusion development during shared reading. We sought to increase the interactivity of traditional tales books by incorporating elements of technology and storytelling. By combining these elements, interactive books can provide more direct feedback and narrative possibilities for children. Interactive storytelling books can also engage children through sensory stimuli such as digital sounds, videos and augmented reality. The effects of engaging children as storytellers on vocabulary development have been less well studied [2]. We believe the interaction between children with special educational needs with others is potentially important to their social development and inclusion.

Considering this motivation, the present study recruited 30 teachers divided into six groups. Our protocol began with the presentation of several interactive storytelling technologies on the market, for example, LeapFrog, an interactive learning system which includes a stylus that reads invisible dots on compatible books and activity sets, triggering vocabulary, songs, questions and challenges; TOK - A tangible interface for storytelling to allow children and teachers build their own digital enhanced learning activities and OSMO - A system that uses the iPad's camera to enable tangible interaction for children. OSMO provides a mixed-reality storytelling app while encouraging kids' creativity. With this experience, two challenges were designed: (1) to incorporate technology into a traditional storybook and (2) create an interactive storytelling book for left-handed children. During five work sessions each group developed two proposals.

The first proposal was designed with QR codes, which link an audio file with a narration of tales, songs, questions or challenges. Each group selected a storybook to develop learning strategies for inclusion of SEND children. The participants recorded the voices of actors of the tale, as well as the activities through their smartphones or tablets. For the second group challenge, participants had to design an innovation with NFC (Near Field Connection) tags and augmented reality patterns to facilitate left-handed activities among teachers and children. It is important to mention that many unpredicted strategies were developed during working with teachers, for example, the way the book is opened, the way to encapsulate QR codes and how to present the story in 3D pop-up scenarios. Modern day technology possesses a wide range of smart elements and devices that can still be better explored in new book designs. We are sure that these innovations will foster children's learning, cooperation and inclusion. However, further studies are necessary to investigate both immediate and longitudinal effects of specific interactive storytelling books on children's social development and their inclusion in learning activities.

The rest of this article is structured as follows: Sect. 2 details the background and related work, Sect. 3 presents the method used, Sect. 4 presents the results of designing

Interactive Storytelling books, and finally, Sect. 5 presents the conclusions and future work of this research.

2 Background

Children with special educational needs and disabilities face difficult challenges in the educational, social and even family environment. SEND children have to face their own deficiencies in social interaction, but also the social exclusion by other members of their environment [3]. For instance, at classroom many teachers pull SEND children out of the literacy hour or block because they believe that these learners, as a rule, need special instruction and content. Actually, many children including those with learning disabilities, cognitive disabilities, autism or ADHD can participate quite successfully in the general education classroom with appropriate supports such as adapted materials, individualized goals or objectives, and co-teaching [4].

There are some studies on children that suggest that unstructured outside play can be very helpful for some SEND children. The unstructured, fast-paced nature of play in these setting necessitates using teacher-mediated interventions to enhance inclusion of children with special needs in cooperative interactions with their typically developing peers [5]. On the other hand, within the classroom the technologies become an element that can help the inclusion. Computers, tablets or smartphones are able to engage in didactic collaborative storytelling. Storytelling is one of the oldest methods of communication and learning. Digital storytelling is the combination of traditional, oral narration with multimedia and communication tools [6].

In our study we integrate these two elements to create interactive books in order to develop reading skills and inclusion [7]. Through storybooks children develop critical early literacy skills by linking concepts with corresponding physical actions to establish the foundation or reading comprehension. Digital storytelling is particularly conductive to create novel interactions [8, 9]. The effects of engaging children as storytellers on vocabulary development have been less well studied. Positive effects of shared reading for children's language development are boosted by including instruction of word meanings and by increasing interactivity [10]. This research seeks to understand how interactive books can be implemented with SEND children for fostering inclusion and reading skills.

3 Method

The study used a descriptive qualitative method that focused in the analysis of the data obtained from Design Thinking methodology, that provides a solution-based approach to solving problems.

3.1 Participants

We recruited 30 teachers who are studying a Master in Education, mention Innovation and Leadership at Universidad Tecnológica Indoamérica. They are teachers of public and private elementary and middle schools. The participants were divided into six groups of 5 each in the Educational Infopedagogy module. The average age of the students was 38.6 years. In relation to gender 80% corresponded to female.

3.2 Materials

The materials used in the research are grouped into two categories: classroom materials and technology. In the first category we used physical storybooks, paper, cardboard, colors, markers, adhesive tape, glue and foamy. In the second category we used hardware, such as laptops, tablets and smartphone. We also used a QR Generator web site (https://www.codigos-qr.com/), MIT AppInventor Platform and some Apps: Hi-Q MP3, Animal 4D+, Space 4D+, Humanoid 4D+ and QuiverVision 3D Augmented Reality.

3.3 Procedure

Following the Design Thinking methodology, five sessions of eight hours each one were perfomed. In the first session we conducted a series of brainstorming to create as many solutions as possible that might make children fostering reading. We began with the presentation of several interactive storytelling technologies on the market. In the second session, we challenged to incorporate technology into a traditional storybook with QR codes. Teachers worked in six groups, The results were presented and the learning strategies registered in a forum of a Moodle Platform.

The groups defined the problem and needs according their experience.

In the empathise stage, teachers used the platform in six groups. Afterwards, they ideate the design of the pedagogical strategy according to the storybook used in class. After teachers designed an original storybook with the materials and technology studied.

Finally, in the test stage each group test their interactive storybook with their students at classroom.

After that, the combination and filtering of the ideas were done to select the final solution, which was evaluated with the help of two pedagogues.

4 Design of Interactive Storytelling Books

This section shows some results designed by the groups of teachers. We have divided into two categories: Interactive books with QR codes and Storytelling books for left-handed children.

4.1 Interactive Books with QR Codes

Within the category of interactive book, teachers created innovative learning strategies for children. The participation and interaction by the reader was made with QR codes. The main idea of this interface was to introduce narrative an questions throught QR codes. First with the Hi-Q app recorded audio in MP3 format. Subsequently teachers generated QR codes of different sizes, which were pasted them in a physical book or they designed a sheet of cardboard with their own story as the Fig. 1 shows. The audio files and pictures were integrated in App Inventor application. In this interface children can use a smartphone to listen a story or answer a question that generates the QR code.

Fig. 1. Storybooks with QR codes.

Teachers evaluated these storybooks with their students achieving interest and motivation in the learning process. With this technology teachers could design their own educational technology resources to create multimedia reading experience [9].

4.2 Storytelling Books for Left-Handed Children

The challenge was to create an interactive storytelling book for left-handed children. To simulate teachers in this work we introduce NFC (Near Field Connection) tags in the same way of QR codes, which generates a sound, narrative or question throughout history. In addition, we introduce augmented reality.

One of the strategies developed by teachers is that books open upwards to make it easier for a left-handed child in the reading process. Teachers also developed an interactive pop-up storybooks. Teachers realized that the QR codes could also help children with visual impairment or children who can not read yet. Many of these stories were also designed with high relief to help develop tactile stimulation.

Importantly, teachers developed interesting stories to engage the child in reading. In the evaluations we can observe that the storytelling were not flat, these had some elements that made it interesting.

Some of the interactive storytelling books included multimedia contents or activities for left-handed children in each QR or NFC code. Other storytelling books had activities designed within the same book.

The use of augmented reality also contributed to the interaction and inclusion of children. Figure 2 shows an example of the interactive storytelling book.

Fig. 2. Interactive book with QR codes, NFC and Augmented Reality AR.

The use of NFC tags facilitated the interaction of children with special needs, unlike the QR codes that need more precision with the camera of the smartphone.

We believe that it is an innovative idea that uses disruptive technology rarely seen in our environment and applicable to a vulnerable and little forgotten population.

5 Conclusions

The aim of this research work was to demonstrate to participants that everyone can create educational resources, everyone can tell stories. In consequence, the results reflect that storytelling can enhance visualization skills, providing a scaffold for reading comprehension.

From the experience gained during the design process and the final evaluation of interactive storytelling books, teachers were motivated to design their own educational resources. This experience can help teachers in using interactive features in a meaningful manner.

Technology is an essential factor in motivating children to collaborate with other in the learning process. Positive effects of shared reading for children's language development are boosted by including multimedia and by increasing interactivity with the integration with technology.

We noticed that teachers developed novel learning strategies in the Storytelling books for left-handed children. The study was substantive and thoughtful, giving impetus for further researches in varied directions. For future research, we are planning testing the interactive books in a real environment, in order to measure the impact on children learning.

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Improve Accessibility and Visibility of Selected University Websites

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Abstract. Currently, there are millions of websites, but not all of them are accessible and visible in search engines, and in the different devices and technologies used. The purpose of this research is to 1) suggest an accessibility evaluation model according to the Web Content Accessibility Guidelines 2.1 standards; 2) correlate Webometrics and SCImago rankings to improve visibility, and 3) determine whether an accessible website can improve visibility. As a case study, the authors applied to 30 web pages from Latin American universities. The results indicate that although an educational institution is in the first rankings of the Webometrics and SCImago classification, they do not necessarily satisfy web accessibility requirements. This study can be a guide for the definition of institutional efforts to improve accessibility and visibility in the design of more inclusive and visible websites.

Keywords: Accessibility · University · Visibility · Websites · WCAG 2.1

1 Introduction

"We Are Social and Hootsuite" the digital reports [1] indicate that in the last 12 months internet users grew rapidly by 8.6%, these figures imply that there are 350 million new users and represent a total of 4,437 billion at the beginning of April 2019. As stated by the World Health Organization, there are more than one billion people, approximately 15% of the planet inhabitants [2], with some disability. Disability figures rise concerning people who age, which is why the number of chronic illnesses also rises.

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Currently, there are millions of websites, but not all are accessible, a website to achieve the popularity and success expected must be perceptible and accessible in different search engines, as well as in devices in such a way that supports assistive technologies. This study aims to assess the level of accessibility according to the standards of the Web Content Accessibility Guidelines (WCAG) 2.1 [3], and the perceptibility applied as a case study in 30 home pages of Latin American universities selected according to Webometrics[1] and SCImago[2] rankings.

According to SCImago, websites are essential and strategic for the dissemination of information and research carried out by an educational institution. Millions of users can visit a website more if it is more visible to search engines, which implies the need to increase the link with other websites. This study revealed that there are several problems related to levels of web accessibility, among which is the “Alt” attribute in images.

In this study we analyzed several parameters that help select Latin American universities, among the parameters investigated, are 1) the total volume of scientific production, 2) the relative quality, measured through impact indicators of the work, and 3) the percentage of documents that are published in journals classified by the level of impact in the first quartile of each category. Among the rankings, we have selected the SCImago ranking, which takes Scopus[3] as a principle, and the web ranking of Webometrics universities, which is used by Google Scholar.

The rest of the article is structured within the following way: in Sect. 2 we tend to depict the connected works, in Sect. 3 we tend to offer the methodology and also the case study, in the Sect. 4 we tend to show the results and also the discussion, finally, in Sect. 5 we tend to embody the conclusions and future works derived from this analysis.

2 Background and Connected Work

Accessibility is the way users can communicate, interact, and navigate the web with ease. To better the level of accessibility, the Web Content Accessibility Guidelines 2.1 (WCAG 2.1) proposes 4 principles of accessibility, 13 guidelines and 78 compliance criteria, and some sufficient techniques and advisory techniques [3].

There are several studies related to web accessibility in higher education institutions, among the most recent there are: Ismail et al. [4] propose that in the analysis of accessibility of higher education websites it is essential to consider inclusion. The study applied the evaluation of sites with TAW[4]. The authors noted 15995 warnings on the scale and 1356 unexamined items. Nagaraju et al. [5] analyzed 43 surveys on web accessibility that applied the WCAG 2.0. Initially, they identified similarities with previous and current research activities. They conducted a comparative study to determine accessibility barriers. Nir et al. [6] argued that because of the increasing range of pupils with incapacities in academic establishments, it is essential that policies

1 http://www.webometrics.info/en/Latin_America.

2 https://www.scimagoir.com/rankings.php?country=Latin%20America.

3 https://www.scopus.com/.

4 https://www.tawdis.net/.

and variations square measure enforced to make sure accessibility to much range of users. The web pages examined presented accessibility barriers, the most frequent being “contrast,” and “lack of alternative text.”

In the authors’ previous studies, Acosta-Vargas et al. [7] presented web accessibility problems identified in 348 Latin American university websites, consistent with the Webometrics ranking. In the assessment, the authors used the WAVE[5]; the results revealed that the websites of the universities included in this study violated the WCAG 2.0 guidelines. The authors propose strengthening accessibility policies in each country and applying the guidelines to make websites more inclusive.

The study [8] presents a collection of knowledge associated with the analysis of accessibility in 368 sites of selected institutions in Latin America taken from the Webometrics rankings. The dataset documents the foremost often errors in a method that alerts web developers, supporting them in making a lot of comprehensive and accessible websites for all kinds of individuals. The information shows that university websites have frequent issues associated with the lack of alternative text linked to images. The authors found that some of the websites violated WCAG 2.0 and 2.1 based accessibility requirements. The dataset was shared with public access for analysis and replication in the Mendeley repository[6].

Acosta-Vargas et al. [9] conducted studies for the analysis of web accessibility with heuristic ways for users with low vision. The study used a modification of the Barrier Walkthrough technique projected by Giorgio Brajnik, considering the WCAG 2.1. The modification was to incorporate persistence to work out the severity of the associate degree accessibility barrier. The tactic was applied to forty websites, together with those of thirty universities in Latin America, per the Webometrics ranking, and ten websites among the foremost visited, per the Alexa ranking. With this heuristic technique, the evaluators ended that though a website is in an exceedingly high ranking position, this does not imply that it is accessible and inclusive. However, the manual technique is just too long and, therefore, too expensive to unravel accessibility issues. This analysis might function as a start line for future studies associated with web accessibility heuristics.

SCimago Institutions Rankins [10] applies a methodology based on the classification of academic institutions related to research that in turn are classified by an indicator that combines three different sets of indicators based on 1) the performance of the research, 2) the results of the innovation and 3) the social impact measured by the visibility of its website [11]. SCImago considers several criteria [10], among them, 1) 50% of research, 2) 30% of innovation, and 3) 20% of the relationship with society. This methodology proposes 1) to define and identify a list of research institutions, 2) to assign publications and citations to each institution when considering the institutional affiliation of each author. On the other hand, Webometrics is an initiative of the Cybermetrics Laboratory; it applies four related indicators, 1) impact and visibility (50%); 2) presence (5%); 3) openness and transparency (10%), and 4) excellence (35%).

[5] https://wave.webaim.org/.

[6] https://data.mendeley.com/datasets/t6bmb24c9w/1.

3 Method and Case Study

The case study applies to 30 universities that are in the top places in Latin America in the ranking of SCImago and Webometrics. The method applied to assess accessibility and visibility consists of six phases, as shown in Fig. 1, section left.

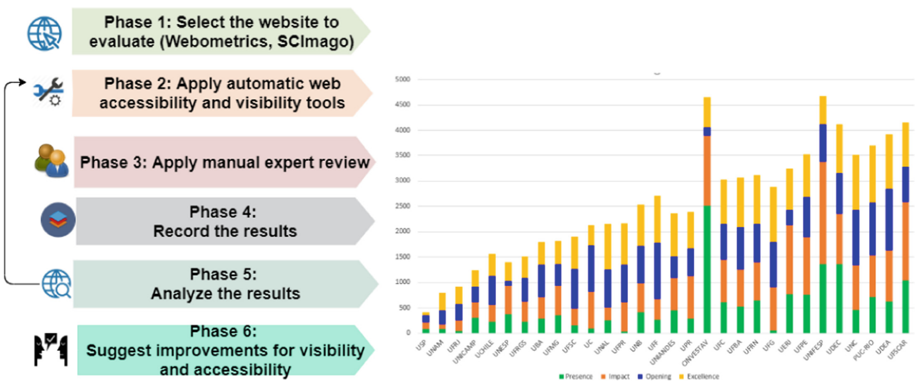

Fig. 1. Left: Method for assessing accessibility and visibility on a website. Right: Presence, impact, openness, and excellence components.

Table 1. Latin American universities, according to the Webometrics and SCImago.

LA Ranking	Acronym	Presence	Impact	Opening	Excellence	Errors
1	USP	80	127	137	70	36
2	UNAM	79	92	279	339	1
3	UFRJ	39	213	312	348	7
4	UNICAMP	292	319	298	331	2
5	UCHILE	225	330	570	428	1
6	UNESP	366	559	103	369	55
7	UFRGS	223	399	471	421	7
8	UBA	284	426	634	445	14
9	UFMG	346	584	435	458	6
10	UFSC	154	324	782	644	33
11	UC	91	723	913	406	3
12	UNAL	252	250	748	907	18
13	UFPR	30	574	738	817	22
14	UNB	414	563	740	821	26
15	UFF	259	407	1118	930	17
16	UNIANDES	441	648	423	854	45
17	UPR	286	845	544	714	0
18	CINVESTAV	2511	1385	165	593	75
19	UFC	603	850	702	875	3
20	UFBA	525	727	837	976	35

(*continued*)

Table 1. (*continued*)

LA Ranking	Acronym	Presence	Impact	Opening	Excellence	Errors
21	UFRN	645	754	751	963	29
22	UFG	52	849	889	1092	16
23	UERJ	765	1359	304	813	34
24	UFPE	758	1128	794	844	14
25	UNIFESP	1360	2017	746	556	23
26	UDEC	1355	991	813	955	22
27	UNC	457	873	1099	1080	67
28	PUC-RIO	704	827	1035	1130	99
29	UDEA	618	1011	1218	1069	27
30	UFSCAR	1036	1550	690	873	22

Phase 1: Select the website to evaluate (Webometrics, SCImago); we select the Webometrics and SCImago websites of the Latin American universities that occupy the first places within the ranking. Table 1 shows the selected universities in Latin America. It contains the Latin American ranking, the acronym, presence, impact, opening, excellence, and Errors. *Phase 2: Apply automatic web accessibility and visibility tools*, in this phase, most pages of the websites of the chosen universities, extracted from Webometrics and SCImago, were evaluated, using the WAVE tool that identifies accessibility barriers. *Phase 3: Apply for manual expert review*; in this phase, two experts in web accessibility intervened to review the main page of each site, the data was recorded in the spreadsheet. *Phase 4: Record the results*, the data were recorded in a spreadsheet, all data from this case study was recorded in a spreadsheet, to share and replicate the experiment, the data set rests in a Mendeley repository. *Phase 5: Analyze the results*; in this part, the results within the Mendeley dataset were analyzed. Figure 2 shows that the universities that are in the highest-ranking do not necessarily have high scores in the components of presence, impact, openness and excellence; further details are provided in the results section. *Phase 6: Suggest improvements for visibility and accessibility*, to achieve an accessible and inclusive website we suggest 1) place a title in the head of the document; 2) encourage the exchange of content with buttons on social networks; 3) check the appearance of the website with a mobile and a tablet; 4) add an exclusive mobile style through media inquiries; 5) ensure the pages of the website embrace a meta description. The meta description can control how the search engine result will appear. 6) define significant headings for all web pages; the headlines help the placement of the website in the search engines and that visitors can browse the content. 7) enable GZIP compression on the webserver or in the application.

4 Results and Discussion

Figure 1, section right shows that even though an institution is in the top rankings, it does not meet high levels of presence, impact, openness, and excellence. Figure 2, section left shows the University of Sao Paulo (USP) in the first place of the Webometrics ranking containing 36 errors of the websites when relating to Webometrics and SCImago. In the second place, the Universidad Nacional Autónoma de México (UNAM), presenting only one error. In third place is the Universidade Estadual Paulista Julio de Mesquita Filho (UNESP) that contains 55 errors despite being among the first three places in the ranking. Figure 2, section right shows the 30 universities evaluated with WAVE, where 29% of errors are related to the principle of understandable, in second place is 27% for operable, 25% for perceptible, and 19% for robust.

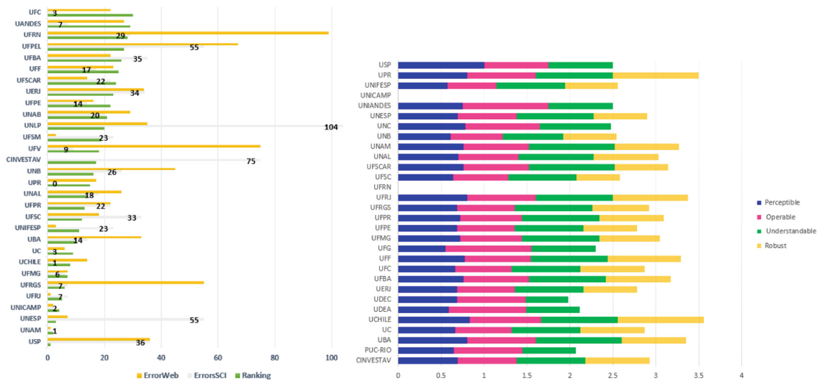

Fig. 2. Left: Accessibility errors when linking Webometrics and SCImago sites. Right: Principles of Web Accessibility

5 Conclusions and Future Works

This study revealed that there are several problems related to levels of web accessibility, among which is the "Alt" attribute, which helps search engines to recognize the images that web designers incorporate into web pages and help visually impaired users to use a screen reader that interprets the content or meaning of an image. Although technology has evolved a lot, search engines still have problems interpreting the content of images included in a website. Therefore, the attribute "Alt" is a very valuable parameter at the level of visibility and positioning; it helps us to generate large amounts of traffic on a website because the text will allow the images to be displayed in the results of Google Images[7]. As future work, we suggest looking at new methods of evaluating the accessibility of websites. Implement and disseminate WCAG 2.1 in

[7] https://www.google.com/imghp?hl=en.

institutional policies for the design of more accessible websites. We recommend applying the suggestions made in this study to achieve higher visibility in search engines since, in future work, the method can be applied to achieve greater accessibility and visibility in government portals [12].

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Toward Accessible Mobile Application Development for Users with Low Vision

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Abstract. The development of accessible mobile applications has become a great challenge for accessibility experts since aging affects users' capabilities. Among them, the most frequent is that of visual impairment, specifically low vision. Currently, many mobile applications help with daily activities, but not all are accessible, which means that a large number of users cannot easily access and interact with them. To test accessibility in mobile applications, Google has an Accessibility Scanner for Android which is a tool that helps to verify the compliance with the accessibility guidelines proposed by the WCAG 2.1. A case study is presented that applies this tool to the development of a mobile application for the sports center "Crossfit Coyote Fitness." This research addresses the limitations of this method, contributing to future studies related to accessibility methods for mobile applications in achieving more inclusive applications.

Keywords: Accessibility · Mobile application development · Low vision · WCAG 2.1

1 Introduction

Nowadays, the number of Internet users worldwide is close to 4.5 billion, and there is a growing trend. Advances in the field of Internet of things allow controlling different devices through smartphones. The result of this technological innovation is the emergence, for instance, of smart houses, buildings, transportation, or medical care. The estimate for 2019 was that more than 8 billion devices would be in use [1], a number which was expected to grow at a fast pace.

In recent years, there was a growing development of mobile applications; however, many of these applications are not accessible. Therefore, accessibility has become a great challenge for application designers. Currently, many mobile applications help

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with daily activities, but not all are accessible, which means that a large number of users cannot easily access and interact with them.

The paper presents a case study regarding the development of an Android mobile application for the "Crossfit Coyote Fitness" sports center designed to help customers and the sports center to manage activities, time, and resources. To ensure the development of an open mobile application, accessibility standards were followed throughout the development cycle, considering users with low vision, particularly solving contrast problems.

The Crossfit Coyote Fitness sports center offers several courses; therefore, the clients can alternate the options of activities and schedules. The application has an attractive parameter that allows customizing the activities, the assignment of instructors, and schedules.

Additionally, the application allows displaying a list of available courses, with their activities and schedules, in an interface that is easily accessible and interactive for the end-user. Likewise, the student's payment status can be made easily from the access to the application by cell phone.

Throughout the development cycle of this project, the Scrum methodology was applied, which allows the client's requirements to be managed with flexibility, productivity, and quality. The project involved the Crossfit Coyote Fitness sports center's site administrator, who will be in charge of administering the system from the website.

The rest of the article is structured as follows: Sect. 2 introduces the background, Sect. 3 depicts the methodology and the case study; Sect. 4 presents and discusses the results, and Sect. 5 offers some conclusions and perspectives of future work.

2 Background and Related Work

"Mobile accessibility" refers to making websites and applications more accessible for people with disabilities when using mobile phones and other devices [2]. Web Accessibility Initiative (WAI) addresses accessibility issues and guides designers and developers, considering people using a wide range of devices to interact with the web.

To test accessibility in mobile applications, Google has an accessibility validator for applications with the Android operating system, Accessibility Scanner, which is a tool that helps to verify the compliance with the accessibility guidelines proposed by Web Content Accessibility Guidelines (WCAG) 2.1 [2]. Accessibility guidelines include four principles 1) perceivable, 2) operable, 3) understandable, and 4) robust, which includes three levels of accessibility, depending on the policies and legislation of each country; in most cases, Accepts up to the average level corresponding to "AA."

Furthermore, Manresa-Yee et al. [3] argue that the design of the natural interface on mobile devices is essential for people with reduced mobility. The results showed that using the system with alternative access to interact with mobile devices improved the interaction between the user and the application.

Acosta-Vargas et al. [4] present a study on the accessibility assessment of ten mobile applications with the Accessibility Scanner. The results indicated that not all mobile applications are accessible. Therefore, they suggest applying WCAG 2.0 standards in order to develop more inclusive mobile applications.

Another previous work of the authors [5] identified that at present, the lack of adequate methods to test if a mobile application is accessible had become a great challenge for accessibility experts. The study proposes to use WCAG 2.1 through manual review and automatic review with the Google Play Store for Android validator. The research proposes recommendations to improve and raise awareness among mobile application designers so that more inclusive mobile applications accessible to all types of users are built.

3 Method and Case Study

As a case study, the SCRUM methodology was applied to the development of a mobile application for the sports center "Crossfit Coyote Fitness." SCRUM is an agile software development methodology, whose objective is to maximize the return to investment of a company, based mainly on building the functionality that the client considers more excellent value. Therefore, the client's commitment is essential as it will be integrated into each iteration of the processes [6], Fig. 1 presents the SCRUM development cycle.

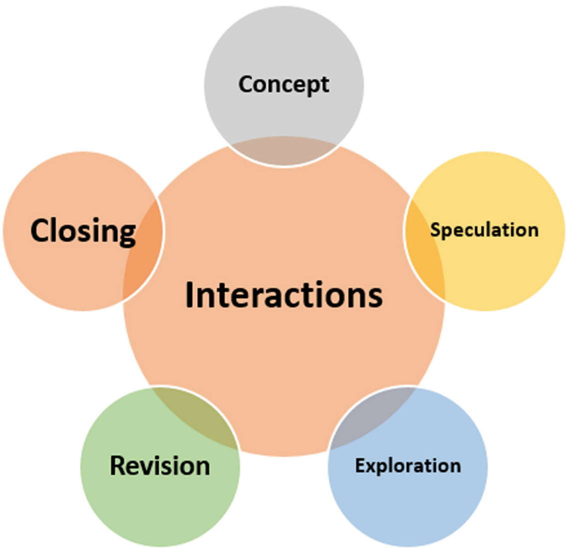

Fig. 1. SCRUM development cycle.

While the method used to evaluate accessibility consists of nine phases described in Fig. 2. The phases are as follows: 1) select the automatic review tool for mobile applications, 2) select a group of users with low vision, 3) list the mobile accessibility barriers for users with low vision, 4) define the scenarios in which the application will be reviewed, 5) apply the automatic review tool, 6) manually review confronting the list of accessibility barriers, 7) record and analyze the results, 8) apply the improvements in the mobile application, 9) repeat the cycle to reduce the most significant number of accessibility barriers.

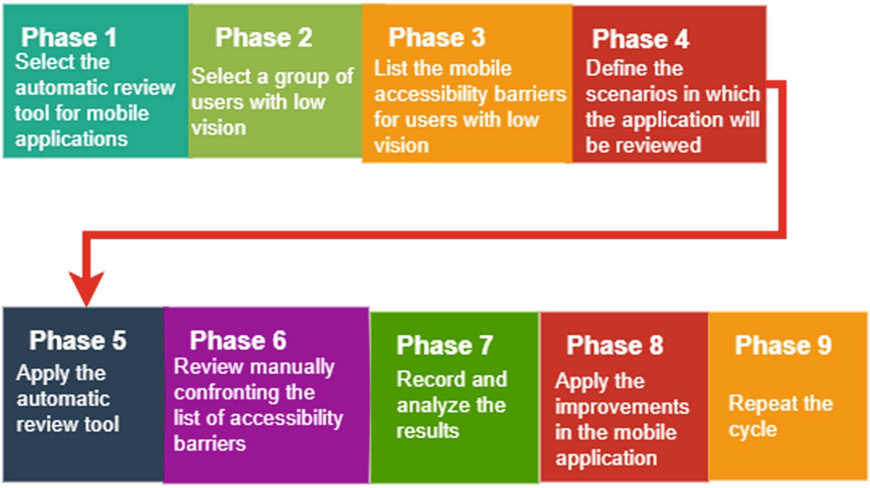

Fig. 2. Method to assess accessibility in a mobile application.

The method applied has some limitations. Being manual takes too much time and is therefore, too costly to solve accessibility problems. This research can contribute to future studies related to accessibility methods for mobile applications to achieve more inclusive applications.

4 Results and Discussion

Table 1 summarizes the WCAG 2.1 guidelines that help in the manual review of accessibility compliance of the "Crossfit Coyote Fitness" mobile application for users with low vision. Table 1 contains the guidelines, components, controls, compliance criteria, and the principle of accessibility. When analyzing the recorded data, 52.9% corresponds to the perceivable principle, 29.4% corresponds to operable, 11.8% to understandable, and 5.9% corresponds to the robust principle. It is observed that the most significant number of barriers are related to the principle of perceivable, that is to say, that the information and the components of the user interface must be shown to users in ways that they can understand, this barrier is related to Guideline 1.1 referring to the alternative text. After performing the accessibility tests in the mobile application, the following recommendations were identified (that are repeated frequently in most screens of the mobile application): 1) "Element labels" (when applying labels to the elements, they can be read by a screen reader); 2) "Text contrast" (the contrast ratio of the text of the element is 3.12. This relationship is based on an estimated foreground color of #FFFFFF and an estimated background color of # 2196F3. Therefore, it is suggested a contrast ratio greater than 4.50 for small texts or 3.00 for significant texts).

Table 1. Summary of the WCAG 2.1

Guideline	Component	Control	Compliance	Principle WCAG 2.1
Audio and Video	Controls	Size, Style, Position	Not applicable	Perceivable
Design	Contrast	Color	75%	Perceivable
Design	Color	Meaning	90%	Perceivable
Design	Size	Components	85%	Perceivable
Design	Adjustability	Adjust size	0%	Perceivable
Publisher	Buttons	Tags	75%	Operable
Publisher	Links	Tags	100%	Operable
Publisher	Titles	Tags	100%	Operable
Focus	Content	Order	90%	Operable
Focus	Content	Focus on components	80%	Operable
Forms	Tags	Labels on the entries	80%	Understandable
Images	Types of images	Avoid images with text	90%	Perceivable
Images	Images and text	Grouping text and image in a link	100%	Perceivable
Links	Images and text	Inclusive for all users	100%	Perceivable
Notifications	Notifications	User experience	90%	Perceivable
Notifications	User experience	User experience	90%	Understandable
Dynamic content	User experience	User experience	90%	Robust

Figure 3 presents a screenshot as a result of applying the Google Accessibility Scanner tool, where the absence of the button tag is indicated.

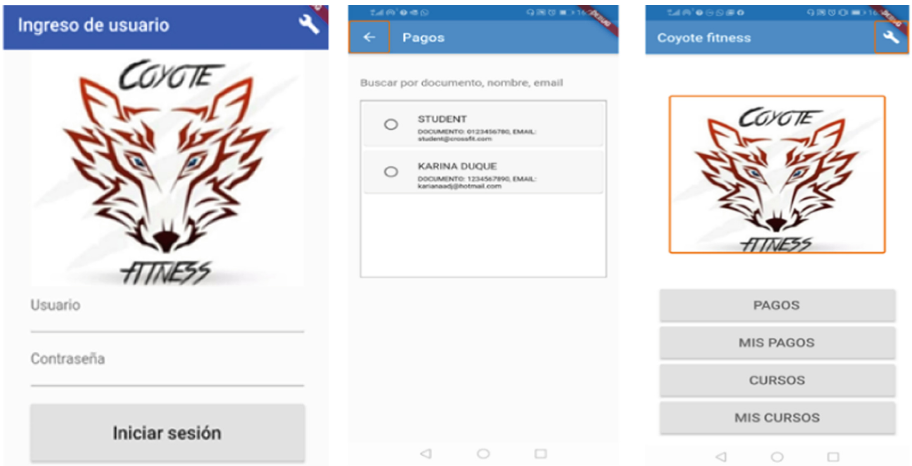

Fig. 3. Screenshot as a result of applying the Google Accessibility Scanner

5 Conclusions and Future Works

One of the barriers that are repeated most frequently is the one related to "Text contrast," when using objects in programming, the code in the parent class was modified to solve the problem of contrast in the mobile application interface. The design and development of the project were carried out with the Java programming language for the web part and Dart for the mobile part, which has met the system development needs. During the development of the project, there is constant contact with the end-user to develop the system according to its primary needs, and this is done thanks to the SCRUM development methodology. We suggest applying good practices that include manual reviews by expert personnel, to identify possible deviations from the accessibility requirements and propose the relevant corrections to improve the mobile application. It is estimated that the accessibility of mobile applications for visually impaired would improve considerably if two issues are considered: voice recognition accuracy and accessibility in low-end devices. Argentine Symposium on Technology and Society takes into account that a person can say up to 150 words per minute [1], it is clear that time and effort should be spent trying to improve the accuracy of voice recognition as well as the type of assistance provided to the user to edit and correct recognition errors. Finally, for the mobile application to be inclusive, it is recommended to perform manual tests with user groups with low vision to achieve a higher degree of accessibility. It is recommended applying the mobile application evaluation method throughout the development cycle. The findings of this research can contribute to future accessibility studies in mobile applications.

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Model for Generation of Profiles for Persons with Disabilities in e-Learning Environments

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Abstract. Education is a fundamental human right recognized in the Universal Declaration of Human Rights. Current e-Learning environments enable education at large scale with reduced costs. Unfortunately, persons with disabilities (PWD) experience barriers to access these platforms and the educational resources they host. To contribute with solving this problem, this study presents a model for the generation of profiles for PWD in e-Learning environments. The model proposed in this study allows registering accessibility needs and preferences regarding the use of different sensory modes for the perception and understanding of information depending on the current life situation of the PWD. The model is based on the specification IMS Access for All 3.0 PNP and the standard ISO/IEC 24751-2. The validation of the model was carried out with a high-fidelity functional prototype that was tested with automated tools and by users with blindness, low vision and color blindness.

Keywords: User profiling · Accessibility · Disabilities · PWD · Educational resources · e-Learning · IMS Access for All 3.0 PNP · ISO/IEC 24751-2

1 Introduction

Education is a fundamental human right recognized in the Universal Declaration of Human Rights [1] and in the Convention on the Rights of Persons with Disabilities [2]. The study carried out by [3] points out that education is a significant aspect for the development of the population and much more in developing countries such as those in Latin America and the Caribbean (LAC), where less than 22% of its inhabitants have higher education. According to the World Bank [4] there are 50 million of persons with disabilities (PWD) in LAC, and from those only 2% finishes higher education.

Current e-Learning environments enable education at large scale with reduced costs. Unfortunately, PWD experience barriers to utilize these platforms and the

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educational resources they host. To contribute with solving this problem, this study presents a model for the generation of profiles for PWD in e-Learning environments.

There is substantial previous research in accessibility of e-Learning environments. Nevertheless, the combining field of user profiling and accessibility is a less researched topic. Some studies about accessibility metadata, such as [5–7], focus in the profiling of web content and educational resources. Other studies, such as [8–11], point out the usefulness of accessibility metadata in user profiling. Nevertheless, none of them present a model and a functional accessible prototype for the generation of profiles for PWD as developed in this study.

The rest of this paper is organized as follows: Sect. 2 presents theoretical background; Sect. 3 presents the research method; Sect. 4 presents results and discussion; and Sect. 5 presents conclusions and future work.

2 Background

This section introduces the specification IMS Access for All (AfA) 3.0 Personal Needs and Preferences (PNP) and the standard ISO/IEC 24751. The main goal of IMS AfA 3.0 [12] is to simplify the use of standard ISO/IEC 24751. Both define the process for matching a digital educational resource to the user's needs from the definition of those needs and preferences to the matching mechanism to find the educational resource which satisfies the user's needs, as detailed in Fig. 1.

The standard ISO/IEC 24751 has three parts. The ISO/IEC 24751-1:2008 that presents the framework and reference model [13]. This part was reviewed and confirmed in 2019. The ISO/IEC 24751-2:2008 that contains the specifications of the needs and preferences of the users, currently under review [14]. The ISO/IEC 24751-3:2008 that contains the digital resource descriptions of AfA, also currently under review [15].

From these parts, the ISO/IEC 24751-2:2008 "Information technology—Individualized adaptability and accessibility in e-learning, education and training—Part 2: "Access for all" personal needs and preferences for digital delivery" is the most interest for this study. The standard ISO/IEC 24751-2:2008 provides an information model for describing the user needs and preferences when accessing digitally delivered resources or services [14].

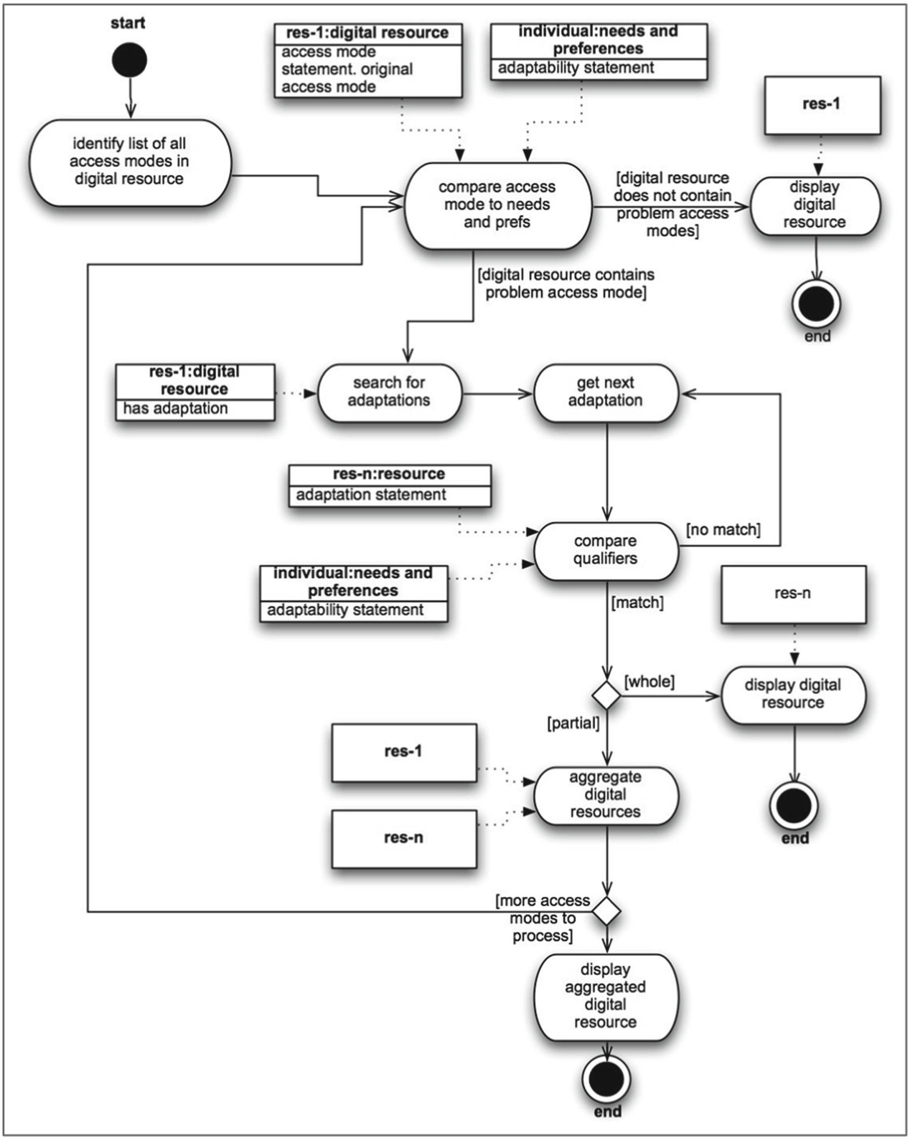

Fig. 1. Matching process between educational resources and users [13]

3 Method

The method used in this study had three phases. In the first phase, a set of generic accessibility needs of PWD were identified and mapped to XML tags. In the second phase, the model for generation of user profiles was designed. The user profile is generated from the user's responses to the questions in the form and stored as an XML file. The specific information of personal needs is related to a single user. But the same user can generate different user profiles which will be used according to the current life situation or environment in which the user is, i.e. post-operatory, dark room, noisy area. The personal needs of users must be easily modified by editing the user profile. In the third phase, a prototype was developed and validated.

4 Results and Discussion

As a result of the first phase, a set of XML tags were defined to map the accessibility needs for blindness, low vision and color blindness as detailed in Table 1. In the second phase, the Unified Modelling Language (UML) was used to design the model for generation of accessibility user profiles. Figure 2 presents the UML state diagram produced.

Table 1. Metadata tags of generic needs for blindness, low vision and color blindness

#	XML Tags	Blindness	Low vision	Color blindness
1	<AccessibleFiles>	On	On	On
2	<AuditoryAccess>	On	On	Off
3	<ColorContrast>	Off	On	On
4	<KeyboardAccess>	On	On	On
5	<MinimumFlashes>	Off	On	Off
6	<ReadableContent>	On	On	On
7	<ResizeContent>	Off	On	On
8	<TextAccess>	On	On	Off
9	<TextAlternatives>	On	On	Off
10	<TextNarrative>	On	On	Off
11	<TimeAdjustable>	On	On	On
12	<VisualAccess>	Off	Off	On

In the third phase, technologies such as HTML5, CSS3, PHP, JavaScript and Bootstrap were used to implement a prototype of the model that is presented in Fig. 3.

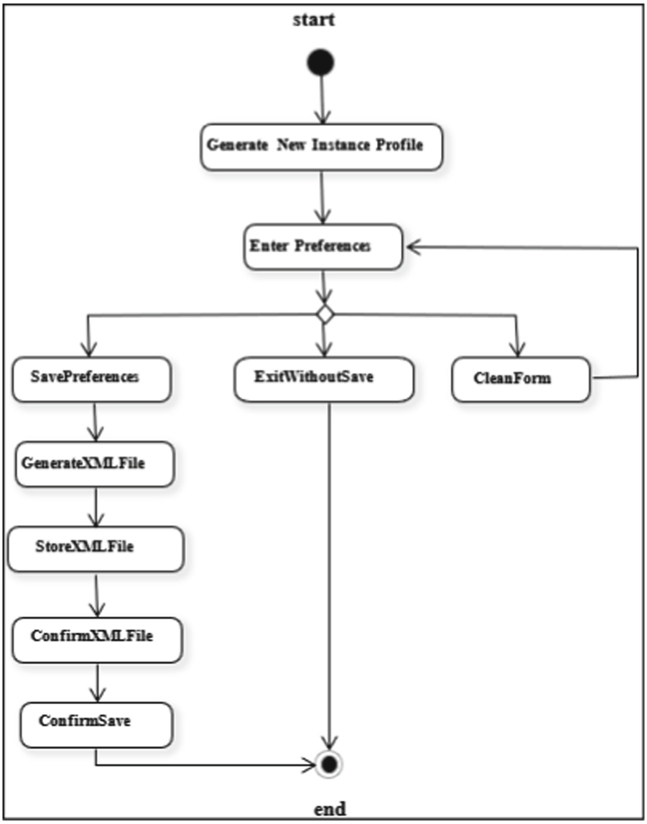

Fig. 2. UML state diagram of the model for generation of accessibility user profiles

Fig. 3. Prototype of the form for generation of accessibility user profiles (in Spanish language)

The automated validation was carried out using WAVE Web Accessibility Evaluation Tool. WAVE identifies accessibility and Web Content Accessibility Guidelines (WCAG) 2.1 errors [16]. Figure 4 shows that WAVE reported no errors, but it also pointed out that manual testing is always necessary to ensure optimal accessibility.

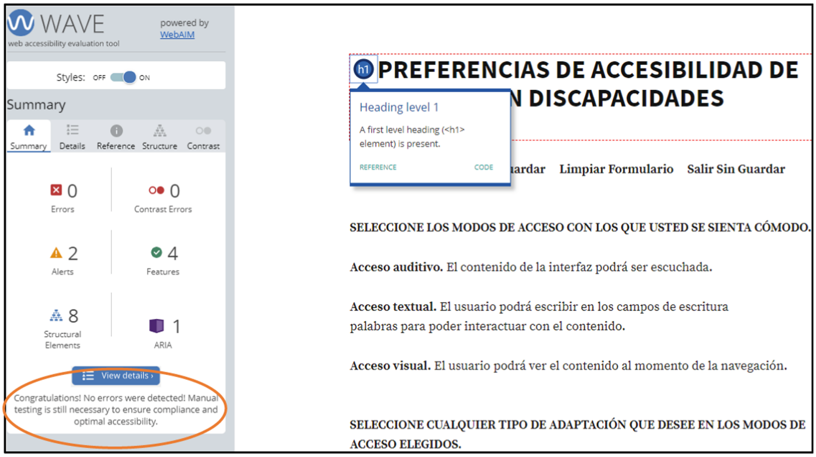

Fig. 4. Results of automated validation with WAVE

The manual validation was done with the support of 10 users belonging to the Ecuadorian Society of the Blind "Luis Braille". Among them, there were users with blindness, low vision and color blindness. Seven tasks were defined to measure the degree of difficulty and whether the users required help to execute the tasks. Table 2 shows that users found most of the tasks very easy except from those relate to access the input field to enter the profile name. All the users managed to execute the task without help.

Table 2. Results of manual validation with user

#	Tasks	Very easy	Easy	Difficult
1	Access input field for profile name	75%	25%	0%
2	Enter the profile name	12.5%	75%	12.5%
3	Navigate the check boxes	100%	0%	0%
4	Select the accessibility options	100%	0%	0%
5	Use the save button to generate the profile	100%	0%	0%
6	Use the clean form button	100%	0%	0%

5 Conclusion

To our best knowledge, there is not a model as the one proposed in this study since recent research efforts have focused more on profiling the educational resources but not on profiling the users who require access to those resources. As stated by the ISO/IEC 24751-1:2008, both profiles are necessary to provide the recipient e-Learning platforms with the information needed to present adaptations based on the preferences of the users and equivalent educational resources.

The validations with PWD allowed not only the improvement of the model and the prototype, but also the identification of accessibility needs and preferences that are useful for each type of PWD to propose generic profile patterns.

As future work, authors plan to increase the number of XML tags to cover a greater variety of disabilities and design the service to send the user profile information to the e-Learning platforms.

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Speech Training System for Hearing Impaired Individuals Based on Automatic Lip-Reading Recognition

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Abstract. Using automatic lip recognition technology to promote social interaction and integration of hearing impaired individuals and dysphonic people is one of promising applications of artificial intelligence in healthcare and rehabilitation. Due to inaccurate mouth shapes and unclear expressions, hearing impaired individuals and dysphonic people cannot communicate as normal people do. In this paper, a speech training system for hearing impaired individuals and dysphonic people is constructed using state-of-the-art automatic lip-reading technology which combines convolutional neural network (CNN) and recurrent neural network (RNN). We train their speech skills by comparing different mouth shapes between the hearing impaired individuals and normal people. The speech training system can be divided into four parts. Firstly, we create a speech training database that stores mouth shapes of normal people and corresponding sign language vocabulary. Secondly, the system implements automatic lip-reading through a hybrid neural network of the MobileNet and the Long-Short-Term Memory Networks (LSTM). Thirdly, the system finds correct lip shape matched by sign language vocabulary from the speech training database and compares the result with lip shapes of hearing impaired individuals. Finally, the system draws comparison data and similarity rate based on the size of lips of hearing impaired individuals, the angle of opening lips, and the differences between different lip shapes. Giving a standard lip-reading sequence for the hearing impaired for their learning and training. As a result, hearing impaired individuals and dysphonic people can analyze and correct their vocal lip shapes based on the comparison results. They can perform training independently to improve their mouth shape. Besides, the system can help hearing impaired individuals learn how to pronounce correctly with the help of medical devices such as cochlear implants. Experiments show that the speech training system based on automatic lip-reading recognition can effectively correct lip shape of the hearing impaired individuals while they speak and improve their speech ability without help from others.

Keywords: Hearing impaired individuals speech training · Human-computer interaction · Automatic lip-reading · Sign language recognition · Deep learning

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1 Introduction

Hearing Impairment (HI) is one of the major global health problems. The number of hearing impaired individuals is increasing year by year [1]. According to the Sixth National Census in China, the number of hearing-impaired people in China in 2010 was 20.54 million. Among which hearing impaired children increase by 300,000 annually [2]. Therefore, it is necessary to prevent hearing impaired individuals from becoming dysphonic [3] as soon as possible. However, the lack of medical staff and resources are considered as two of the main obstacles to the treatment of hearing disorders worldwide [4, 5]. Automatic lip-reading technology plays a vital role in visual perception [6], especially the use of automatic lip-reading technology to promote social interaction for the hearing impaired is one of the most promising applications of artificial intelligence in healthcare and rehabilitation [7].

Automatic lip-reading means that the system captures the lip movements of the speaker through automatic detection to recognize speech information [8]. It can be widely used in information security [9], speech recognition in noisy environments [10] and driver assistance systems [11]. In recent years, the Google team has proposed a lightweight neural network that can decompose the convolution kernel, named MobileNet. It can effectively reduce network parameters and compress the size of the model. Considering that the lip movement is a continuous process with time information, we propose a hybrid neural network system combining MobileNet and Long Short-Term Memory Network (LSTM), and use ResNet50 (Deep Residual Network) to ensure the accuracy of the training set.

Our proposed speech training system for the hearing impaired based on automatic lip-reading recognition is mainly divided into the following four parts: First, we create a speech training database that stores mouth shape of normal people and corresponding sign language vocabulary. Secondly, the hybrid neural network system of MobileNet and LSTM is used to realize automatic lip-reading. Then, find the correct lip shape that matches the sign language vocabulary from the database, and use ResNet50 to ensure the accuracy of sign language recognition. Finally, the lip shape of the hearing impaired is compared with the correct lip shape, and the comparative data is drawn according to the angle and shape of the lip opening, and the standard lip-reading sequence of the hearing impaired is given for learning and training. The advantages of this system are as follows: (1) The combination of ResNet50 and the hybrid neural network of MobileNet and LSTM not only ensures the advantage that the accuracy does not decrease even if the network is deepened, but also reduces the use of parameters and reduces the complexity of the model. (2) Hearing impaired people can come from the main training according to the comparison result of automatic lip-reading recognition, and correct and improve the mouth shape similarity. (3) The system supports the use of cochlear implants and other medical devices to assist hearing impaired people to learn how to pronounce correctly, thereby helping them restore their speech ability.

The rest of this article is organized as follows: In Sect. 2, we introduce the preparation and structure of a speech training system. Section 3 contains the experimental results and analysis of our proposed method. Section 4 provides conclusions and recommendations for future research.

2 Proposed Model

In this section, we present the research framework and main steps shown in Fig. 1. First, we match the gestural labels with lip labels one by one, and used the ResNet50 network to ensure accuracy. Secondly, the MobileNet network is used to segment the lip image area to extract features. Then, we use LSTM networks to learn time series information. Finally, the lip shape of the hearing impaired is compared with the correct lip shape with good features extracted from the database. The data is drawn and a standard lip-reading sequence is given for the hearing impaired to learn and train.

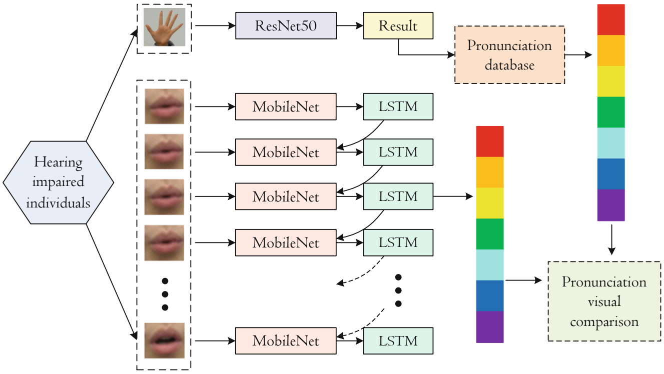

Fig. 1. Structure of our proposed hearing training system for the hearing impaired

2.1 ResNet50 Deep Residual Network

In order to deal with the problem that the accuracy of training set decreases with the deepening of the network, researchers have proposed a new type of deep residual network, named ResNet. As shown in Fig. 2, where F(x) is the residual of y = F(x) + x. The key idea of this network is: when the network has reached the optimal state and continues to deepen the network, the residual mapping will be pushed to 0, leaving only the identity mapping. Therefore, the network is always in an optimal state and the network performance does not decrease with increasing depth [12, 13].

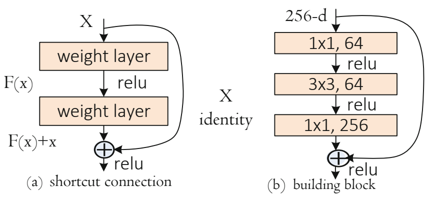

Fig. 2. Structure of ResNet

Figure 2(b) shows a key building block of ResNet-50, which consists of more than a dozen building blocks with different channel numbers, pooling layers and fully connected layers [14]. This building block reduces the 256-dimensional channel to 64-dimensional through the first 1×1 convolution, and finally recovers by 1×1 convolution, reducing the network calculation.

2.2 MobileNet Lightweight Network

Streamlined architecture based MobileNet uses deep separable convolutions instead of standard convolutions to improve computational efficiency, and selects appropriate global hyperparameters to reduce model complexity according to the constraints of the problem [15, 16]. The standard convolution is shown in Fig. 3(a). MobileNet decomposes standard convolution integrals into Depthwise convolutions and Pointwise convolutions. These two separate layers are key components of many effective neural network structures [17].

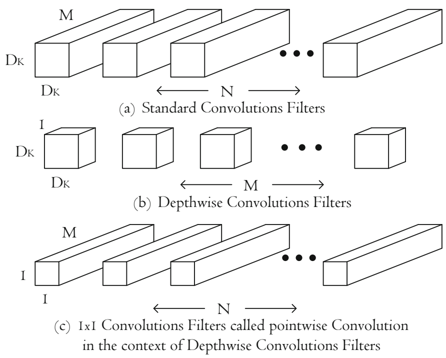

Fig. 3. Structure of MoblieNet model

The Depthwise convolution layer, shown in Fig. 3(b), is called deep convolution, and it performs lightweight filtering by applying a convolution filter to each input channel. The Pointwise convolutional layer is shown in Fig. 3(c). It builds new features by calculating a linear combination of input channels through a 1×1 convolution. In addition, BN and ReLU activation functions are used in the model to speed up training and improve recognition accuracy [18].

2.3 Long Short-Term Memory Network

In order to solve the problem of gradient disappearance and gradient explosion when RNN processes long sequence data, Hochreiter [19] proposed a sequence-dependent form of RNN [20], called long short-term memory (LSTM). Figure 4 shows the operations performed in the corresponding LSTM unit. Among them, x_t and h_t represent input and output vectors, respectively. i_t, f_t, o_t and c_t represent input gate, forget gate, output gate, and storage cell.

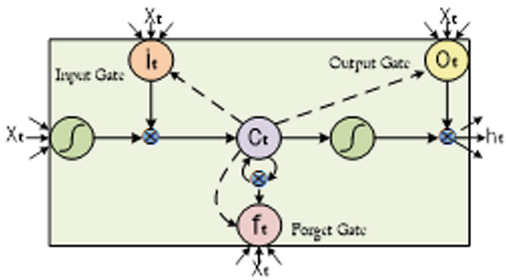

Fig. 4. Basic unit diagram of Long-Short-Term memory

The computational steps of control gates and storage cells in LSTM are as follows:

1. Input Gate: Used to control input node information. The expressions of input and output and candidate information are as follows:

$$i_t = \sigma(U_i x_t + W_i h_{t-1} + b_i) \tag{1}$$

$$g_t = \tan h\left(U_g x_t + W_g h_{t-1} + b_g\right) \tag{2}$$

Where U_i, W_i and b_i represent the weights and deviations of the input gates, U_g, W_g and b_g represent the weights and deviations of the candidate states, σ represents the S-type activation function, and $\tan h$ is the activation function.

2. Forget Gate: Used to control which information to discard with reference to the current LSTM unit. Its expression is as follows:

$$f_t = \sigma(U_f x_t + W_f h_{t-1} + b_f) \tag{3}$$

Where U_f, W_f and b_f represent the weight and deviation of the forget gate, respectively, and σ represents the S-type activation function.

3. Storage Cell: Used to save status information and update status. Its expression is as follows:

$$c_t = f_t \odot c_{t-1} + i_t \odot g_t \tag{4}$$

Where $\odot$ represents Hadamar product.

4. Output gate: used to control the output node information. The expressions for the initial output and final output are as follows:

$$o_t = \sigma(U_o x_t + W_o h_{t-1} + b_o) \tag{5}$$

$$h_t = o_t \odot \tan h(c_t) \tag{6}$$

Where U_o, W_o, and b_o represent the weight and offset of the output gate, respectively.

2.4 Lip Shape Comparison

We compare the lip sequence of the hearing impaired with the correct lip shape of the well-extracted features in the database and obtain similarity. Its mathematical expression is as follows:

$$\text{Similarity rate} = \left[1 - k\left(\frac{|X_1X_2|}{256}\right)^2\right] \times 100\% \tag{7}$$

Where X_1 and X_2 are the lip shape and the correct lip shape of the hearing impaired, respectively, and k is the penalty coefficient.

3 Experimental Dataset and Results

In this section, we evaluate the designed speech training system and analyze the results on our dataset. We randomly disrupt the dataset and divide the training set and the test set via 90% and 10%. Our fusion network is built by keras, 2080Ti GPU and Adam optimizer are used for training. The training model is inputted in 32 units and the learning rate for iteration is 0.001. The input images of gesture and lip are both sized in 224 × 224 × 3, then sequence features are extracted with size 1024 × 10 using the same LSTM model.

The results of gesture and lip-reading recognition are illustrated in Fig. 5 where the accuracy rate of gesture recognition reached over 98% and the accuracy rate of lip-reading recognition reached over 87%. The reasons about the accuracy of lip-reading recognition is lower than that of gesture recognition are as follows: (1) The gesture area is large, the movement is single, and the features are easy to capture. (2) The lip area is small and the difference between lip movements is weak. (3) There are fewer researchers related to lip-reading recognition, which leads to insufficient data-sets.

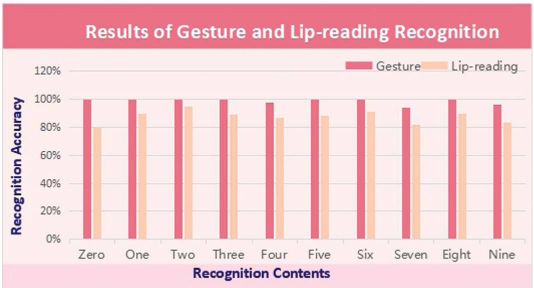

Fig. 5. Results of gesture and lip-reading recognition

We evaluate the designed speech training system by calculating the degree of lip difference between the numbers and performing simulation tests. Figure 6 specifies the comparison result of the lip shape difference between each number and 0. The similarity between the lip-reading sequence of the number 0 and itself is greater than 90%, and the similarity with most of the other numbers is not greater than 50%. Because the best English lip shapes for numbers 4 and 0 are close, the similarity between the two is slightly higher than other numbers.

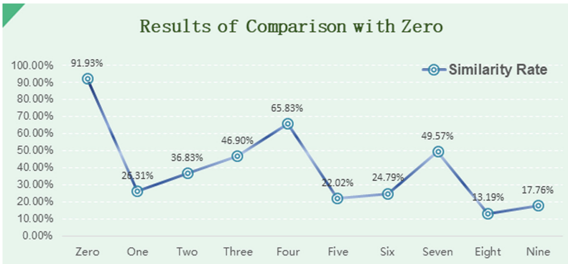

Fig. 6. Results of comparison with zero '0'

The simulation test results are shown in Fig. 7. The first line is the standard lip shape of the English pronunciation of the number 6. The second line is the lip-reading sequence after the tester intentionally changed the lip shape of the pronunciation. The third line is the lip-reading sequence where the tester imitates the standard lip-reading image and correctly pronounces the number 6. According to the system matching results, the matching degree after deliberately changing pronunciation is 71.76%, and the matching degree of correct pronunciation is 86.83%.

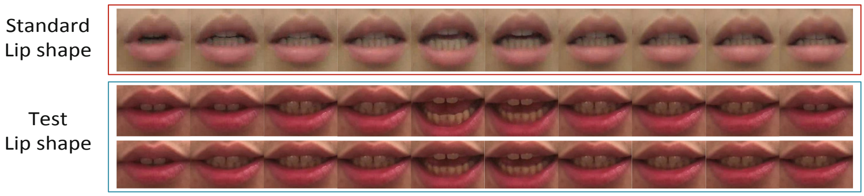

Fig. 7. Effect chart of simulation test

Combining the results of Fig. 6 and Fig. 7 together, we can conclude that when the system matching degree is less than 70%, the manner of pronunciation is weak; when the system matching degree is between 70% and 85%, the manner of pronunciation is with slight problem; when the system matching degree is greater than 85%, the manner of pronunciation is of good performance.

This experiment shows that hearing impaired people can use our system for independent training, and correct their pronunciation lip shape effectively based on the standard lip-reading sequence and the lip-reading comparison results given by the system.

4 Conclusions

This paper proposes a hybrid neural network system of ResNet-50, MobileNet and LSTM of the speech training system for hearing impaired people with automatic lip-reading recognition. Firstly, the gesture tag was matched with the lip tag one by one through ResNet-50. Secondly, the MobileNet is used to segment the lip image area to extract features. Then, we use LSTM to learn time series information. Finally, the lip shape of the hearing impaired is compared with the correct lip shape with good features extracted from the database. The data is plotted and a standard lip-reading sequence is given for the hearing impaired to learn and train. The gesture and lip-reading video database in this paper are made by six different producers (three men and three women). The recorded content is the independent gesture and pronunciation of ten English words 0–9. Experimental results show that our system can help hearing impaired people to correct pronunciation of lip shape and support their continuous self-training. In future research, we will train the lip-reading recognition model on the dataset of real-time broadcast videos (including video samples). From the real environment, we explore more accurate lip-reading recognition methods to improve the universality of the system and the better assistance of hearing impaired.

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Contributions to Improve Accessibility and Usability of Academic Journal Management Systems. Case Study: OJS

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Abstract. Assistive technologies have allowed people with disabilities to overcome many barriers. For instance, people with visual disabilities are able to access information on the Web by using screen readers and generating different actions in their navigation, which would not be possible without assistive technology. The generation of accessible resources and understanding user behavior from the journal editorial process point of view have created changes in the editorial process itself, from the reception to the publication of the articles. In this digital age, in which information has become global and open to a diverse population, resources should be accessible. Unfortunately, this is not usually the case. Resources must be made accessible to people with different conditions, including visual and hearing impairments. The goal of this study is to identify the challenges faced by a person with a visual disability during the editorial process of journals on the Open Journal Systems (OJS) platform. Such challenges include understanding the layout of the elements and controls on the platform interface, creating HTML versions of academic articles, configuring journal websites, and so on. The aim of addressing these challenges is to create accessible resources that can be used by all readers of OJS journals regardless of their conditions. The information presented in this study was collected over six months, and a descriptive analysis was performed. It can be noted that some accessible resources have already been implemented, such as the presentation of academic articles in MP3 format (which can be downloaded or reproduced online) and the publication of HTML versions of complete articles with navigation levels. There is also a video resource in which authors expose their research, and the articles themselves are presented in an accessible PDF format (which respects levels of accessibility that allow greater reading enjoyment for users with vision impairments). These contributions allow people with visual disabilities to better integrate into editorial teams of scientific journals. Work continues so that the resources published on the OJS platform can reach readers with disabilities at greater regional and global levels.

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Keywords: Assistive technology · Editorial process · Open journal systems · Person with visual disabilities · Accessibility and usability

1 Introduction

The growing demand for learning materials as well as communication and digital media has been exponential [1]. Collaborative teams that develop and seek solutions for environmental problems by applying scientific knowledge become creators of innovative educational resources [2]. Such resources have been integrated into the educational system, and this has created a need to improve access. The development of online resources should consider functional diversity as a fundamental element, since it applies to almost all users. Electronic inclusion is needed to improve problems and provide a better user experience for those who require additional support [3].

In particular, people with visual disabilities face problems with websites since they require assistive technologies and have difficulty accessing or using information. The importance of website usability in their lives must be recognized. In this context, universities must create accessible resources since open educational resources provide: (1) reduction in student education costs and (2) equal opportunities in student learning [4].

The objective of this study is to identify the challenges faced by a person with visual impairments during the editorial process of journals on the Open Journal Systems (OJS) platform. These challenges include understanding the layout of the elements and controls on the platform interface, creating HTML versions of academic articles, configuring journal websites, etc. The main objective of addressing these challenges is to create accessible resources that can be used by all readers of OJS journals regardless of their conditions.

1.1 Accessible Scientific Content

Currently, accessing research results through publication of articles in digital journals has created opportunities for researchers around the world, including greater visibility, impact, efficiency, transparency, and sustainability of research results. However, the articles published in digital format, and the platforms that store these publications, do not always maintain accessibility levels nor do they meet accessibility and usability standards, which is contrary to what both private and public organizations have established in existing regulations and standards [5]. Therefore, despite the wider access to research results, accessibility barriers are still maintained [6]. Few scientific digital journals have implemented accessibility policies on their websites or in the documents they publish because the process of generating accessible documents implies greater efforts in editing [6].

This article is structured as follows: Sect. 2 presents the materials, tools, and method used as a fundamental basis in the proposal. Section 3 presents a detailed proposal for the improvement of the editorial process during the production of accessible resources on the OJS platform. Section 3.1 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 Method

In this section, we describe the tools, materials, and method used for the development of accessible resources in the management of academic journals.

2.1 Materials

The sample used for the present study consisted of 10 articles belonging to 4 areas of knowledge that are already published on the OJS platform, as detailed in Table 1.

Table 1. Articles of the study sample.

Knowledge area	Total	Knowledge area	Total
Information technology	2	Business	3
Psychology	4	Education	1

2.2 Tools

The tools applied in this research were: Windows 10 Operating System, Microsoft Word, Adobe Acrobat DC, the Job Access With Speech (JAWS) screen reviewer (Version 2020.1912.11), and the Open Journal Systems platform (version 3.0.1). The JAWS flat-screen reviewer is a system developed for computer users with Windows operating systems whose vision loss prevents them from viewing the screen content or navigating with a mouse. The JAWS software provides an electronic output voice that presents the contents displayed on the computer monitor [7]. As for the OJS platform, its editorial management process contributes to the open access movement and online publication. It also allows the creation and dissemination of research results. These new spaces for disseminating knowledge, created by OJS users, allow us to contribute at any time and place [8].

2.3 Method

On the OJS platform, we worked with a user who had publisher rights in order to perform the different publishing processes. The process began with the entrance into the platform through the shipments screen, during which different movements were made using the JAWS screen reviewer's commands. The challenges experienced are detailed in Table 2.

Table 2. Editorial process and challenges.

Process	Challenge
Number settings	Identifying fields campos
Gallery creation	Creating accessible galleries
Publish articles	Configuring post
DOI assignment	Configuring DOI and register

3 Results and Discussion

3.1 Results

The publication of a scientific article is the final step in the editorial process for a digital journal. In the present study, to publish an article, the person with the visual impairment indicated problems identifying the tabs that OJS shows for the configuration of the journal number. To identify the configuration elements, the combo box scroll command (which identifies the tabs) was used. The command is activated with the "enter" key, and the cursor is used to exit; this helped identify each element to be configured (see Fig. 1).

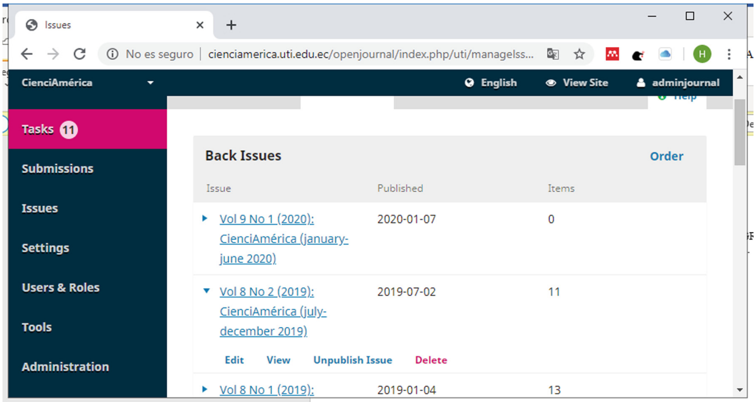

Fig. 1. Magazine number setting.

The galleries are the elements created to present the article in different formats for the digital journal. For this case study, the creation of the article in PDF format, the audio summary and HTML format, and the video presentation of the article were considered. At this stage, the challenge was to create the galleries because the images had to be loaded individually, which complicated the process until each element was loaded. In the PDF format gallery, only the respective file should be loaded (see Fig. 2). The audio and video galleries, however, were configured with external links (see Fig. 3).

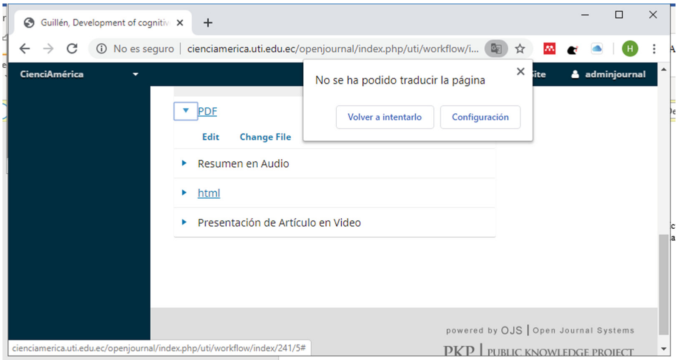

Fig. 2. PDF gallery format configuration.

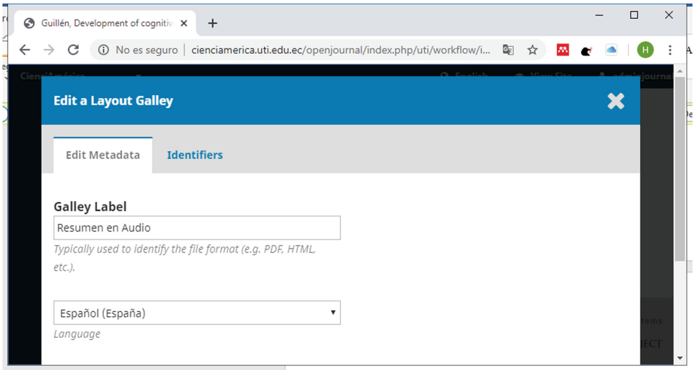

Fig. 3. Audio gallery setup.

3.2 Discussion

At first, the configuration of the number of the journal to be published and the creation of galleries presented problems for the user with the visual impairment until commands were used to identify the disposition of elements and navigation. Subsequently, the process was much more accessible, and the user with the visual impairment could generate the resources for the articles.

It is important to take into account that the user with the visual impairment has experience in the use of the JAWS screen reviewer, which could be a benefit in the use of the OJS platform.

Information technologies have transformed the expectations of authors and readers, since access to information is decisive, and this has dramatically changed the way knowledge is generated today [9]. However, despite the changes in information formats, there are still accessibility barriers, which can be solved using the functionality of resource creation tools such as MS Word [6].

The contribution of this research is that accessible resources can be generated in the editorial process by using the JAWS screen reviewer on the OJS platform. In addition, this experience has resulted in the creation of a job for a person with a visual impairment.

4 Conclusion

The development of accessible resources, which can benefit all users, allows research and global information to be even more widespread. On the other hand, the work carried out by a person with a visual impairment proves that it is possible to achieve optimal results on assigned tasks with the support of technology that eliminates accessibility barriers.

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Using Expert Evaluation to Assess the Usability of an Educational Mobile Game for Cognitive Skills Training

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Abstract. The labor market inclusion of people with intellectual dis- abilities is one of the main concerns of current societies. Non-profit associations make everyday efforts to improve the living conditions of these citizens. This contribution presents a heuristic evaluation of an educational mobile game helping social workers and health professionals in their training in order to incorporate into the labor market citizens with intellectual disabilities. The application provides technological support for cognitive skills training and is aimed at people with mild to moderate intellectual disability and who do not present physical difficulties that prevent the normal use of a mobile device. We use a development process that combines the iPlus methodology together with a collaborative user-centered approach. Suggested recommendations based on the results can improve the usability of the game developed.

Keywords: Usability inspection · Intellectual disability · Cognitive skills training · Social integration

1 Introduction

In contemporary society, the most disadvantaged groups that have failed in social integration are people who have an intellectual disability; especially in the workplace aspect, due to the difficulty they must adapt and develop activities in unknown environments. According to the WHO, 15% of the world's population is affected by some physical, psychic or sensory disability that hinders their personal development and social, educational or occupational inclusion [1]. This percentage is equivalent to more than one billion people, representing this figure almost double the population of Latin

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America with a notable disadvantage compared to the others. Intellectual disability is defined as deficiencies and limitations characterized in adaptive behavior and intellectual functioning present in practical, social and conceptual adaptations, these situations being classified as non-standard cognitive skills. People with intellectual disabilities constitute one of the groups that requires priority attention that makes possible their educational, social and labor inclusion, which improves their quality of life by equating opportunities aimed at equality, equity and non-discrimination. In the labor aspect, the difficulty becomes more complex in the development of activities in unknown environments [2]. The labor market inclusion of people with intellectual disabilities is one of the main concerns of current societies. Non-profit associations make everyday efforts to improve the living conditions of these citizens. There is therefore a growing concern to eliminate, as much as possible, these disadvantages through specific actions. For example, the missing function(s) must be recovered and, when complete recovery is not possible, compensate it with rehabilitation, which consists in both developing the necessary skills and abilities, and in equipping people with compensatory elements.

Today, advanced information and communication technologies (ICT) are facilitating changes in society, also in social and productive relationships. These tools are considered essential for the production and transmission of knowledge, the generation of wealth and, in general, for achieve a better quality of life, particularly for citizens whose possibilities are diminished due to some physical, cognitive or sensory disability situation. Mobile applications as an emerging segment of ICTs are being a fundamental element in supporting training activities. We are convinced that these can significantly improve the training and training of people with intellectual disabilities. However, it requires that the applications developed be usable, effective and also accessible. This document describes the application of a heuristic usability assessment instrument in an educational mobile game [3] helping social workers and health professionals in their training in order to incorporate into the labor market citizens with intellectual disabilities. The application provides technological support for cognitive skills training and is aimed at people with mild to moderate intellectual disability and who do not present physical difficulties that prevent the normal use of a mobile device. The development of the requirements of the educational game was done using the iPlus methodology [4], while the iterative refinement of the interfaces was driven by a collaborative user-centered methodology [5]. The results show the need to improve the interfaces and interactions and reflect on previously not considered functionalities.

The remainder of the document is presented as follows. Section 2 presents certain associated works followed by the description of the educational mobile game, including the main applications task. Section 4 describe the task-oriented usability evaluation performed. Section 5 presents the evaluation results and their discussions. Section 6 concludes the article and presents future efforts.

2 Related Work

In preliminary stages of any design and development process, usability evaluations are needed. ISO 9241-11 establishes a baseline reference for usability [6]. Within this baseline framework, usability is applied to situations in which end users interact with any information systems, including mobile applications, products (e.g. industrial and consumer products) and services (e.g. personal and technical). ISO 9241-11 determines that a product can be used by specific user profiles allowing them to achieve their objectives with satisfaction, efficiency and effectiveness in a specific execution environment known as the context of use [6]. The usability is associated with the satisfaction of end-users, their interactions and efficiency during user interaction. Usability evaluation [7] helps to minimizing the risk of error and potential usability problems with a system, particularly those related to interface and interaction design.

Usability evaluation methods make use of a set of metrics. Nielsen offers a widely known heuristic inspection method [8]. Heuristic assessment is considered as one of the usability inspection methods in usability engineering which concerns the usability of the software systems [9]. heuristic evaluation provides the advantages of being fast and inexpensive compared to the usability testing [10]. Pribeanu [11] analyzes the 10 heuristic criteria of usability of Nielsen [8] and presents a new method based on 4 categories and 14 heuristics including ergonomics criteria. The four categories are: (1) user guidance; (2) user effort; (3) user control and freedom; and (4) user support.

3 A Mobile Educational Application for Cognitive Skills Training

People who, given their conditions, have intellectual disabilities represent those groups which are more likely to fail at work integration due to the difficulty they must adapt and develop activities in unknown environments. The study case describes an educational mobile game that is developed from the need to train cognitive skills in order to incorporating end-users in productive activities, such as in a bakery. Before they can interact in an unfamiliar environment, it is necessary to train daily work routines.

The educational mobile game is founded on the resolution of temporal sequences of actions and the revision of vocabulary that are used in various contexts of daily life. It allows people with intellectual disabilities to remember photographs and their sequence to reinforce and internalize the activities of their work, converting them into habits and therefore into knowledge. The game gives security to the user that the things he is doing have already been learned and teaches the user to have a sense of danger, the tools and protective equipment they must use during the work.

In this context, the educational game is useful for learning based on sequences and allows reinforcing visual memory, auditory memory, working memory, vocabulary and executive functions that help to strengthen its field of defense and personal autonomy. It also, reinforces work schedules in a visual way and simulates in small steps what is done in a bakery; it consists of presenting sequences with activities of workstations of the bakery. The sequences are ordered in terms of increasing difficulty, the successes and the time is evaluated.

3.1 Application's Tasks

The application is aimed at people with mild to moderate intellectual disability and who do not present physical difficulties that prevent the normal use of a mobile device. The application is only for use in landscape mode (horizontal screen) and it is recommended that it be used in devices over 10 inches for a better user experience.

Table 1 presents the tasks according to two roles considered in the study for usability evaluation. The first role is the Tutor who oversees supervises people with intellectual disabilities. This person is responsible for creating the specific vocabulary of each workshop, the sequences, review the progress of each student and select the student in charge to perform the training. The User is defined as the person with intellectual disabilities who will perform the training in the educational game. This person must perform the review the vocabulary and solve the temporal sequences of each workshop. "Panel A" of Fig. 1 presents the user interfaces describing the functionality for selecting and exercises. "Panel B" presents the user interface to edit an exercise. Finally, "panel C" shows the user interface to perform an exercise.

Table 1. The evaluation tasks per user.

Role	Reference	Task
Tutor	TT1	Create a user account
	TT2	Edit an exercise
	TT3	Manage student accounts
	TT4	Login students to perform the exercises
	TT5	Visualize student results
User	TE1	Vocabulary revision
	TE2	Select an exercise

4 The Usability Assessment

The experimental protocol of the usability study for the mobile educational game is presented in this section. Three usability experts applied the Pribeanu's method [11] involving the educational mobile game. The evaluation performed for each expert lasted around 1 h. None of the experts had previous experience with the educational mobile game. Each expert was given the description of the functionalities, together with the user manual of the educational mobile game. Likewise, each user received a document describing the usability evaluation method and the descriptions of severity levels. As a complement, each expert received a set of instructions accompanied by an evaluation form containing the tasks listed in Table 1. The usability problems were evaluated based on a severity Likert scale. This scale varies between the ranges of 1 to 5. The value of 1 being the lowest on the scale, indicates an absence of usability. On the contrary, a value of 5 expresses a high usability catastrophe. The usability assessment was performed by following the Pribeanu's task-based approach [11]. Each task presented in Table 1 was valuated according to the 14 usability criteria (see Table 3). The

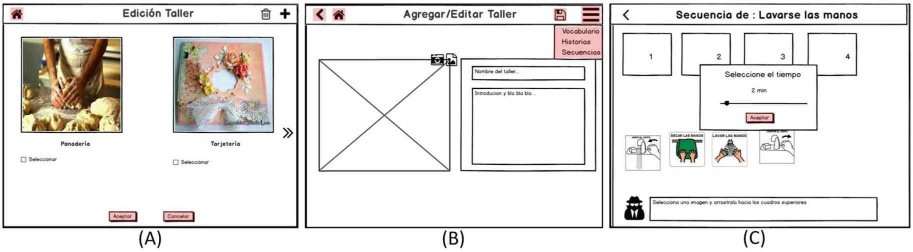

Fig. 1. The educational mobile game user interfaces [6].

evaluation process was carried out according to the following steps: (1) Each evaluator made use of the application. (2) Every usability expert performed a separate evaluation. The assessment was carried out considering the templates containing the 14 heuristics and the 5 levels of severity. (3) The results of each evaluator were received and analyzed individually and condensed.

5 Results

The quantity of concerns that were found by each usability expert is summarized in Table 2. This amount of usability problems detected varied between 81 and 116. Also, tasks TT2, TT4 and TT1 were where most of the problems were concentrated. From the results, we proceed to analyze the individual valuations to eliminate duplicate valuations and the problems we consider false. After performing this work, we found that by consolidating the results, a total of 289 usability problems were obtained (see Table 2).

Table 2. Usability results per task and severity.

Task	Severity					Total problems
	1	2	3	4	5	
TT1	141	35	9	11	1	56
TT2	373	60	27	0	0	87
TT3	107	11	1	6	1	19
TT4	266	57	10	3	0	70
TT5	109	15	2	0	0	17
TE1	20	22	0	0	0	22
TE2	63	20	1	0	0	21
Totals	1079	220	50	20	2	292

Table 3 presents in detail all usability problems divided by categories and usability heuristics. From these results, we identify the aspects of the educational mobile game with the highest priorities to be fixed. The usability problems detected mostly correspond to the categories “user support”, “user guidance” and “user control and freedom". Despite the number of problems, we have found that severity levels mostly correspond to aesthetic problems (severity 2) or minor usability problems (severity 3). Some usability problems have been found: (1) The user is not guided through hearing mechanisms; (2) Visual, vocal or vibration feedback when a user performing an interaction is non-existent; (3) There is no visual pointer that guides the user where the focus of interaction is; and (4) Inconsistencies in the styles, icons and the organization of the components of the interfaces.

Table 3. The complete usability results.

Usability heuristics			Severity					Total problems
Group	ID	Description	1	2	3	4	5	
User guidance	H1	Prompting	84	13	2	0	0	15
	H2	Feedback	76	21	2	0	0	23
	H3	Information architecture	84	13	2	0	0	15
	H4	Grouping/distinction	86	7	0	1	0	8
Total - User guidance			330	54	6	1	0	61
User effort	H5	Consistency	90	7	2	0	0	9
	H6	Cognitive workload	77	18	3	1	0	22
	H7	Minimal actions	89	10	0	0	0	10
Total - User effort			256	35	5	1	0	41
User control and freedom	H8	Explicit user actions	88	9	1	1	0	11
	H9	User control	65	29	0	2	0	31
	H10	Flexibility	80	12	3	0	0	15
Total - User control and freedom			233	50	4	3	0	57
User support	H11	Compatibility with the user	82	14	1	0	1	16
	H12	Task guidance and support	62	20	11	5	1	37
	H13	Error management	48	33	12	5	0	50
	H14	Help and documentation	68	14	11	5	0	30
Total - User support			260	81	35	15	2	133
Totals			1079	220	50	20	2	292

5.1 Discussions

We consider that the main limitation of this study is that heuristic evaluation gives the idea of usability problems founded in the educational mobile game from an expert perspective, but, it does not consider usability problems which may occur with general use. User support, user guidance and user effort were, in general, the most severely criticized heuristics. This may have an origin in which there is no clear guide and no feedback about the tasks that the user must perform. In addition, the experts founded inconsistencies in font styles and icons must be improved in order to reduce the cognitive workload imposed to the users. We recommend that all visual elements be reviewed so that redesigns can be adjusted to a viewing standard.

6 Conclusions

The case study is developed from the need to train people with intellectual disabilities to facilitate their integration into productive activities, such as in a bakery. In this article we have presented the application of a heuristic usability method for an educational mobile game. Recommendations have been submitted based on the results obtained. Basically, we have detected the need to improve the user guide and the feedback that users should receive. The consistency and standards were also found to be affected in the evaluation of the educational mobile game. Future works should concentrate on performing new usability evaluation studies, we will focus on making user experience in real situations, with real users.

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Assessing Visual Engagement for Visuomotor Skills Rehabilitation Training in Infants

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Abstract. Simple visual stimuli, with bright colours and dynamically evolving over time, are among the most effective mechanisms through which to engage a baby´s attention. In earlier work, we have developed a visual stimulating tool to aid rehabilitation programs, which can be used with infants of up to 2 years of age. The feedback from the early use of the device has been rather positive. Yet, until now, there was no explicit way to assess the degree of engagement of the infant's attention, or even when the focus of said attention moved away from the stimulus. Hence, it has been difficult to understand whether the proposed specific rehabilitation procedure has failed, for a given infant, or the loss of attention led to a decrease in efficiency in the intervention. In the current work we develop and exploit a simple eye tracking tool, based on a laptop's own webcam, to evaluate the child's loss of attention to visual stimuli. The main differentiating criterion, set forth for this eyetracker, is that it should work without an explicit calibration stage. The use of the specific camera is motivated with the fact that the laptop can be used for visual stimuli deliver, as well as a series of data processing steps. The results attained thus far were rather encouraging, leading even to a subsequent study, replacing infants by adults undergoing a rehabilitation program, after suffering from brain stroke.

Keywords: Visual attention monitoring · Rehabilitation · Eyetracker · No calibration · Infants

1 Introduction

The very early stages of development of an infant are paramount to shape her/his future ability to cope with the World. In fact, it is in the first few years of a child's life that neuroplasticity plays the most important role in developing the functional structure of the infant's brain [1].

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It is estimated that around 1,3 billion persons, Worldwide, suffer from some kind of visual perception impairment [2]. Yet, 80% of those are deemed recoverable without the need to resort to extensive medical intervention, such as surgery. Rehabilitation is, then, the operative word.

Colourful and dynamically evolving visual stimuli are some of the best tools utilized, in practice, in rehabilitation programs with children, in particular when addressing visuomotor perception and coordination [3, 4]. Yet, the success of such strategies is highly dependent on the degree of attention the infant puts on the moving stimuli. In recent years, we have developed a software platform, RehabVisual, to incorporate a series of carefully selected stimuli, as well as a database with a variety of valuable information, to help therapists and paediatricians in their rehabilitation work [5, 6].

The current work addresses a crucial element of the rehabilitation program, that of assessing the participant's engagement with the stimuli, and is strongly based on the MSc Thesis research work of one of the authors (P.D., [7]). To collect relevant information for attention assessment, eye tracking seems a rather obvious direction to take. Yet, most of the existing solutions require a stage of calibration, which was not possible in the context of very young, and easily distractible children. The solution found, based on a laptop's front camera, and assuming continuous flow of movements for the subject's eyes, was presented in [7, 8]. For the sake of completeness of the current manuscript, that will be quickly summarised in the following section.

In this manuscript we will focus in the test of the aforementioned attention-tracking approach, when applied to the study of visuomotor stimulation toddlers.

2 Materials and Methods

RehabVisual delivers visual stimuli via a portable computer's display. We used the computer's own front camera, located at the bottom-centre of the display, to track the participant's visual attention, through eye tracking. After estimating the position for both eyes, in the first frame of the video, the subsequent eye estimates were found through a succession of filtering and heuristics processing steps, while exploiting the continuity of eye movements.

In the following sections we will review some of the major aspects of the visual stimulation strategy, as well as the eye tracking processes. We refer to [7] for a more in-depth overview of both setups. A very short description of the two babies studied in this study will follow that.

Preliminary tests, presented in this manuscript, were carried out with two infants, of two and one years of age, respectively, sitting on the lap of a caretaker.

2.1 The Experimental Setup

The RehabVisual. The overall rehabilitation platform was designed in close collaboration with Physical Rehabilitation Department of Hospital Dona Estefânia, a major paediatric hospital in Portugal. Its Ethics Committee validated also this reported study.

In addition to the visual stimulus delivery apparatus, the RehabVisual software platform offers also a structured database, where administrators; doctors/technicians; occupational therapists; and caregivers store evaluating parameters, enabling them to store and share, quickly and efficiently, data relevant for a successful visuomotor rehabilitation program.

Visual Stimuli. All visual stimuli were built using Microsoft's PowerPoint. They could be as simple as one simple square, circle or triangle, see Fig. 1a, or more complex geometric structures, as the ones displayed in 1b and 1c. Since we worked with very young infants, we chose the simplest of the shapes, *i.e.,* a circle, with a uniform, primary colour filling, to stimulate visually the infant.

During the experiment, the circle changed in colour, and moved within the computer screen with a given speed, adjusted by an operator. The movement varied from slow to moderate and fast, in one of four directions: horizontally, vertically, diagonally and circularly [8]. No other, more complex dynamics were employed, since that would certainly loose the toddler's attention too rapidly.

2.2 The Young Participants

We tested the attention-tracking strategy with two toddlers, while sitting in the lap of an adult they felt comfortable with. Their faces were approximately 60 cm away from the computer screen. Lighting conditions were kept rather stable, with light shining from the children's right hand side.

Figure 2 shows frames from the videos recorded from both children. The two year old toddler is displayed in the upper row, whereas the one year old appears in the bottom one. Note that, as the dynamic display of visual stimuli evolves, the child engages with it, in different parts of the computer screen, *cf.* frames a, d and e; looses some interest in it, as in b; and even looses total interest, as clearly shown in frame c.

All frames with toddlers have blurred faces, to preserve their privacy. Only their eyes are deblurred so that one may evaluate their eye gazing.

2.3 Eye Tracking

First, and foremost, it is important to state that all the procedure summarised in this manuscript, and more thoroughly described in [7, 8], is designed to be used offline. Although it may limit the use of the proposed rehabilitation tool, most of the algorithmic steps may be updated to be implementable online. We let that evolution for further developments of RehabVisual.

The workflow of the eye tracking used is shown in the following diagram (Fig. 3). All processing is performed on individual frames of videos recorded from the computer's webcam, with a 720 p resolution, and a rate of 30 frames per second. The procedure starts with manual intervention, with the annotation of the correct locations of the centres of the eyes, as well as that of the nasion, for the first frame of the video. In the following frames, the regions corresponding to the face and the eyes are found,

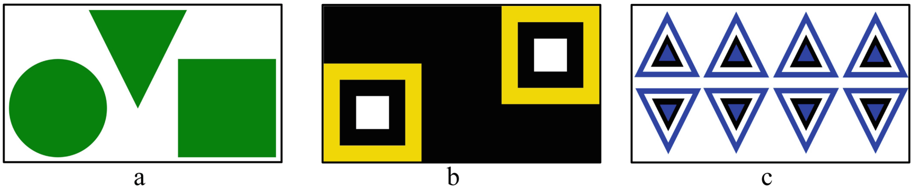

Fig. 1. Visual stimuli employed in the RehabVisual platform with an increased degree of complexity, from left to right.

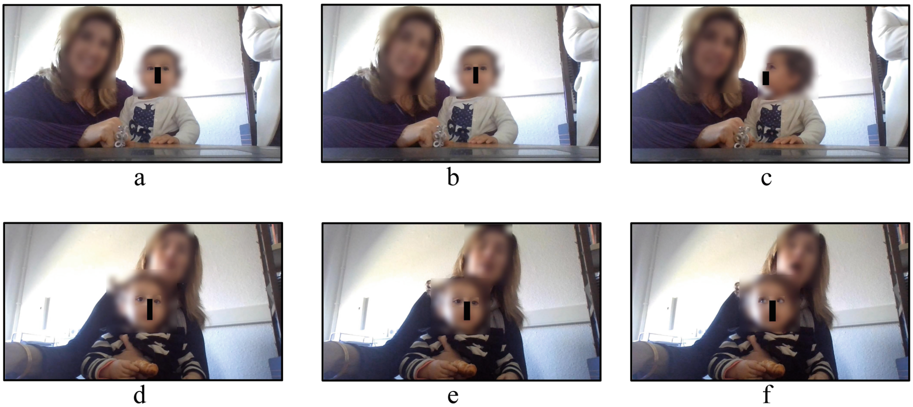

Fig. 2. Different frames of the video recorded by the webcam of the laptop computer. Eye tracking information is calculated from it. Upper row: two year old toddler; Lower row: one year old.

and delimited by individual boxes, using a Matlab[1] function rooted on the Kanade-Lucas-Tomasi tracking algorithm (*cf.*, [9]). The search for the centre of the pupils, and hence the estimate of the direction of gaze, is performed only within the corresponding boxes.

The evolution of the coordinates for the eyes of a person engaged with and following a moving object is rather smooth, in particular if the stimulus evolves in a similar manner. Yet, the loss of eye contact with the stimuli, *e.g.,* when the toddlers turn their faces to the adult (see Fig. 2c), results in a sudden jump in the estimated eye coordinates. Hence, and although most of the tracking procedure is designed to happen automatically, manual identifications, other than the initial one, may still be required. In the flowchart above, that is illustrated in the comparison step between consecutive frame estimates of eye coordinates. It should be stressed out that such interventions are very sporadic. Furthermore, the amount of interventions can also be used as a clear indicator of loss of visual attention engagement.

[1] MATLAB Release 2017a The MathWorks, Inc., Natick, Massachusetts, United States.

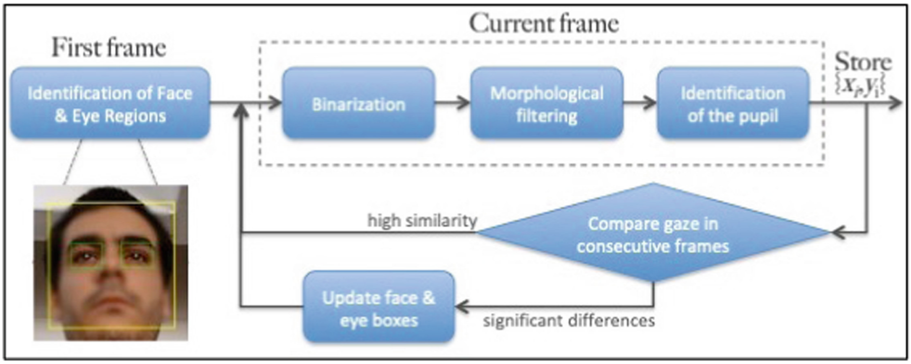

Fig. 3. Flowchart of the eye tracking procedure – adapted from, and further described in [8].

2.4 Distance to Reference

Instead of looking directly at the dynamical evolution of the horizontal and vertical coordinates of the pupils, and to account also for possible rotations of the whole head, a different measure was recorded instead. First, a reference point was chosen, in the intersection between the nasal ridge and a line connecting both pupils. Then, the relative position between each pupil's centre and that reference point was calculated, for each frame of the recorded video. Because of possible eye disparities, we look at both eyes separately, rather than a combined measure.

3 Experimental Results

Figure 4 shows dynamics of the distance to reference for the left eye of the two year old toddler. In the graph, the *xx* axis identifies the frame, whereas the *yy* axis displays the relative position of the eye. In frames 317 and 374, liked with Figs. 2a and 2b, respectively, the relative position of the left eye changes rather smoothly, while the toddler is engaged with the stimulus. Frame 950, corresponding to Fig. 2c, presents a clear loss of visual engagement, as the toddler deviated the attention towards the adult. A drastic change in relative positioning of the left eye follows accordingly.

It is important to state that information regarding attention shifts, as well as very sudden movements within the normal stimulus field of view, are crucial to identify loss of engagement to the stimulus employed.

Similar results as the ones presented above were calculated also for the right eye. Yet, as can be seen from the rightmost frames, there are occasions where that estimate is rendered impossible, due to eye occlusion by the rest of the face.

Figure 5 shows similar attention engagement results for the one year old toddler. As in Fig. 4, three movie frames are highlighted. The 28th corresponds to the image presented in Fig. 2d, whereas the 50th and 83rd correspond to Figs. 2e and 2f, respectively. Please note that, in spite of attempting to use a stimulus of similar duration for both toddlers, the total number of frames presented in the latter is much

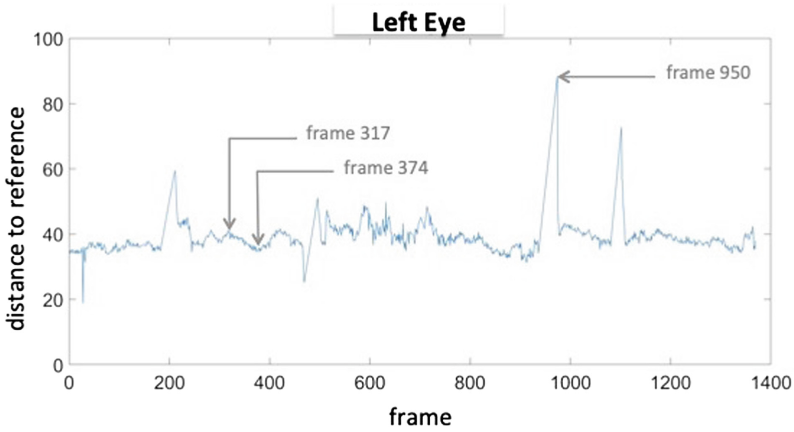

Fig. 4. Following a two year old toddler's gaze. Horizontal movement of the left eye, in relation to a reference point between the eyes. Three frames are highlighted, to illustrate smooth tracking of visual stimuli (frames 317 and 374), as well as one clear case of loss of engagement with the stimulus (frame 950).

smaller than that of the former. That, on its own, is a clear indication that the younger toddler was not capable of keeping the same degree of engagement to the stimulus as the older. In this second experiment we could also observe the effect of a loss of attention that does not relate to a clear head movement. In fact frame 83 shows that the toddler moves the gaze direction clearly out of the stimulus field of view. Since the general face posture of the adult does not change significantly across frames, the stimulus is likely to be still present, but the toddler chose to ignore it. The dynamical data plotted on Fig. 5 shows a very significant deflection in that instant. A close look at the toddlers eyes validates that the gaze moved right- and upwardly.

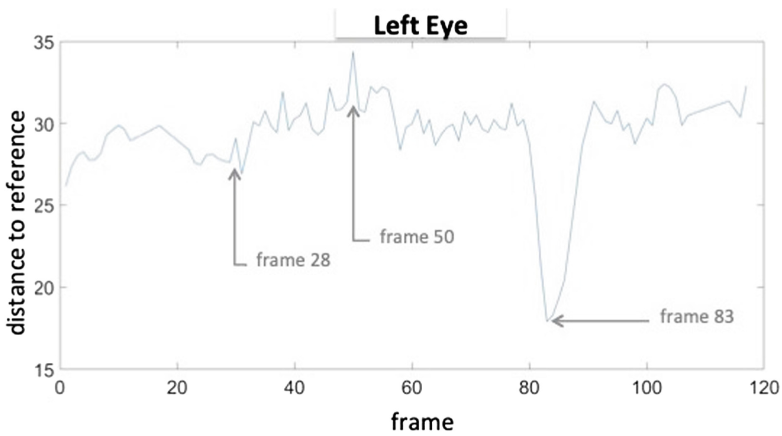

Fig. 5. Similar to Fig. 4, for the one year old toddler.

4 Conclusions

We set ourselves to test RehabVisual, a laptop-based platform for visual stimulation, utilized in visuomotor skills rehabilitation programs, with two toddlers aged one and two years, respectively. In order to insure that stimuli are correctly delivered/perceived, a mechanism for attention assessment has been added to the platform. Using the same portable computer that was employed to deliver the visual stimuli, we were able to follow the infant's engagement to the dynamical visual cues. Although other eye tracking techniques have been proposed, most of them require a stage of system calibration, prior to its use. Yet, toddlers are often too restless to allow for such preparation period. Instead, and with very mild human intervention, we proposed an eye tracking strategy that uses the computer's own frontal webcam, and requires no prior calibration procedures.

Strong on the very promising early results, attained thus far for both healthy adults and toddlers, extensions to other visuomotor rehabilitation programs are being tested. They include studies with patients having suffered from brain strokes. Therein, it is also crucial to evaluate the net visual attention span of each subject, since it contains valuable information on the ability to sustain concentration on a given task (visual, in this case), as well as to understand when the efficiency of the rehabilitation scheme has lost its purpose.

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Human Systems Design in Transportation Applications

Human Systems Design Towards an Integrative Conceptual Framework

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Abstract. Conceiving artefacts and tools is one of the major key characteristics of the human species. Since the beginning of automation and even more since the spreading of computer science, this activity has become more and more challenging especially through the analysis of the different interaction modes between the artifacts and the human. Nowadays, developing an artifact that must interact with a human is requiring an integrative point of view which must include biological, physical and cybernetical concerns. The current norms aimed at characterizing the quality and the relevance of human machine interface are generally limited to standard interfaces and/or to specific domain. The goal of this paper is to propose an integrative conceptual framework and ergonomic design criteria for developing human systems.

Keywords: Human-systems · Epistemology · Interaction · Integration · Conceptual framework · Ergonomic criteria

1 Introduction

Since the beginning, humans, as homo *habilis* and homo *sapiens*, have been conceiving artefacts and tools to master and explore their living environment. And since the Second World War, automation and computer science have improved the capacities and autonomy of systems such as those found in aerospace, industrial, and medical sectors. The quality of these artefacts has impacted their health, performance, safety, viability and survivability. Over the years, from passive to interactive artefacts the conceptualization has evolved from a mechanical thought to cybernetic and computing principles. Based on that paradigm, the human, as user or pilot/manager of these systems, has been reduced, by analogy, to logical and physical properties in the systems engineering and design. In that cognitive or computational approach, the human is considered a problem or a central point perspective even if the human factors goals are

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to improve the safety or the usability. The human remains in-front of and thus separated from the machine, their relations being meditated by an interactive process or a dialog of commands translation, and in which he or she is factorized. Therefore, mainly for safety-critical systems, the quality of interactive systems (computer interface, airplane or car cockpit, industrial control room…) are evaluated by ergonomic criteria.

Today with new and converging technologies, a new paradigm is needed in the human-machine relation. The question of gathering the artificial object and the natural body is central for behavioral health and performance, for safety and viability, or even sometimes survivability.

For example, virtual environments, cobots, exoskeletons, wearable systems, intensive care machines, medical devices or organ prosthesis are requiring different design methods for tackling with the human-machine interaction. Human and Machine are two different elements of the same set or system, not reducible to each other. That difference is grounded on their different natures. The human is both biological and anthropologic. The machine is both artificial and cyber-physical. Thereby the human-machine system is what we call a *Bio - Cyber-Physical System* (Bio-CPS).

Designing Bio-CPS requires a biomimetic and bio-integrative thinking, and thus requires an integrative conceptual framework for modelling and validating the correctness of the whole system in terms of formal description and experimental simulation.

The future of human system integration will be symbiotic and bionic [1, 2]. It will be based on biocompatibility, bio-integration and co-adaptation.

So, one of the main issues is epistemological. What are the updated multidisciplinary concepts and the theoretical principles underlying human systems integration correctness by design for each kind of human-artefact or human-machine systems, from chipped stone to biosynthetic and bio-implantable smart artefacts?

The aim of our paper is to present an integrative conceptual framework and the related *ergonomic design criteria* stemming from our multidisciplinary epistemological analysis and experience feedback in aerospace, UX or autonomous vehicle design.

2 What Human-Systems Are We Talking About?

From human-machine to very high-level organizations, Booher [3] defines six levels of complexity mainly grounded on technical devices, organizational and human factors and their interactions.

Thereby the main differences are the level of complexity, the number of levels inside the scale relativity of the organization and the different nature of the elements or components of the whole system. In that model the interactions are conceived as processes between the different elements. However, our previous works have demonstrated that interactions are multimodal actions, bio-anthropological, logical and physical, coupling the different components of the systems, according to the physical space relativity and the time-space relativity of architecture, behavior and evolution of the human-systems inside the domain of activity or expertise as explained in Fass' human-systems integration engineering framework [4].

As explained in the introduction, there is a strong need for proposing an integrative theory for designing and assessing Human-Systems qualities and performances (safety, security, reliability…) according to biological, logical and physical fundamental properties. In Fass and Gechter [5, 6], the concept of Bio-Cyber Physical System (Bio-CPS) has been introduced. A Bio-CPS can be defined as a system made of components, that can be biological, cyber (i.e. logical) or physical that are deeply integrated, and which are interacting with each other. One of the key elements of these systems is the nature of the interaction between the elements. Obviously, biological, logical and physical components are different by nature, but they also interact differently with various space and time scales. According to the previous section, there is no relevant criteria for classifying Bio-CPS. However, we can draw several elements that should be considered. For instance, the intentional level (Human side) of the interaction could be used with a scale going from a passive interaction to a high cognitive/intentional level one through a reactive behavior.

By the same way, the relative position of the artificial device to the human and his body space can also be a relevant criterion. Thus, the artificial part of the system can be inside the body (intra-body: i.e., bionics, synthetic biology artefacts), around the body with a skin contact (peri-body: i.e., wearable, IoT skin-patches), outside the body but within the space of direct actions – reachable (near extra-body or peri-personal: desktop, workstations, cockpit, control room), outside the body above the space of direct actions (far extra-body or extra-personal space: navigation space systems, smart road, NextGen Aerospace, remotely controlled devices), or at a long distance of the body (ubiquitous or here, know and there: i.e. unmanned systems, teleoperation systems, shared virtual environments).

In addition to these classification criteria, there is a strong need for specification/evaluation criteria to determine if a human-artificial system (or a Bio-CPS) is presenting "good" properties such as usability, workload, explicit control or adaptiveness. This last property is especially sensitive, since, in the case of Bio-CPS, the adaptiveness is a bi-directional relation (i.e. the biological and the artificial part must be in mutual adaptation) which stems from the dynamics of the interactions between all the components whether they are biological, cyber or physical. Thus, this co-adaptation must be put into perspective with the complex nature of the system and the emergence of the organized functions [7, 8], as explained by Fass and Gechter [6].

3 How Do We Design and Evaluate Those Systems?

For designing and evaluating interactive systems that satisfy ergonomic quality, authors in specific domains (Aeronautics, Army systems, Air Traffic control, Space Flight Human System, Web interfaces, …) have proposed different methodologies, different frameworks and guidelines (Aeronautic HFs, Nasa-STD-3001, …).

In the field of human-computer interaction, standards have been developed. When one looks for guidance for designing user interaction and interfaces, one finds 54 published (or under development) international standards. These standards are written by the ISO/TC 159/SC 4 Technical Committee on "Ergonomics of human-system interaction". For example, the ISO 9241-11:2018 [9] defines the concept of usability, the ISO 9241-210:2019 [10], the user-centered design cycle and for each step of this cycle methods are proposed [11]. Specific documents are also available for addressing topics such as the evaluation (and design) of tactile and haptic interactions [12], guidance on visual user-interface elements [13], interaction principles [14], forms [15] and so on. At a more "abstract" level, design heuristics and guidelines have also been proposed (e.g. [16, 17]). Although the *Ergonomic Criteria* [17] have been developed for evaluation purposes, they are used in the design phase of the user centered design cycle for the detailed specification and development of the system interface. But these criteria have two limitations. The first one is related to the fact that they represent a state of the art of the ergonomic knowledge at a specific time. When they were developed and evaluated, the existing knowledge concerned essentially software for desktop computers. Therefore, the question of their generalizability to other interaction technologies or human systems arises. This implies that the guidelines under each criterion should be updated regularly to be applied to human interaction with systems such as virtual our augmented reality.

The second limitation is the lack of a theoretical background that would allow the *Ergonomic Criteria* to be generalized [17]. Even if the ergonomic guidelines under each criterion have been extracted from experimental studies which may have been theoretically based, the set of ergonomic criteria is "a theoretical". But looking at some criteria one may envision the theory behind. This is the case for instance for a criterion such as "Grouping/distinction of items" by location and/or format which may be related to the Gestalt theory.

So, for each new system, for each category of users (professional or general public), there is a need for defining new set of criteria or to update the design guidelines associated with them. This situation seems to be due in part to the lack of rational and proven theoretical principles.

4 Towards a General Framework for Designing Ergonomic Human-System Integration

To overcome the lack of grounding theory and principles for human-systems integration design or engineering we propose a general framework. This framework integrates the results of human-systems integration from the coherent and stable coupling of the human(s) and the artefact(s) mediated by an interface. Designing human-systems integration is specifying the artefact interface that must couple the artificial system to the human sensorimotor, cognitive and emotional functions.

For designing human systems that would satisfy the requirements for utility, usability, safety, … and more generally the ergonomic quality, we need to consider: the complexity of the interactions and their combined nature (bio, cyber, physical), the behavioral space, the interaction modality, the structural elements, form and dynamics of the interface while integrating the ergonomic criteria.

Figure 1 illustrates the general design space of the "Human Systems". This design space could help researchers and designers specify characteristics of the artefacts or systems and their coupling with humans.

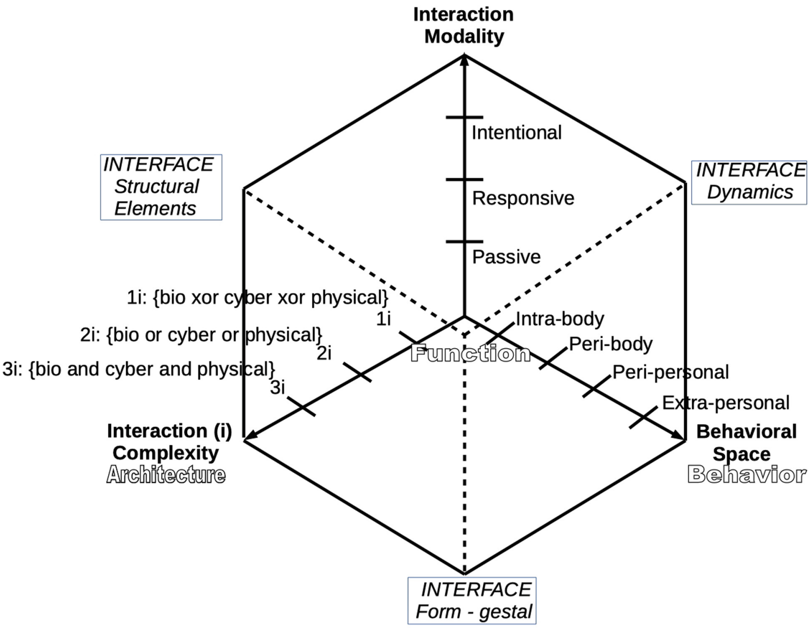

Fig. 1. Our general human-systems design space framework.

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Assessing Cognitive Processing and Human Factors Challenges in NextGen Air Traffic Control Tower Team Operations

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Abstract. Previous research of Terminal Radar Control Facilities and Standard Terminal Automation Replacement Systems interactions by the authors examined how combined NextGen digitized technology affects air traffic controller functions. Applying their updated SHELL model, human factors implications on the Tower Team before and after implementing NextGen technology were examined, focusing on cognitive loading and automated functions affecting each team member. A survey examined where cognitive difficulties occur when controllers are responsible for multiple screen views, remote airfields or helipads, and digitized cameras and blind spots. Scanning challenges were identified where local traffic, ground operations, and data converge onto one screen, and when attention is diverted to distant screens. Also studied were automatic aircraft handoffs and potential for missed handoffs, and, assessing changes from voice communication to text messaging for human error. Findings indicated a necessity for controllers to manage balanced tasking, vigilance pacing, and resource management.

Keywords: SHELL · Human Factors · NextGen · Control tower · Cognitive load

1 Introduction and Intent of the Study

The Next Generation (NextGen) air traffic control system for the United States (U.S.) is continuing to implement new technology to accommodate growth of the aviation industry. New control tower equipment and operations by the Federal Aviation Administration (FAA) may affect the airport environment and invites closer examination. This study assessed the FAA Tower Team concept [1] and how air traffic controller cognition is affected in relation to the new technology. Intended gains in safety and efficiency for tower teams could be offset by human error relative to cognitive loading. This is evident in national runway incursion data indicating that tower controllers are the primary cause of runway incursions 18% of the time [2]. Controller incursion error can lead to deadly aviation accidents like at LAX in 1991 when a USAir Boeing 737 landed on a SkyWest commuter on an active runway at night destroying both aircraft and fatally injuring 12 people [3].

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2 Tower Team Analysis Before Computer Automation

The SHELL model by Hawkins [4] used a simple block layout. The tower controller is represented here by the L (Liveware) in the center and surrounded by four other human factors interfaces: S (Software), H (Hardware), E (Environment) and L (Liveware).

The model for the tower control team in Fig. 1 had four working positions where each job encompassed a SHELL component. The data controller's main job in the S-L and H-L connection was to complete flight strips with departing aircraft information. The E-L interface required controllers to update the flight strips with new information. The task was completed in the L-L team linkage by passing the flight strips to ground controllers. In the S-L interface the ground control position had jurisdiction over all aircraft taxiing for takeoff. The H-L connection required that ground control use line of sight and could be aided by ground radar in low visibility. Critical radio communications in clearance directions between ground control, aircraft and ground vehicles were the key to situational awareness in the E-L linkage. Once the aircraft was near the runway, the ground controller would coordinate through radio in the L-L team interface for the aircraft to switch to local control. The tower local controller followed procedures in the S-L interface to safely direct all aircraft for takeoff and landing. This included standardized phraseology and adherence to separation distances for wake turbulence. Regarding the H-L interface, the local controller depended on clear, concise radio communications through the tower radio with all aircraft and line of sight visual contact to the aircraft. This required a high degree of situational awareness in the E-L interface with the local controller constantly scanning the airspace and runway. In the L-L team connection, the local controller needed to be aware of ground control and incoming traffic from approach control. The tower supervisor was responsible for the actions of each position in the S-L interface. This included oversight of shift changeovers and backing up inexperienced controllers. In the H-L connection the tower supervisor listened to all radios and backed up all taxiway and runway operations. In the E-L interface the supervisor managed traffic flow and unexpected emergencies. The supervisor led the team by employing effective communications in the L-L team connection. With different tower positions and limited technology, teamwork and training were essential. Several tenants similar to aircraft CRM (Crew Resource Management) were employed to ensure the team remained connected in the L-L team relationship. Teamwork was an FAA priority. Good communication consisting of standardized aviation phrases and careful listening supported the teamwork. Assertiveness was valued in promoting each team member to speak up. Most importantly, the tower team remained focused on ensuring good situational awareness. The old model relied on training that was supported by a progressive hierarchy starting at the data controller position and moving up to supervisor. The training mandated that each tower position first had to qualify as an instructor at that position before moving up. In this system a model airport was set up and supervisors used model aircraft to physically simulate aircraft moving about the airfield while trainees learned the controller positions.

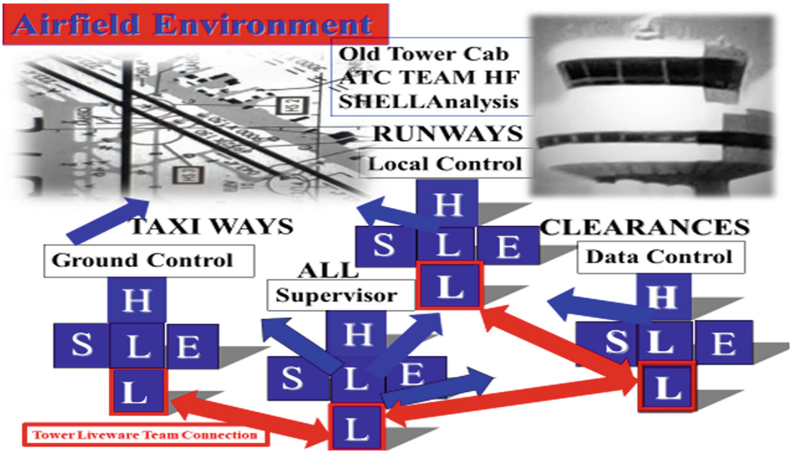

Fig. 1. Tower Controller Human Factors (HF) SHELL analysis based on the model by Hawkins [4] modified to depict the Liveware-Liveware team interface.

3 Tower Team Analysis After Computer Automation

In 2020 the ATC tower has been transformed with digital information and automation for the NextGen system. In Fig. 2 the SHELL 2016 model [5] is updated to account for digitization and crowded interfaces filled with technology. In doing so the previous SHELL model of separate tower positions from Fig. 1 becomes one SHELL as the technology causes all four tower control positions to superimpose upon each other. The same tower positions exist, although technology is transforming the positions into a tighter overlapping team. The automated systems create clouds of technology to replace the direct SHELL linkage interfaces in Fig. 1, thus causing all four linkages of the SHELL to become concatenated. The impact of these technologies on the four tower controllers starts with the S-L interface cloud employing an automated information device known as VIDS (Visual Information Display System). This computer houses all the information relative to tower operations and each controller has their own VIDS to access the same information. The data controller uses it to input the aircraft flight strip data into the National Airspace System while also updating the ADIS (Aviation Data Integration System) information regarding weather, wind data, airfield status, and detailed airfield operations data. Lastly, it has a digital feed from the airfield lighting system and digital video cameras systems that monitor the airfield blind spots and remote airfield operations. In the H-L connection the main hardware in the cloud is the STARS CTRD (Certified Tower Radar Display) and keyboard. A crucial approach control system for NextGen, STARS (Standard Terminal Automation Replacement), has been added to the control tower displays. Visible to all tower controllers, it depicts flight information of aircraft near or in the control tower's airspace. With STARS, the TRACON (Terminal Radar Approach Control) controller can hand off aircraft automatically to the tower local controller. The STARS display increases situational awareness and enables the tower to reduce wake turbulence separation minimums. This enables controllers to expedite takeoffs and landings and reduce aircraft fuel cost. Other hardware in the H-L cloud includes the FIDO (Flight Data Input Operation) flight strip printer, the airfield lighting system and the digital video camera system. The E-L interface now incorporates technologies that overlap from H-L and S-H clouds allowing controllers to manage the environment better. The STARS screen enables all controllers to be situationally aware of aircraft and to locate them visually. The digital video cameras can be monitored by any controller on the VIDS. Through the lighting system certain taxiway lighting or runway lighting can be adjusted. The L-L cloud also feeds into the E-L interface. The Enhanced Terminal Voice Switch (ETVS) creates a tighter overlapping team of tower controllers. All four controllers have an ETVS terminal. Each controller uses one frequency and monitors other controllers' frequencies with touch screens. This enables ground and data controllers to work on the primary ground frequency while monitoring the local controller on the tower frequency. The tower supervisor monitors ground and tower frequencies and has overriding authority. Team members can talk freely, but the final radio call outbound is always recorded.

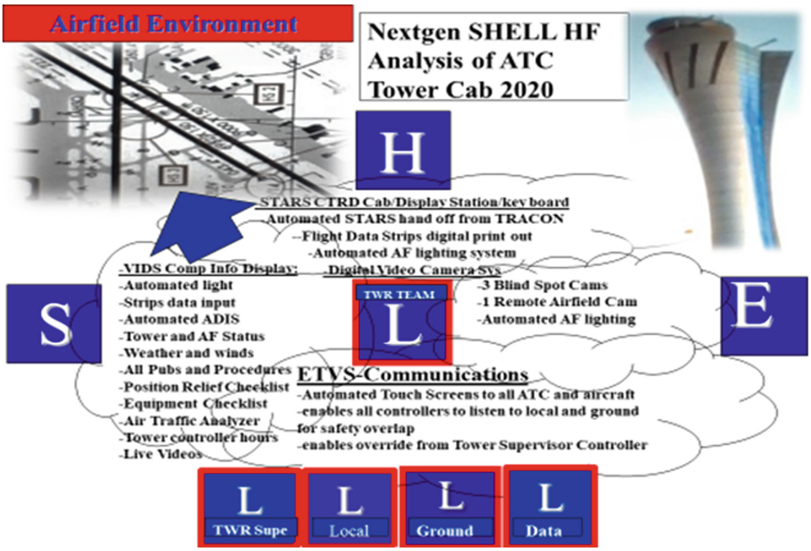

Fig. 2. NextGen Tower Controller Human Factors SHELL Analysis 2020 based on the SHELL 2016 [5] updated for computer information and automation.

4 Other Factors Influencing the Tower Team in 2020

Technology maximizes gains in CRM teamwork from better communications, assertiveness and increased situational awareness. These precepts are further enhanced in a more realistic case study training environment by recordings of incidents from other towers. The training method of qualifying as an instructor in each position has helped ensure that controllers thoroughly understand the different technologies. The most dramatic shift in training from the past is use of a high-fidelity tower simulator. All the positions are equipped with a similar layout of equipment found in the operating tower. The difference is that the simulator tower windows are a realistic virtual view of the airfield.

5 The Next Big Step in NextGen Tower Controller Development

Future elements of the NextGen system in the form of ASSC (Airport Surface Surveillance Capability), CPDLC (Controller Pilot Data Link Communications) and more remote digital videos are coming. The ASSC currently is being tested in the form of ASDE X (using ADS-B out) at 35 major U.S. airports. It would allow the Tower Team to know exactly where all aircraft and ground vehicles are and provide oral warnings of potential runway incursions or ground collisions, however, it adds another display screen to monitor. CPDLC already has proven an effective way to text Departure Clearances to aircraft, but it raises a concern that when used with current communications it may prove distracting for controllers. Digital videos now are used by controllers to monitor blind spots and remote airfields, but the concern remains as to how many extra videos controllers can monitor before their critical scan of the airfield is compromised. These human factors issues invite evaluation from a human cognition perspective.

6 Cognitive Processing Challenges

As seen with the evolution of air traffic control and incorporating new technologies, different behaviors and tasks have modified the cognitive processing challenges for operators. Currently in many air traffic centers, controllers are working simultaneously with existing legacy systems and newer NextGen systems [6]. The cognitive requirements to sustain reliable performance become complex and exclusionary. The authors previously have examined ATC TRACON and STARS functions and discovered cognitive processing limitations and potential areas for closer study that address attention, distraction, and cognitive overload [7]. The Tower Team concept, as established by the FAA [1], further increases situational awareness and cognitive loading. With increasing traffic loads, and tower involvement in runway incursions, concentrated attention on these and other concerns bears immediate assessment for feasible remedies.

Explained earlier, the FAA Tower Team performs three separate, interrelated functions as an integral unit. Team controllers work with the VIDS displaying four separate screens depicting local air traffic, ground environment, data and communications, and remote cameras on the airfield, runway crossings, and helipads. In some locations, controllers direct air traffic operations at multiple remote airfields. Although a controller is not responsible for all the activity seen, they are exposed to it in their continuous scan of VIDS. Controllers also are aware of blind spots in the vicinity that are not captured by cameras or sensors [8]. In addition, they monitor all other transactions conducted by controllers with different assigned tasks. Combined, these engage substantial cognitive processing resources. Consequently, while scanning displays, something that distracts attention and delays their scan can disrupt a train of thought. The potential for conflict or confusion is evident and invites possible overload, even in nominal conditions. A major potential for distraction is when controllers must move to view the large screen mounted above them displaying STARS information.

7 Cognitive Overload

Given the operating environment within the Tower Team, several potential overload situations can arise. With each controller visually scanning all functions, when an unanticipated event occurs they may be uncertain which controller takes the lead. Or, if an anomaly is detected in one of the remote locations, that can disrupt the scan and prospective memory or deferred actions awaiting execution. Where action requires intervention of the supervisor (who can override a controller at any time), this might draw the immediate attention of remaining controllers and divert their scans. Where conditions are nominal, operators can usually function effectively. It is when an emergency or unanticipated event occurs, for example an unauthorized runway crossing, that cognitive overload is likely [9]. Consequences can seriously degrade controller performance.

To assess the potential for cognitive loading issues, a convenience survey (10 items) was administered to 20 Tower Team controllers. Complete results will be published separately. Preliminary findings indicated sometimes or often 75% needed to shift attention, 60% required added time to assess status when re-engaging, and 40% found monitoring digital videos (e.g., remote airfields, helipads, blind spots) intruded upon attention to other tasks. When encountering a diversion from their primary screen, 75% experienced confusion, and, experienced stress in the team environment. However, 85% believed automation did not add to their workload. In a different vein, 85% indicated an automated ground display with warnings of potential collisions or incursions would be of value. Expecting additional NextGen technology regarding digital texting to aircraft, 45% indicated they prefer texting to radios, although 75% believed it would be of benefit as support. The survey results indicate two clear outcomes - first, that there are substantial opportunities for distraction and confusion in the Tower Team environment. And second, controllers are confident in their abilities to manage growing technology applications and they welcome added functions to improve communications. In part, this confidence may be attributed to the advanced training simulators and requirements to operate in each of the positions on the Team. However, the obvious disparity lies in the juxtaposition of these two findings.

As NextGen progresses, new functions and technology, including expanded texting, will arrive. Although limited in practice currently, the use of ADSE-X when implementing ASSC and CPDLC are prime examples of advanced technologies added to controller scan. To achieve balanced tasking and to maintain vigilance of critical functions, implications for CRM tailored for the Tower Team environment are evident.

8 Summary

In the transition from legacy tower operations to continuing development of the Next Gen Tower Team, the potential for disrupted cognitive processing and eventual cognitive overload become clear. As indicated, the functions of local traffic, ground operations, and data transfer and communications are successively building the cognitive processing demands and suggesting thresholds for cognitive overload. As more NextGen functions are implemented, a close examination of effects on controllers is apparent. Likewise, the positive results of superior training and equipment needs to be assessed for possible lessons learned that may apply to other aviation functions.

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Multimodal In-vehicle Touch Screens Interactive System's Design and Evaluation

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Abstract. In pursuit of beautiful, clean, and easing the control platform of numerous buttons, in-vehicle tough screens are arising. However, many studies have shown that, in-vehicle secondary tasks adversely affect driving safety, especially touch screens need a long-time focus but offer little feedback. In this paper, a new design of in-vehicle touchscreens' interface system is proposed. The new design introduced the concept of multimodal (vision, auditory and haptic) and used sliding gestures to interaction. Auditory and haptic are fully utilized to transfer information and provide feedback, attempting to decrease the occupation of vision recourses when driving. This article also conducted a driving simulation experiment to make an evaluation of the design. Experiment data indicated that, the new design can realize eyes free without influencing the accuracy and completion time of secondary tasks, enhanced user experience meanwhile. This design will provide reference to the more intelligent and humanistic vehicle central control touchscreen.

Keywords: In-vehicle touch screen · Multimodal · Interaction design · Driving safety · User experience

1 Introduction

Despite a solid foundation for the national economy and transportation industry has been providing, the rapid development of the transportation system has also caused a lot of traffic accidents and resulted in great casualties and economic losses [1]. Drivers are the main factors in the transportation system. Statistics show that 90% of all the traffic accidents are directly related to drivers [2] and 25%–37% of road traffic accidents are related to the distraction of drivers [3]. On average, drivers will be distracted every six minutes. The main reason for distraction is to adjust the facilities inside the car through the buttons [4], in other words, to do the secondary task through the central control platform.

The intelligence vehicles reduce the driving difficulty, but add more secondary tasks. Mobile phones, navigation and mobile office will make drivers "information overload". Drivers' attention is distributed due to more than one electronic equipment, which is not conducive to driving safety [5–7]. Integration and management of the information is the best way to reduce the risk of driving distraction [5]. In order to use as many electronic devices as possible in the limited space of the car, combining them

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into an integral human-computer interaction interface becomes an inevitable trend. A touch screen, similar to a tablet, can better integrate smart phones and web services into cars.

Touch screen has the advantages of strong expansibility. It can solve the problem relating to increasing buttons while the traditional mechanical key could only hold the post of one function. In addition, the touch screen gained the consumers' affection with the high-tech feeling. The control platform is an important part of the interior decoration of the vehicle. Its appearance, texture and functionality directly affect the quality of the vehicle interior decoration, which has a great impact on customer satisfaction and user experience. Touch screens also meet the people's enjoyment needs. Current drivers are beginning to become more youthful, and many young drivers said they are willing to accept text messages and voice mail in their cars [8].

However, it is undeniable that compared with mechanical buttons, there are some disadvantages of the virtual buttons of the in-car touch screen, which are mainly reflected on the characteristics of poor precision and lack of feedback. Virtual buttons lack muscle memory, a driver cannot distinguish keys through the button's material, shape or fixed position, causing a poor precision. When necessary, the driver has to rely on visual to complete the secondary task. Focusing on the screen for a long time has a great impact on the driving safety. Secondly, lack of feedback from the virtual buttons makes the driver unable to determine whether the button is pressed and whether the instruction is executed, resulting in a much lower user experience. The literature shows that the difference of tactile feedback greatly influences user experience, and good tactile feedback can make task difficulty decrease [9].

Driving is a complicated task characterized by multiple tasks. When drivers do driving-related secondary tasks through in-car touchscreen, how to improve the user experience, meanwhile, distract drivers as little as possible and ensure driving safety becomes a matter of concern. In previous studies [10, 11], researchers have studied the input and output of hearing, touch, but the multimodal concept has not been used in the in-car touch screens to the best knowledge of the author. In this study, we design an interactive system of the in-car touch screen. Besides optimizing the visual design, we add auditory channel and haptic channel to output information as well as providing feedbacks, filling the research blank. The design is evaluated and validated through the simulated driving experiment after completed, at last, this study gives some suggestions for future designs.

2 Methods

2.1 Prototype Design

We exploited an application named "Eyes free" which could be installed in a tablet computer with Android system to simulate in-vehicle touchscreens. In this App, icons with the form of a large-area tile (similar with the windows 8' start interface), was placed in the upper part of the touch screen because the upper part is the same height with driver's glimpse. It is beneficial to the driver operation compared to the lower part. The functions like adjust volume, control air conditioning wind size are traditionally conducted through the “+”, “−” buttons. While they are now replaced by sliding gesture on any position of touch screen, which do not need to gaze to find a specific button and improve the fault tolerance rate (see Fig. 1). For functions such as return and exit, we adopt the method of long-time press (about 2 s) on any position of the screen to return or exit current function without clicking the specific return key. The meaning of gesture is to keep with people’s cognition and to make it convenient for memory. Sliding and long-time press gestures could be completed at any position of the screen with no eye focus, avoiding the driver to find and click on the button, reducing the visual resources utilization greatly.

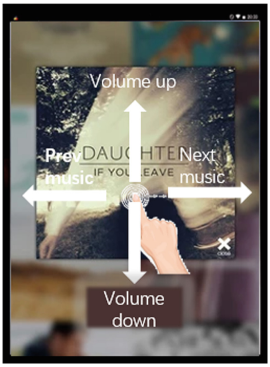

Fig. 1. Sliding gesture interaction

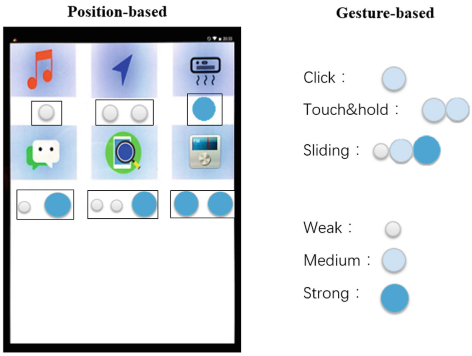

Fig. 2. Vibration schematic diagram

To reduce the occupation of visual resources, our design makes full use of auditory channel to convey information and provide feedback. There will be a voice broadcast to tell drivers what button he has chosen. In addition, there are different non-speech sounds to provide feedbacks after driver’s operation like adjusting volume, return and exit. The auditory feedbacks remind drivers the operation has been completed, enhancing the user experience.

Similar to the auditory channel, we also used haptic channel. We divided the vibration to two groups: position-based and gesture-based. The position-based vibration means the vibration motor will show different vibration intensity and frequency based on the position, in other words, based on the icons. The gesture-based vibration means vibrating differently depend on different gestures such as click, long-time press and sliding. The position-based vibration could convey the information what icon the driver has clicked, and the gesture-based vibration could provide feedbacks to tell the driver that the operation has been executed. In consideration of the in-vehicle touch-screen is not handheld device, based on our experience, it is vibration is hard to detect by our hands. Thus, we choose an external wearable vibrate motor to provide vibration. The vibrate motor communicates with touchscreens via XY-SWFS20 wi-fi module. The different vibration intensity and frequency are controlled by STC12C5A60S2 microcontroller with 9014 triodes and different resistances. In our design, we adopted three obviously distinguishable vibration intensities, defined as weak, medium and strong, to achieve position-based and gesture-based vibration. The schematic diagram is shown as Fig. 2.

2.2 Simulation Driving Experiment Design

To investigate the design's effectiveness, we conducted simulation driving experiments. Driving simulation systems based on human-computer interaction has the advantage of low cost, high safety, designable scene and repeatable experiment. We designed both highway and city driving simulated tracks using UC/win-road. For the highway, its speed limitation is 100 km/h with six-lane in both directions while for the city track, its speed limitation is 40 km/h with four-lane in both directions. The participants used a Logitech G27 steering and foot pedals to control their vehicle. The participants were required to drive without changing lanes and complete the secondary-tasks via touch screens during the driving. The secondary-task instructions like "Open the air conditioner", "Play music", "Turn the volume up" will appear on the top of screen in text meanwhile verbal form during the driving.

The whole experiment was divided into five trials. The first and the last trial were completed in non-driving condition. In the first trial, participants only operate the in-vehicle touchscreen using vision, no auditory and haptic channel. It is a blank experiment, which data of task-completion time could as a baseline. In the second trial, visual and auditory channel were provided to test the effect of auditory channel while in the third trial, visual and haptic channel were provided to test the effect of haptic channel. In the fourth trial, all the channels were provided to test the multimodal effectiveness. For the trial 2, 3, 4, a Latin square design was used to arrange the order to avoid the sequence effect. At last, participants would be blindfolded using an eyeshade to complete the last trial only using auditory and haptic channels. The fifth trial is to test whether multimodal design is effective in extreme cases, whether it can liberate the eyes of the driver, and realize the eyes free. During the driving, we used SmartEye AB, a camera-based eye tracker, to record the participant gaze fixation points and the duration of their gaze fixation in milliseconds (ms).

2.3 Procedure

Each participant completed five trials mentioned above, and the whole experiment lasted 1 h on average. With participant consent and pre-test questionnaire including general demographics and previous experience completed, participant seated in the simulator seat and adjusted to a comfortable position. After that, under the help of experimenter, the participant would be familiar with the operation of in-vehicle touchscreens (A tablet PC with the app "Eyes free"), feel the different intensity and frequency of vibration. Then, the experimenter demonstrated the functionality of the wheel and pedal set, then, allowed participants to drive a practice track till they could successfully control the vehicle. The last two minutes' data will be used as a benchmark to evaluate their driving levels and behaviors. Before the formal experiment, participants were fitted with the eye tracker and gaze calibration was adjusted for each participant.

Participants were told the aim of the experiment is to complete the secondary-task under the premise of ensuring the safety of driving, if possible, to use vision as little as possible during the operation of the touch screen. In addition, the experimenter instructed participant to obey speed limits, avoid collision, and maintain vehicle in the specific lane without changing lanes when driving. The entire experiment process will be videotaped by the camera for research purpose only.

3 Results

We recruited 23 participants who have a valid driver's license from campus, 14 males and 9 females with an average of 22 years old (SD = 4). All of them had more than one year's driving experience, and have had using touch screen phones or tablets more than three years, nearly half of them using more than five years. Only one of the 23 participants was left-handed, and the rest were right-handed.

3.1 The Accuracy and Completion Time

The accuracy of secondary tasks was recorded by the experimenter in the process of the experiment. When complete the secondary tasks, drivers are allowed to make an error as long as they correct it in time. As long as they complete the task independence finally, it is deemed right. The correction process will be reflected on the completion time. The Raw data show that the accuracy of secondary tasks was more than 95% under different experimental conditions, indicating that the interactive design of the in-vehicle touch screen is easy to learn and easy to operate.

The completion time was analyzed from video after the experiment, and the time was accurate to milliseconds. We only compared the completion time of trial one and trial five, because the secondary task instructions in these two trials were exactly the same. The main difference between the two trials was whether to use vision. On average, in trial five, participants used 1.112 s for each task (SD = 0.040 s), which is a little longer than trial one (M = 1.048 s, SD = 0.033 s), however, the t-test result did not show a significant difference between these two trials ($p = 0.367$). Also, there was no significant difference between these two trails ($p = .819$) in terms of accuracy.

3.2 Lane Deviation

To better assess driver distraction, we measured participants' lane deviation. Lane deviation was acquired from UC/win-road driving logs. As prescribed by the experimenter, drivers could not change lanes, so the lane deviation value should be between $[-1, 1]$. The value which is greater than 1 because of the unexpected situation will be eliminated. Because each driver's driving habits were different also the vehicle starting position was different, we calculated the root mean squared error (RMSE) of lane deviation instead of raw data to measure stability of the driver's lateral control. A repeated measures ANOVA was conducted to analyze the effects of Trial (2, 3, 4) on lane deviations. Although, the average in trial 4 is smaller than trial 2 and 3, there was no significant main effect of trial on lane deviations.

3.3 Glance Time off Road

Due to limitation of the eye tracking software, gaze data could not be reliably collected from participants wearing eyeglasses. Therefore, the glance time off road was composed of 15 participants. Trial 4 shown much lower glance time off road than trial 1. A paired-samples t-test suggested a significant difference ($p = .000$) in glance time off road between trial 4 ($M = 0.397$ s, $SD = 0.021$) and trial 1 ($M = 0.934$ s, $SD = 0.102$).

3.4 Perception Questionnaire

Participants completed an online questionnaire at the end of the experiment. The responses ($N = 23$) were summarized in Table 1 and covered four categories: satisfaction with page design (icon size, spacing, aesthetic), satisfaction with interactive design (sliding gestures, long-time press), satisfaction with audio channel, satisfaction with haptic channel.

Table 1. Data of satisfaction. (Five-point Likert Scale, 1 = Most negative, 5 = Most positive)

	Page design	Interactive design	Audio channel	Haptic channel
Mean	4.26	4.62	4.62	3.83
SD	0.85	0.71	0.56	1.09

4 Discussion

In general, the data of accuracy and completion time between trial 1 and trial 5 shown that the design of multimodal in-vehicle touchscreen could achieve "eyes free". Even if do not use vision, with our multimodal design, the accuracy will not decrease, meanwhile, the completion time will not change significantly. The average glance time off road of each task in trial 4 was 0.397 s, which is lower than the recommended maximum time (1.5 s) spent looking at an input device [12], thus, there will have no significant impact on traffic safety. Furthermore, data collected from the post-test questionnaire gave us participants' opinions of each channel. Most of participants were satisfied with the multimodal design expect the haptic channel was rated a little lower. At same time, the RMSE of trial 3 (Haptic channel-only) was higher than trial 2 and 4. We suspect that it will occupy cognitive resource when decode the information conveyed by vibration, consequently, affecting the driving performance [13].

Due to the limitation of eye tracker, we eliminated 8 participant's data. This may have had an impact on our glance time off road. However, we were still able to analyze gaze data from over 65% of the participants. In addition, the number of participants was small and they were mainly youth. Maybe in the future we will do more experiments to cover more people. Although driving simulators are routinely used as a research tool in traffic psychology and its validity has been accepted, there is a great difference between simulation and reality such as no risk and low user experience.

By evaluating our design with simulation driving experiment, we could conclude that, completing secondary task with multimodal touch screens could not have an influence on driving safety, meanwhile, improve the user experience. Based on our results, we propose two recommendations for the in-vehicle touchscreen design:

- Sliding gestures should be adopted which could improve the fault tolerance rate and decrease distraction comparing to finding a specific icon;
- Provide audio and haptic feedback to tell the driver what the icon he has clicked and whether the operation has been executed, which could improve the user experience.

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Using VR Generated Pedestrian Behaviors in Autonomous Vehicle Simulations

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Abstract. Simulation is a requirement for the safe and effective deployment of autonomous vehicle software given the wide range of possible scenarios which a vehicle can experience. These simulations need to accurately represent interactions with not just other vehicles, but also pedestrians. Humans often do not move in a perfectly linear way when interacting with the objects around them. Their position and rotations change as their focus and interest is piqued in various directions. Data collected by Deb et al. shows pedestrians in VR do not react the same to autonomous vehicles as they do to manned vehicles. Therefore, it is not suitable nor desirable to use straight line paths with pedestrian animations in simulation environments. In this experiment, we leverage the position and rotation data collected by Deb et al. during VR pedestrian crosswalk studies as a source for realistic pathing behaviors for animated pedestrians in the Mississippi Autonomous Vehicle Simulator.

Keywords: Modeling and simulation · Pedestrian behavior

1 Introduction

Simulation is widely accepted as a requirement for the safe and effective deployment of autonomous vehicle software given the wide range of possible scenarios which a vehicle can experience. It is not physically possible to test the software of autonomous systems across all possible subsets of situations it might encounter. It is for this reason that most autonomous vehicle developers leverage simulation systems. These simulation systems, running millions of calculations per minute, present a variety of scenarios to simulated autonomous vehicles. Among the scenarios which need to be accurately represented are interactions with pedestrians. This interaction with pedestrians presents a challenge for those seeking to use simulation to develop and test autonomous systems. Traditional methods for simulating pedestrian behavior are typically limited to straight-line behaviors which are typically observed when a pedestrian crosses the road in front of a vehicle. However, pedestrians, when presented with the task of crossing a busy intersection, do not take a linear path when crossing in front of a vehicle. This

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paper outlines the extension of a high-fidelity physics-based simulation library developed at the Center for Advanced Vehicular Systems (CAVS), known as the Mississippi State University Autonomous Vehicle Simulator (MAVS) to include new pedestrian crosswalk behaviors consistent with those seen by participants in VR when presented with an autonomous vehicle.

2 Related Work

The Euro NCAP test protocol for automatic emergency braking (AEB) is a test protocol designed to evaluate the effectiveness of automatic braking safety features to protect pedestrians [1]. This test protocol focuses on different scenario which are used to test AEB systems on new vehicles. Within this protocol, one scenario faced by vehicles being evaluated is a pedestrian crossing the road. The pedestrian in the test scenario, moves across the street along a pre-determined linear straight-line path. This simple trial shows the ability of systems to automatically break in time to prevent a collision with a pedestrian. As autonomous systems become more proactive, AEB systems like these will continue to play an important role in safety. However, additional functionality through intelligent system analysis will become necessary as autonomous vehicles move through high density pedestrian areas where the task turns from emergency breaking to anticipating human behavior. Humans often do not move in a perfectly linear way when interacting with the objects around them. Positions and rotations of pedestrians can change when something captures their attention. This form of non-verbal communication through can provide insights into the actions a person might take as different objects enter their focus. Deb et al. has previously shown that when pedestrians in Virtual Reality (VR) are presented with a crosswalk scenario in which they must cross an intersection as an autonomous vehicle approaches the stoplight, these pedestrians often do not move in a straight line [2]. As participants approach the vehicle and notice there is no operator in the traditional driver's seat, they move away from the vehicle to provide a larger buffer zone. This movement profile is evident in the position and rotation tracking data for these pedestrians. Understanding that pedestrians often change their planned path, deviating from a straight line when encountering an autonomous vehicle is important. Given that data collected by Deb et al. shows pedestrians in VR do not react the same to autonomous vehicles as they do to manned vehicles, it is not suitable nor desirable to use straight line paths with pedestrian animations in large simulated testing environments. In this experiment, we leverage the position and rotation data collected by Deb et al. during VR pedestrian crosswalk studies in order to provide better pathing for animated pedestrians in the MAVS (Fig. 1).

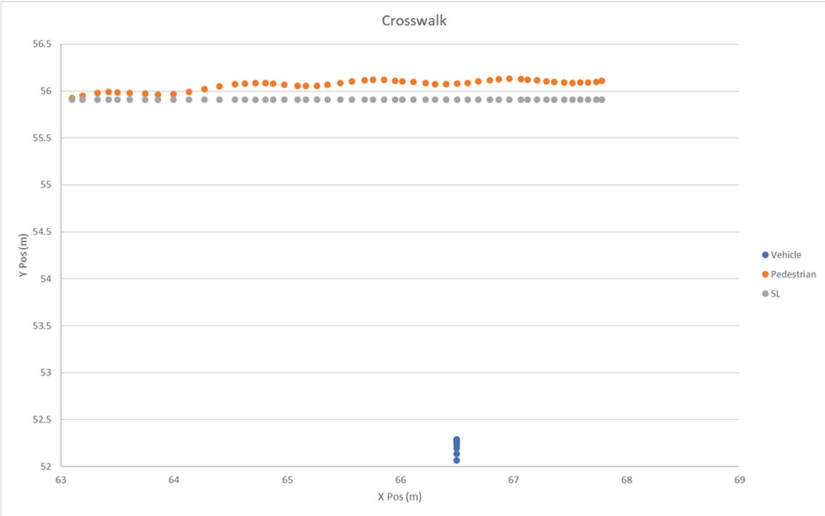

Fig. 1. Example data file highlighting the non-linear nature of a pedestrian's movement when presented with an autonomous vehicle.

The MAVS was developed to provide a library which would enable high-fidelity sensors simulations based on physics [3]. A large portion of simulation environments in use today leverage game-engines such at Unreal Engine 4 or Unity. These simulations are designed to look good visually but often the sensor and environment physics are not realistic. As a simulation library, MAVS provides a wide variety of features for simulating autonomous vehicle. These features include real-time sensor simulation, High Performance Computing (HPC) compatibility, multiple vehicle dynamics, automated off-road terrain generation, ROS integration, a python API, and automated data labeling. MAVS enables real-time sensor simulation by leveraging Intel's Embree ray-tracing kernel. MAVS supports both Linux and Windows distributions and can leverage HPC capabilities in order to run batch simulations to account for thousands of different environmental conditions. Vehicle dynamics in MAVS can use the built-in RP3D dynamics model or leverage any other model one wishes to use via co-simulation. Built into MAVS are numerous tools for creating off-road environments based on a variety of environmental inputs. Several different ecosystems can be selected, and plants from that ecosystem are procedurally place within the environment. These plants then undergo a growing period where the plants growth is simulated, and an ecology model determines how well plants grow or die. By leveraging this automatic ecosystem generation, thousands of environments can be quickly created and tested against for any system. Environmental features such as terrain roughness, night/daytime with an accurate celestial model can be generated and changed for each environment (Fig. 2).

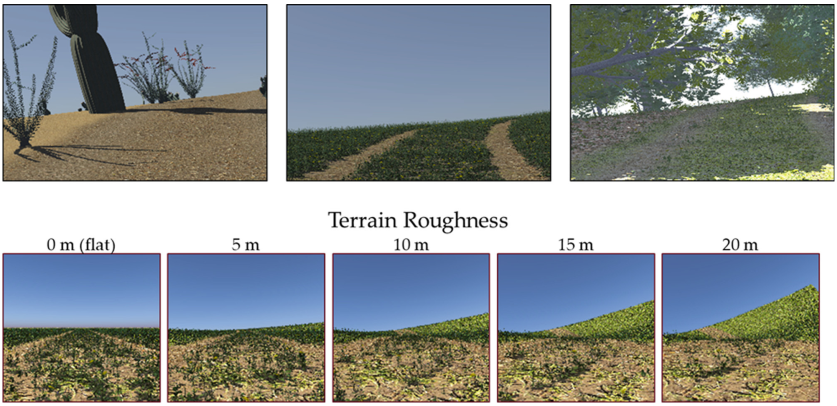

Fig. 2. Example of different ecosystems and terrain roughness in MAVS.

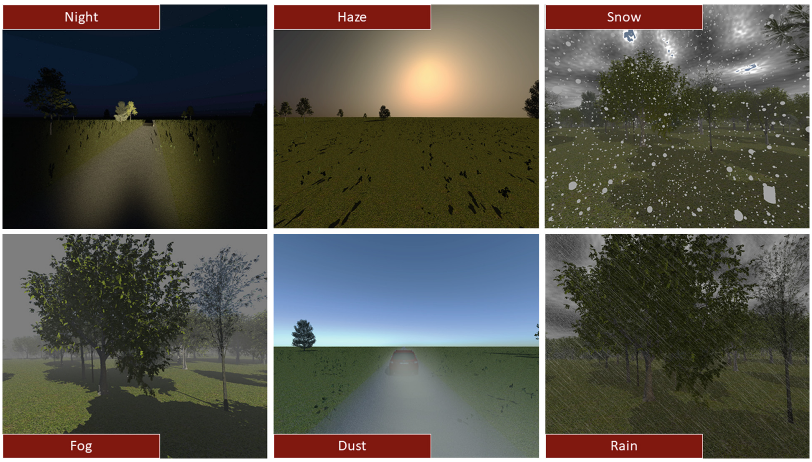

Fig. 3. Example of different environmental conditions within MAVS.

Additionally, weather conditions such as haze, snow, fog, dust, and rain can be simulated, with a variety of intensities [4]. Interaction with the MAVS is simplified due to a python API. Additionally, the MAVS supports publishing sensor and vehicle data to the Robot Operating System (ROS) (Fig. 3).

3 Methods

Source data provided by Deb et al. was collected in a Virtual Reality crosswalk simulation environment [2, 5]. This crosswalk experiment had participants cross a busy street at an intersection when an autonomous vehicle approached the crosswalk zone. From this experiment, position and rotation data was recorded for each crosswalk scenario experienced by the participants. Using the MAVS as a simulation environment, positional and rotational data was processed in a python script to provide a format which was suitable to use within MAVS. These poses were used to update a pedestrian model and a vehicle model.

The sequence of pedestrian data was used to present pedestrian data to a large vehicle in simulation. The simulated vehicle was equipped with a single 64 beam Ouster OS1 lidar and a simple RGB camera on the hood of the car. Both sensors where approximately 5.57 ft (1.7 m) off the ground. The vehicles position and the pedestrian's position were updated accordingly at each time step. Simulated lidar and camera data were stored for replay and analysis (Fig. 4).

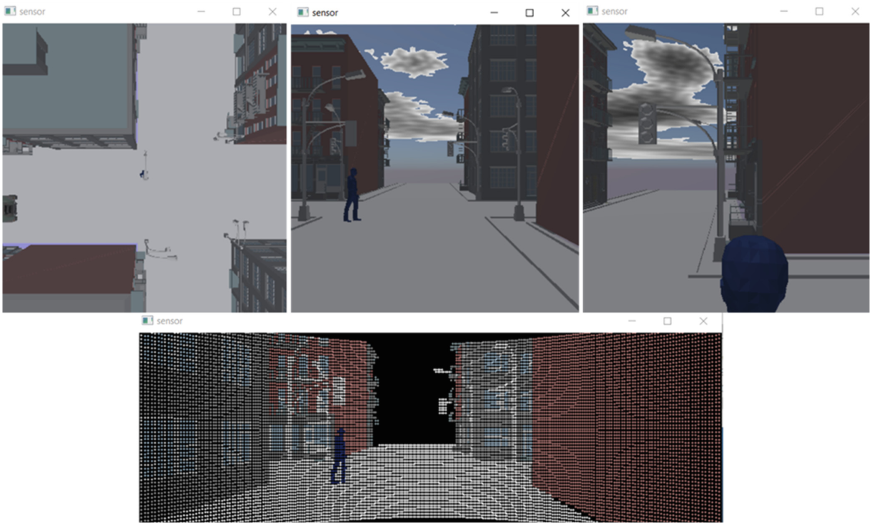

Fig. 4. Images of Pedestrian simulation in MAVS (Top down, Vehicle View, Pedestrian View, Lidar on Vehicle).

4 Conclusions

This work relates the initial stages of implementing nonlinear paths for simulated pedestrians based on data collected from participants in a simulated crosswalk environment in VR. The data provided from these experiments have shown that pedestrian behavior when presented with an autonomous system is not consistent with the straight-line model widely adopted. By leveraging this implementation of nonlinear pedestrian movement, future experimentation can investigate the effects of realistic pedestrian movement on standardized advanced driver-assistance systems (ADAS) such as the NCAP test suite [1]. Additionally, by providing a realistic movement model of pedestrians, systems which seek to use non-verbal communication expressed through movement behavior can be tested and developed using MAVS.

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Interaction Design in Educational Applications

Development of Real-Time Learning Analytics Using Scraping and Pivot Tables

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Abstract. In a PC classroom attended by a large number of students, the author conducted a face-to-face, blended lesson using Moodle and proposes a method to efficiently analyze student learning logs. The system (TSCS Monitor) allows the user to visualize the analyzed results in a time-series presented in both table and graph form. In this paper, real-time processing using scraping was integrated to the above functions in order to reduce the burden of system operation on the teacher and obtain analysis results faster while conducting classes. With the integrated scraping function, it is now possible to automatically download Moodle course logs. Teachers can check the clickstream of course materials in real-time in a time-series cross-section table simply by starting TSCS Monitor during class. The author tested the system, released the analysis results to the students, and assessed the effects on the students via a class evaluation questionnaire.

Keywords: Real-time · Learning analytics · Scraping · Visualization · Time-series · Cross-section · Pivot table · Moodle

1 Introduction

Recently, research and development has been carried out on ways to compile and access information useful to teachers and learners by analyzing classroom data collected by CMS (Course Management Systems), LMS (Learning Management Systems) and e-book in real-time [1]. For a class conducted in a PC classroom and attended by a large number of students, the author has created a face-to-face, blended lesson using Moodle and applied a method to analyze the learning logs of the students [2]. The system (Time-Series Cross-Section; TSCS Monitor) developed by the author is based on VBA (Visual Basic for Applications) and works with Excel [3].

TSCS Monitor analyzes course material clickstreams from various perspectives using Moodle course logs and a pivot table, and allows the user to visualize the analyzed results in a time-series presented in both table and graph form. In this paper, real-time processing using scraping was integrated to the basic functions of TSCS Monitor in order to reduce the burden of system operation on the teacher and obtain analysis results more quickly while he/she is conducting the class. With the added scraping function, it is now possible to automatically download the Moodle course

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logs. Teachers can check in real-time the course materials clickstream in a time-series cross-section table simply by starting TSCS Monitor during class.

2 Related Research

Research and development focused on producing effective ways to improve lessons and teaching materials from accumulated learning log will continue to be conducted and expanded. Such research is called educational data mining (EDM) or learning analysis (LA). Research and development efforts seeking to provide teachers and learners with real-time feedback based on an analysis of learning history data collected by CSM/LMS, etc., to support teachers in the construction and presentation of lessons and to enhance the educational effects of learners are clearly important.

A system called E2Coach at the University of Michigan also sends messages to students based on their course score data. These messages motivate students to take the actions necessary for success, reminding them, for example, to ensure sufficient time to prepare for the next exam [4]. Course Signals at Purdue University is an early-intervention system developed to provide real-time student feedback based in part on student records accumulated in Blackboard and past learning logs. The system evaluates the learning behavior of students and provides ongoing feedback in the form of personalized emails from the teacher; it also uses a colored signal light to indicate how the student is doing [5].

Hardy and colleagues developed a tool to track student browsing situations by using supplementary online teaching materials for students who registered for face-to-face blended classes in introductory physics and measured the results of final exams and resits [6]. May et al. developed a system with a user interface that enables real-time tracking of group discussions in language learning and visualizes each student's interaction level with a radar chart [7]. GISMO, an interactive monitoring tool, was developed as a plug-in system for Moodle and today is used by many Moodle users. By installing GISMO into the Moodle reporting tool, Moodle course administrators can analyze student access activity by specific materials and resources, the number of times a student accesses a forum, and quiz results [8].

3 Real-Time Feedback and LA

3.1 Real-Time Feedback in Class

In this case, as a prerequisite to real-time feedback, a class in which dozens to hundreds of learners browse the course materials from a CMS using a web browser is used. Each student is expected to participate in the lesson while reading the course materials on a PC, tablet or smartphone, and to answer quizzes and questionnaires. If the data collected by CMS can be fed back in real-time, with analysis results for each individual, for the entire class, and for each of the course materials, it is expected that this will produce a supportive effect on teaching and learning. For example, by analyzing the browsing status of course materials in real-time, the teacher can see if a large number students are late in opening the course materials, and can prompt the class to open the course materials at a slower speed. The teacher can then wait for as many students as possible to open the materials.

Furthermore, even in a class with many students, it is expected that the teacher can be more focused on the class by notifying the learner in advance that the teacher grasps his or her individual learning state accurately. In addition to identifying learners who are not sufficiently engaged in class, it is also possible for the teacher to review the course materials that have been delayed and those before and after these materials. Furthermore, analytical data and knowledge are made available that might encourage the teacher to reconsider the contents of the teaching methods and better course materials may be obtained.

3.2 Scraping and Preprocessing for Pivot Table

The purpose of scraping in this paper is to support classes conducted using Moodle in real-time; it was mainly developed to automate the following two processes: (1) automation of the operations, from logging in to Moodle to downloading the stored course logs; and (2) generation of time-series cross-section tables and graphs for browsing the course materials from the downloaded course logs and visualizing the browsing status of the course materials. The details of scraping vary depending on the programming language and browser used. Here, IE (Internet Explorer) was used as the browser to download the Moodle course log in this paper. Furthermore, VBA was used for Moodle operations, from logging in to Moodle to downloading the course log, and for preprocessing the downloaded course log to generate time-series cross-section table and graph.

For this paper, we developed a scraping program using VBA to perform real-time analysis during class. The following shows the scraping procedure, from starting IE to downloading the Moodle course log, generating the time-series cross-section table and graph by the TSCS Monitor, and the corresponding automatic transition of the screen.

(Step 1): Start IE and open the Moodle login screen. (Step 2): Enter your username and password, and log in to Moodle. (Step 3): Open the course entry page. (Step 4): Open the page to download the course log. (Step 5): Select the course name and all participants. (Step 6): Select “Today…” from the date for performing real-time analysis during class. (Step 7): Select all activities, all actions, all sources, and all events. (Step 8): Click the “Get these logs” button. (Step 9): Use the slider to move to the bottom of the page. (Step 10): Select Microsoft Excel (.xlsx) to download the table. (Step 11): Click the download button. (Step 12): Click the “Save” button to save to the specified folder. (Step 13): Click “Open folder”. (Step 14): Preprocessing for Pivot table. (Step 15): Generation of time-series cross-section table and graph.

4 Collection and Analysis of Learner Data

4.1 Learner Data Collection Using Moodle

For this paper, we used a personal computer classroom capable of accommodating 60 people and conducted a face-to-face lesson. We attempted real-time feedback in a situation where students learned while browsing course materials on Moodle according to the teacher's instructions. While browsing the course materials on Moodle, the teacher also used other software such as Excel. Learning logs were collected for analysis in the course "Introduction to Social Data Analysis," which the author is in charge of at the university. Students learn the basics of Word and Excel in advance.

In the course, computer-literate students use personal computers. First to fourth year students are eligible enroll. At the time of the study, 56% of the students were males, 44 were females; the age range for most of the students was from 18 to 22 (2019 Fall). The content of the lessons is an introduction to statistics using Excel. Learning takes places over 15 weeks, starting with Excel's basic operations, representative values, variance, standard deviation, simulation, frequency distributions and pivot tables, attribute correlation, covariance, correlation analysis and regression analysis.

Course materials are mainly created in PDF files: 12 chapters, 112 sections, 10 external URL. The B5-sized PDF file for all course materials are 154 pages. The course materials were divided into 112 files; headings were attached to chapters and sections, and uploaded in Moodle's topic mode. When uploading in topic mode, the name of the entered topic is recorded in the Moodle log. In this paper, since the name of the topic is the name of the chapter of the course material, we made it possible to display in the log which course materials the student opened.

4.2 Learner Data Release for Experiment

In the fall semester of 2019, we generated a time-series cross-section table in real-time using the proposed scraping function while conducting the class. In the first class of the course, students register themselves in Moodle. At that time, the students are instructed on how to view the course materials on Moodle. At the same time, it is explained that when the students browse the course materials on Moodle, their histories are being recorded. This paper features the data collected in a lesson using the course materials on Moodle conducted on December 18, 2019. The course log was downloaded in Excel format from Moodle, and a time-series cross-section table was created using the scraping and TSCS Monitor described here.

The time required to complete the generation of the time-series cross-section table from the Moodle course log was approximately 33 s for a normal lesson, including a 5-min quiz. The time required for the final quiz was approximately 44 s. For the final quiz, the processing time was prolonged due to the concentrated clicks, indicating that further improvement is needed.

In the final lesson of the semester, we distributed a class evaluation questionnaire. At the same time, we released an analysis table of the course material log to the students and asked for their opinions. The names of the student respondents were kept anonymous so that individuals could not be identified. In the lesson, we explained the importance of the frequency distribution and the pivot table, and everyone examined the creation of the frequency distribution table using a pivot table. Each student could manipulate the pivot table and view the course material log from several viewpoints. The Excel file released to students included tables and graphs compiled for each student and the course material log for every minute, every two minutes, and every three minutes. In all, there were 13 worksheets (Fig. 1).

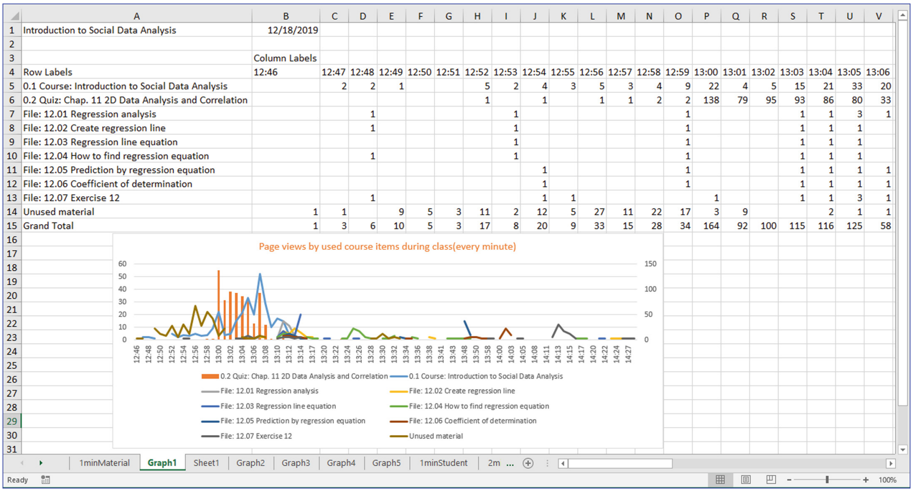

Fig. 1. Partial results of the analysis of the course material clickstream presented to students

5 Experiment and Discussion

The aim of the experiment was to analyze student attitudes toward teaching by sharing the course material logs of Moodle. Questions covering a number of areas were included: the participation of the teachers, the course materials, the quizzes, the course material log, the class as a whole, etc. The anonymous survey responses were collected using Moodle; the students were told that the results would not affect their class score. Prior to asking for their responses, the teacher (author) explained to all the students how to operate and how to view the list of course material logs using the pivot table.

Table 1 lists the questions on the class evaluation questionnaire and gives a summary of student responses. There were 47 attendees on the final day; all of them responded to the questionnaire. The majority of the respondents were in years 1 to 4; several were in year 5 or higher.

From a simple tally of the responses in Table 1, the following can be observed: For the item “Did you concentrate on the class?”, 78.26% of the responses were positive (“Agree” or “Somewhat agree”). For the item “Did you understand the contents of the lesson?”, 53.19% of the responses were positive (“Agree” or “Somewhat agree”), while 29.79% of the responses were neutral (“I cannot say either”) and 17.02% were negative (“I did not think so” or “Somewhat disagree”).

Table 1. Questionnaire items and class responses (Introduction to Social Data Analysis conducted on December 18, 2019).

	Questions	Responses 1	2	3	4	5			
		I do not think so	Somewhat disagree	I can not say either	Somewhat agree	Agree	Total (N)	Mean	SD
1	Did you concentrate on classes?	0.0%	6.5%	15.2%	41.3%	37.0%	46	4.087	0.890
2	Did you understand the contents of the lesson?	4.3%	12.8%	29.8%	36.2%	17.0%	47	3.489	1.061
		10-20%	30-40%	50-60%	70-80%	90-100%			
3	How much did you read the course materials of the class?	0.0%	4.3%	10.6%	31.9%	53.2%	47	4.340	0.841
4	Did you read and understand the course materials used in the lesson?	4.3%	10.6%	31.9%	31.9%	17.0%	45	3.489	1.058
5	Do you think it is good to release the analysis table of the course material log to the students?	2.2%	8.7%	23.9%	30.4%	34.8%	46	3.870	1.067
6	Do you think releasing the analysis table of the course material log to the students will cause them to become more focused?	4.3%	19.1%	31.9%	17.0%	27.7%	47	3.447	1.212

As indicated here, nearly 80% of the students felt that they could concentrate on the lessons, while little more than 50% felt that they could understand the contents of the lessons. Therefore, it is suggested that there is a factor for concentrating on the lesson other than understanding the content of the lesson. However, Spearman's correlation coefficient for the responses to the two questions was 0.704 ($p = 0.00$, $p < 0.05$), indicating a fairly strong positive correlation.

For the question "Do you think it is good to release the analysis table of the course material log to the students?", 65.22% of the responses were positive ("Agree" and "Somewhat agree"). For the item "Do you think releasing the analysis table of the course material log to the students will cause them to become more focused?", 44.68% of the responses were positive ("Agree" and "Somewhat agree"). However, 19.15% of the respondents answered "Somewhat disagree". The responses to the two questions here appear to be scattered (other than for "I do not think so"). However, Spearman's correlation coefficient for the responses was 0.553 ($p = 0.00$, $p < 0.05$), indicating a positive correlation. Students who think that it is good to show the list of the click-stream of the course materials to the students tend to feel that it will make them concentrate more on the class.

Spearman's correlation coefficient for the responses to the two questions "Did you understand the contents of the lesson?" and "Do you think it is good to release the analysis table of the course material log to the students?" was 0.596 ($p = 0.00$, $p < 0.05$), indicating a positive relationship. It is likely that students who could not understand the contents of the class had a negative impression regarding the release of the list of course logs.

In the questionnaire, we also asked students to indicate the percentage of the materials uploaded on Moodle that they had read. Table 1 shows the responses. As can be seen in the table, 31.91% of the students indicated that they had read 70–80% of the materials and 17.02% answered that they had read 90–100%, which means that 48.94%

of the students had read 70% or more of the course materials. On the other hand, 46.81% of the respondents read less than 60% of the course materials. In class, one monitor was available for every two students, and the teacher's explanation was given while presenting the course materials, which appears to have influenced the way the class proceeded. However, it seems that there are other factors causing students not to read the course materials.

Finally, Spearman's correlation coefficient for the questions "Did you understand the contents of the lesson?" and "How much did you read the course materials of the class?" was 0.413 ($p = 0.011$, $p < 0.05$), which is indicative of a positive correlation. This suggests that some of the students who did not understand the content of the class did not read many of the course materials, implying that they had a reasonable tendency based on the class format described in this paper.

6 Conclusion

In this paper, real-time processing using scraping was added to the basic functions in order to reduce the burden of system operation on the teacher and to obtain the analysis results faster while conducting classes. With the developed scraping function, it is now possible to automatically download Moodle course logs. Furthermore, teachers can check the click stream of course materials in real-time in a time-series cross-section table simply by starting TSCS Monitor during class. We conducted an experiment to show the results of real-time cross-section analysis of the clickstream of course materials in class to the students in actual classes. The results of the effects and impressions given to the students by the class evaluation questionnaire are summarized.

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Phonological Awareness Intervention and Basic Literacy Skill Development with Kiteracy-PiFo

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Abstract. Phonological awareness refers to a global awareness of the sound structures of speech and the ability to manipulate those structures. Children with phonological awareness problems may have difficulty associating environmental sounds with appropriate objects and they generally do not play with sounds. This paper describes the manufacturing process of an educational kit to strengthen phonological awareness skills. Kiteracy-PiFo is a kit based on the literacy method Picto Phonic (PiFo), which is made up of one teddy bear with a built-in RFID reader and 30 tags that represent the letters of the alphabet. The kit was designed to carry out a longitudinal study in order to evaluate the effectiveness of interventions for children between 5 and 6 years old. In the manufacture of the kit participated 70 students, 5 from Computer Science Career, 20 from Digital and Multimedia Design Career, 45 from Psychology Career and 30 from Master in Education, mention Innovation and Leadership. All of them worked with 7 teachers who guided the development and intervention activities. A total of 25 kit were built, 5 of which were destined at 5 schools in Cartago-Costa Rica, 10 schools in Quito-Ecuador and 10 schools in Ambato-Ecuador. These kits were used to work on the development of phonological awareness with 667 children.

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Keywords: Phonological awareness · Kiteracy-PiFo · RFID technology · Literacy skills

1 Introduction

The phonological awareness allows children to recognize and use the sounds of language. In preschoolers it means being able to identify words that rhyme and phonological awareness, vocabulary development, and fluency in letter naming. For this reason, early psychopedagogical intervention is important in children aged 5–6 years [1]. This study investigated the effectiveness of interventions for pre-schoolers children through an interactive system. The system called Kiteracy-PiFo is based on the literacy method Picto Phonic (PiFo), which focuses in the grapheme-phoneme correspondence rules. The purpose of this system is to enhance interaction thought an instructional technology to develop phonological awareness. The system uses RFID (Radio Frequency Identification) technology, which is a form of wireless communication that is used to identify tagged cards by a reader. The RFID reader is embedded in a teddy bear in order to hide technology and strengthen the task through storytelling and educational strategies. The teddy bear of Kiteracy-PiFo uses a USB cable for the connection to the computer. A program developed in C# identifies the code of each card and visualize the information. The screen shows an animation of the bear pronouncing the phoneme and explaining the stroke of the letter. Each letter corresponds to the Spanish alphabet, including the letters “ch”, “ll”, “ñ” and “rr”. The system also includes memory and association activities through games and riddles.

The Kiteracy-PiFo was designed to evaluate the effectiveness of PiFo method incorporated with technology. To carry out this experimental phase, 25 kits were manufactured, 5 of which were destined at 5 schools in Cartago-Costa Rica, 10 for public and private schools in Quito - Ecuador and 10 for schools in Ambato - Ecuador. In Costa Rica participated 211 students of 10 schools, 5 of them were randomly selected for the control group with 104 students and the rest for the experimental group with 107 students of 5–6 years old. In Ecuador the intervention was carried out with a pre-test and a post-test thought PECFO test (Test of Phoniligical Awareness - Prueba de Evaluación de Conciencia Fonológica). In the study participated 300 students in Quito and 250 students in Ambato. In both cases students between 5 and 6 years old. To determine the effectiveness in the learning of phonological awareness with Kiteracy-PiFo a longitudinal study was carried out during a year. The strengths and weaknesses were observed, referring to the expected average achievements per school year, according to the scales for Costa Rica and Ecuador, countries where the main authors come from. The results obtained allowed to determine that the application of Kiteracy-PiFo contributes to strength phonological awareness learning and understand the acquisition of reading skills. These findings hold important implications for education and development in reading pedagogy.

The rest of this article is structured as follows: Sect. 2 details the background and related work, Sect. 3 presents the method used, Sect. 4 presents the results and discussion, and finally, Sect. 5 presents the conclusions and future work of this research.

2 Background

The research presented in this article is based on a preliminary studies carried out in Costa Rica and Spain, in which a prototype of a kit based on tangible objects was made, in order to Down syndrome children can develop language skills, attention, perception, memory, abstract thinking and of motivation [2]. Kiteracy-PiFo is a new version of the prototype focused to develop phonological awareness skills for 5–6 years old children. The main feature of the kit is the use of a teddy bear in order to generate motivation through playful strategies.

Studies show that the play is part of children's daily life and it is an important aspect of their development because it promotes not only entertainment, but also influences the psychological, physiological and social development of children [3, 4]. In this context, Kiteracy-PiFo introduces playful strategies to the classrooms with the support of technology. The goal is to reinforce the PiFo literacy method, which uses paper cards and multimedia resources [5]. It is well known that teachers have limited resources, particularly time, to cover the multitude of pedagogical knowledge and skills needed to effectively teach diverse learners [6]. Given this limitation, innovative technology is becoming increasingly popular to supplement instruction [7], especially in young children and Children with Special Educational Needs (SEN) [8].

Learning to read in young children is focused on ability to map the sounds of words to letters and clusters of letters that make sounds. This process can generate difficulties with phonological awareness, which is a crucial skill for reading in an alphabetic writing system [9]. Previous research demonstrated that the use of a teddy bear in a literacy acquisition delivered excellent results in terms of interaction with Down children. Unfortunately, little research exists to support the effectiveness of this approach for young children and SEN children [10]. The current research study explores the effectiveness of a longitudinal intervention programme in phonological awareness and improvements in speech production for children with speech and language delays.

3 Method

Research activities took place in two countries, Ecuador and Costa Rica. In this section we describe the process of manufacturing 25 kits of Kiteracy-PiFo. The intervention program will be written later in a new article.

3.1 Participants

We recruited 70 students of Universidad Tecnológica Indoamérica, 5 from Computer Science Career, 20 from Digital and Multimedia Design Career, 45 from Psychology Career and 30 from Master in Education, mention Innovation and Leadership. Additionally, we signed an agreement with the University of Costa Rica to collaborate in the design and application of Kiteracy-PiFo. It is important to note that 7 professionals participated in the project organization. The author of the PiFo method, a doctor in

Computer Science, a child psychology, a designer, an expert in disabilities and two teachers of Psychology.

3.1.1 Materials

The project contemplated 25 teddy bear, 5 designed with the representative symbol of Costa Rica, the sloth bear. According to the author of the method and the psychologies the sloths help empathy with children due to its oh-so-adorable face, snuggly body and very -pura vida- lifestyle. The remaining 20 for Ecuador, we selected the spectacled bear or Andean bear which it is endemic to the tropical Andes and is the only bear species in South America.

On other hand, we use a RFID Card Reader for each teddy bear, the technical specification is LANMU Smart ID Card Reader EM4099 USB - 125 kHz Contactless Proximity Sensor. In addition, 750 RFID plastic cards were also used.

Some office supplies were used for labels, packaging and instructions. The letters were made with foamy and die cut with a laser cutter. The software was coded in Visual C# language.

3.2 Procedure

The manufacturing process was divided in four phases: Design, programming, assembly and application.

The design phase was conducted by the designer with students and the rest of professionals. They drew and animated the characters, letters and pictograms. In addition, the recorded the voices and phonological sounds according the instructions of the method author. Finally, the design team also worked on the logo design and packaging.

The programming phase was conducted by the doctor in Computer Science to develop the software with programmers. The activities were designed with the author of the methods and the child psychologist. The accessibility was tested by the expert in disabilities.

The assembly phase was conducted by the three psychologists, who guided the psychology students to assemble the 25 kits. They incorporated the RFID sensor in each teddy bear and pasted in each card the letter of the alphabet. The team configured and tested the code ID by the sensor in order to check if software manages the presentation of contents, digital cards with graphemes and videos provided by the method. With the author of PiFo method, the psychologists wrote a Teaching Guide document, which was elaborated with the instructions for its installation and the didactic use of the interface.

Finally, in the application phase the psychologists worked with psychology students in the training of PECFO test (Test of Phonoligical Awareness - Prueba de Evaluación de Conciencia Fonológica). It was necessary to know the use of test application for the intervention process, because PECFO will be used in a pre-test and a post-test. Students of Master in Education, mention Innovation and Leadership contributed in the evaluation of kits and their playfull strategies.

4 Kiteracy-PiFo

Kiteracy-PiFo, owes its name to the union of the three key elements of this project: “kit”, which is a set of things that complement their use or function, “earcy” of the English word “literacy” and “PiFo”, which is the method of teaching reading that gives the program pedagogical content. Thus, Kiteracy-PiFo is a kit composed of software and tangible letters to strengthen the student-computer interaction in the literacy process based on the PiFo method.

4.1 Picto Phonic (PiFo) Method

The Picto Fónico (PiFo) method for teaching literacy was proposed by Costa Rican professor María de los Ángeles Carpio Brenes. This belongs to the category of phonetic methods and coined a concept of Picto Phonic Strategies. Its name is due to the integration of two aspects, the pictogram, based on a drawing that has or is associated with the shape of the letter under study; and the phonic, because the drawing illustrates a keyword whose initial sound is that corresponding to the letter represented [5]. The student learns to recognize graphemes and to associate them with his phoneme through the initial sound of the keyword and the drawing that illustrates this, thus stimulating a dual process of learning to read [1].

The method proposes a didactic sequence that guides each teacher in the teaching of reading and writing through the use of dynamic resources such as songs and videos. Within phonological awareness, special emphasis is placed on the association of sounds, that is, the correspondence rule Grapheme-Phoneme.

4.2 Manufacturing Kiteracy-PiFo

This prototype focuses on the perceptual stage of the PiFo method, aimed at the development of phonological awareness and the establishment of grapheme-phoneme correspondence rules.

This kit is supported by plastic cards and multimedia contents with pictograms and videos to generate interaction and accessibility for an inclusive education. Figure 1 shows the assembly phase where students are setting the kits. Since this new prototype aims to make technology invisible and generate levels of interaction and emotion, Kiteracy-PiFo is used, a teddy bear, which has a built-in RFID sensor. The stuffed animal hides the RFID sensor and acts as a reading assistant. The prototype is shown in the Fig. 2 with the letters and the sensor.

The use of RFID tags facilitate the interaction of children. Each card has a unique ID code, similar to the barcode or QR codes, with the difference that RFID technology does not require precision when approaching a mark or pattern on the sensor, but that it works by approximation (between 0 to 12 cm).

Fig. 1. Psychology career students assembling 25 Kiteracy-Pifo kits.

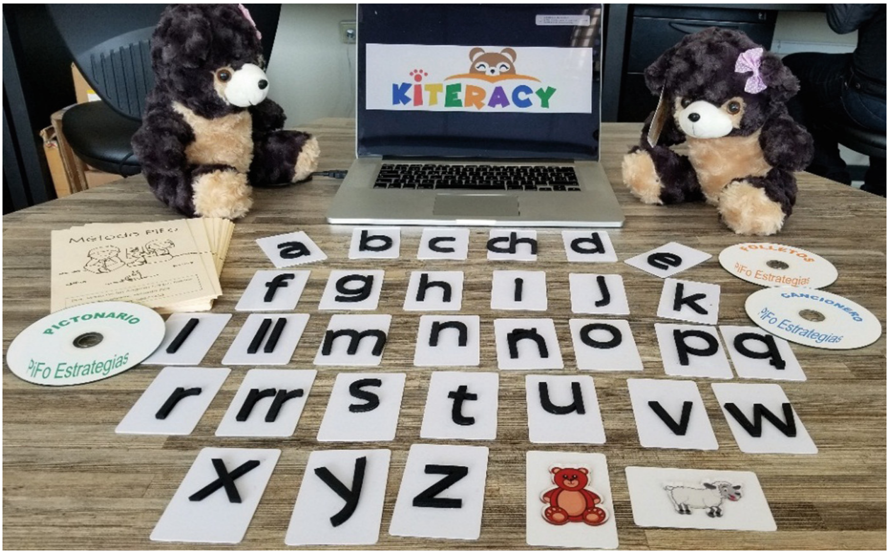

Fig. 2. Kiteracy-Pifo kit for phonological awareness.

5 Conclusions

From the experience gained during the design and manufacturing process, we believe that Kiteracy-PiFo will contribute to the development of literacy acquisition and we area motivated to apply in 25 schools.

The tangible interface led to playful interaction spaces and generated positive emotions in teachers and students. The use of tangible user interfaces seems to be the new trend in the future for Special Education, as it favors accessibility and participation in inclusive environments. With preliminary results in the application phase and the evaluation with the professional of the team, it seems that Kiteracy PiFo generated a greater degree of interaction.

The results obtained in preliminary evaluation by educators also allowed that children showed greater concentration, visual and auditory perception, motor skills when manipulating objects, attention and concentration when focusing on objects and not on technology.

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Analysis of the Behavior of a User's Sensory Mechanisms During the Interaction Processes with an Object of the New Media and Its Work System

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Abstract. It has been detected through dynamic networks that the activation of certain sensory mechanisms in the processes of interaction with the YouTube Object generate breakpoints in the Focal Attention Processes aimed at the Visual Symbols. Likewise, it was detected that the user's interoceptive responses in the interaction processes with the device's work system were related to the spatial location of the visual symbols, and the interoceptive responses in the interaction processes with the YouTube Object were determined by the sensitive qualities of visual symbols. Also the studies showed the existence of a possible relationship with the interoceptive responses, the behavior patterns of a user and the Focal Attention processes delegated to visual symbols. Therefore, it is intended to promote reflections and enabling knowledge on the use of the objects of new media based on the interaction processes generated by a user.

Keywords: Human interaction processes · Object of the new media · Sensory mechanisms · Artistic and design environments · YouTube · Normal-vision persons

1 Introduction

Users[1] carry out various types of interaction through the Objects of the New media and their work systems to obtain specific information where various processes of human interaction[2] take part. In various educational and work environments in Mexico the New media are used to transfer specific information to different users. However, the effects generated by the qualities of the Objects of the New media and their work systems are not analyzed; Generating an undifferentiated use of them.

[1] User: Individual interacting with the system [1].

[2] They are different forms of communication in relation to a user with an artifact [2]. Cañas, José J., y Yvonne. Waerns. Ergonomía cognitiva. Aspectos psicológicos de la interacción de las personas con la tecnología de la información. Madrid: Médica Panamericanas S.A., 2001. P. 27.

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The studies showed that these processes tend to vary depending on the sensitive characteristics of the work system which modifies the hierarchy of the user's sensory mechanisms and this in turn affects other processes. However, there are not many studies that evaluate the sensitive qualities of the objects of the new media and their work systems in relation to the user considering his or her behavior patterns and characteristics of technological devices.

One of the most common objects of the New media[3] in an art learning and design environment in Mexico is the YouTube[4] object. Through this object a user performs systemic interaction processes to obtain specific information in a given time. The variation in the activation of sensory mechanisms is affected by the characteristics of the Object of the new media determined by the technological device; This in turn affects the attentional processes [4] and the user responses given during the interaction process. Which is relevant in art and design learning environments where the user has behavioral patterns determined by their discipline like the exploration of aesthetic-formal elements and visual symbols on an object. The analysis of the process was divided into two phases: the first related to the interaction processes performed in the work system of the device and the second related to the interaction processes into the object of the new media.

2 Process Description

The studies were developed based on the observation of interaction processes carried out by a Normal-vision person (Nv) with the YouTube object and its work system. The user was a designer woman with postgraduate studies. The device used was the cell phone. Dynamic networks were used for the representation of Phase 1. In which the activation of the sensory mechanisms and the responses given by the user during the process of interaction with the work system of the device were shown. And the representation of Phase 2, in which the relationship between the sensory mechanisms and the responses given by the user during the interaction process with the YouTube object were shown. The YouTube object had audible information.

2.1 Methodology

The methodology used for these studies was the comparative analysis of data with the use of dynamic networks for the visualization of information. For this study, the interaction processes carried out by the user based on the YouTube object, the activation of sensory mechanisms and the responses given during the process were considered in the construction of the networks. The use of this methodology was applied in both phases. The process was applied to a Normal–vision person who executed the following tasks: 1. Locate the object YouTube in the work system of a cell phone 2.

3 "An object of the new media can be defined as one or more interfaces from a multimedia data base" [3].

4 Concerning to the Dynamic media: media in which the presentation to the user changes according to time Example: These include video, music, animation [1].

Enter into the object of the New media. 3. Perceive the information of the object of the New media for five minutes. The following tables and figures describe the analysis process (Tables 1, 2 and 3).

Table 1. General nomenclature.

Sign	Description	Sign	Description	Sign	Description
Iv	Visual Interaction	Is	Sonor interaction	Pd	Digital pressure
Prop	Proprioception	Intero	Interoception	Sv	Visual symbol
Img	Gross motor interaction	Em	Emotion	Elem	Elements
ImfD	Fine motor interaction with fingers	PAF	Focal Attention Process	PAG	General Attention Process

Table 2. Adjacency matrix. Interaction Process with the device work system. Elaboration Olmos & Gil 2019.

	8 Pd	9 Iv	10 Prop	11 ImfD	12 Intero	13 PAF	14 Sv
8 Pd	0	1	1	0	1	0	0
9 Iv	1	0	1	1	0	0	1
10 Prop	1	1	0	0	0	0	1
11 ImfD	1	1	1	0	0	0	0
12 Intero	0	1	1	0	0	1	1
13 PAF	0	1	1	0	1	0	1
14 Sv	0	1	1	0	1	1	0

Table 3. Node grades.

Sign	Grade	Sign	Grade	Sign	Grade	Sign	Grade
Iv	10	Sv	8	PAF	6	Pd	6
Intero	7	Prop	9	ImfD	4		

Figure 1 shows the activation of the sensory mechanisms of Visual Interaction (Iv), Proprioception (Prop), Fine Motor Interaction with Fingers (ImfD), Interoceptive Responses (Intero). Being the processes of greater degree the Visual Interaction (Iv), Proprioception (Prop) and Fine Motor Interaction (ImfD, Pd)., Followed by Interoception (Intero). Attention processes were focal (FAP) [4]. The transfer of information was done through Visual Symbols (Sv). Interoceptive responses were detected in this part of the process which were related to the transfer of information with Visual Symbols (Sv), Visual Interaction (Iv), Digital Pressure (Pd) and the Focal Attention Processes (FAP). Being the Visual Interaction (Iv) the sensory mechanism with most probability in generate an interoceptive response through the Visual Symbols (Sv). A distance 1 of the Proprioceptive processes (Prop) was perceived with each and every one of the active sensory mechanisms during the process, also, a distance 1 of the Proprioceptive processes (Prop) was perceived with the answers given by the user. Which indicates a centrality. A uniform sensory mechanisms activation was perceived in the process (Tables 4 and 5).

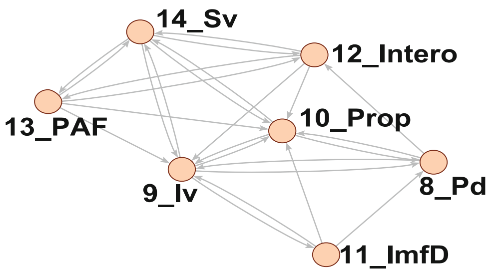

Fig. 1. Dynamic network that shows the relationship and distance of the sensory mechanisms in the process of interaction with the Device work system. Elaboration L. Olmos & J. Gil 2019.

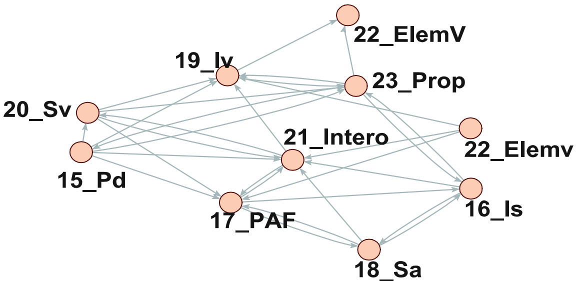

Fig. 2. Dynamic network that shows the relationship and distance of the sensory mechanisms in the process of interaction with the YouTube Object. Elaboration L. Olmos & J. Gil 2019.

Table 4. Adjacency matrix. Interaction Process with the New Media Object. Elaboration Olmos & Gil 2019

	15 Pd	16 Is	17 PAF	18 Sa	19 Iv	20 Sv	21 Intero	22 ElemV	23 Prop
15 Pd	0	0	1	0	1	1	1	0	1
16 Is	0	0	0	1	0	0	1	0	1
17 PAF	0	1	0	1	0	0	1	0	0
18 Sa	0	1	1	0	0	0	1	0	0
19 Iv	0	0	0	0	0	0	0	1	1
20 Sv	0	0	1	0	1	0	1	0	1
21 Intero	0	0	1	0	1	1	0	0	0
22 Elemv	0	0	1	0	1	0	1	0	0
23 Prop	1	1	0	0	1	0	0	1	0

Table 5. Node grades.

Sign	Grade	Sign	Grade	Sign	Grade	Sign	Grade	Sign	Grade
Iv	7	PAF	8	Sv	6	ElemV	5	Intero	9
Is	6	Pd	6	Sa	6	Prop	8		

Figure 2 shows the activation of the sensory mechanisms of Digital Pressure (Pd), Sound Interaction (Is), Visual Interaction (Iv), Proprioception (Prop). Being the processes of highest degree: Visual Interaction (Iv) and Proprioception (Prop). Attention processes were Focal (PAF). The transfer of information was done through Visual Symbols (Sv), Audible Symbols (Sa) and Visual Elements (ElemV). Interoceptive responses (Intero) were detected in this part of the process which were related with Visual Interaction (Iv), Visual Symbols (Sv), Visual Elements (Elemv), Sound Interaction (Is), Audible Symbols (Sa), Focal Attention processes (PAF) and Digital Pressure (Pd). Being the Visual Interaction the most in probability in generate a interoceptive response through the Visual Symbols (Sv). A distance 1 was observed with the Interoceptive processes (Intero), with the most active sensory mechanisms and with the answers given by the user. Which indicates a centrality. A uniform sensory mechanisms activation was perceived in the process.

3 Results

Based on the comparative data analysis, the following results were given: In the first phase it was observed that the user active the sensory mechanisms related to Visual Interaction (Iv), Proprioception (Prop), Interoception (Intero) and Fine Motor Interaction (ImfD and Pd). The greater activation of sensory mechanisms was related to the user's spatial location of visual symbols. Based on this, there is the probability that Focal Attention processes were an automatic reply in the identification of visual Symbols like in the case with the YouTube's symbol. Likewise, in this study Interoceptive (Intero) responses of the user were related in the space-time location of the YouTube Object and were directly linked to the spatial location of the Visual Symbols (Sv) and the Visual Interaction (Iv). Therefore, it was perceived that the spatial location related to the location of visual symbols was the mechanism with most probability in generate Interoceptive responses compared with the visual symbols (Sv).

In the second phase, it was observed an increase in the Focal Attention Process (PAF) focused on two types of symbols: audible and visual. In this phase was perceived that the Audible Symbols (Sa) generated the strongest Focal Attention Processes (PAF). However, the user's Interoceptive (Intero) responses during the process of interaction also were close to be generated by the Visual Interaction (Iv) through the Visual Symbols (Sv). Likewise, there was observed a lower probability that the processes of Focal Attention to the Visual Elements (ElemV) could happen before to the Visual Symbols (Sv). So there are reasons to think that the transfer of information occurred with the following hierarchy: from Visual Symbols (Sv) to Visual Elements (ElemV).

4 Conclusions

These studies showed that visual interaction was the factor that active the Focal Attention Processes constantly in both phases. However, it was perceived that the Sound Interaction generated a stimulus capable of generate a breaking point in the Focal Attention process to the Visual Symbols. Even so, the Visual Symbols were the most in probability in detonate the Interoceptive responses as a constant factor throughout the process and the most in probability in generate Focal Attention responses. Which was directly related to the transfer of information from both the work system and the Object that were mostly Symbolic. And it can also be related to the user's profile.

Likewise, two predominant factors were observed in the generation of Interoceptive responses: the spatial location of Visual Symbols and the qualities of Visual Symbols. In the first case, Proprioception affected interoceptive responses in the following relationship: the longer the location of the visual Symbols, the greater the probability of generating Interoceptive responses. This may be directly related to the frequency of use of the media interface by the user. In the latter case, the Visual Interaction affected the interoceptive responses in the following relationship: the greater Focal Attention with visual Symbols, the lower the probability of generating emotional responses from the visual Elements. Likewise, it was observed in this study that in the first phase the YouTube Object generated in the user interaction processes related with the spatiality, and in the second phase it generated interoceptive responses in the user related with emotional interest. Based on this, the Focal Attention Processes were directly linked in the first phase with the user's spatial location in the media interface and in the second phase they were related to emotional responses.

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Complex Human-System Interactions

Applying Haptics to Interactive Large Screen Displays

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Abstract. Within industries such as nuclear, petroleum and chemical processes, monitoring and control is done from a centralized control room. The introduction of individual digital workstations, replacing analogue panels with buttons and knobs has resulted in two challenges: i) lack of haptic feedback of actions, and ii) decreased transparency in team members' actions. This paper proposes that a handheld haptic device, used directly in a large-screen display could mitigate these challenges. We present lessons learned from a working prototype connected to a nuclear simulator. Requirements for the prototype included a scratch free display surface with built in precision position tracking; and a haptic device with two channels for interaction. We found that the use of haptic feedback is feasible and strengthens the experience of direct interaction. Nonetheless, it was challenging to perform actions requiring rotational movement. Further work should include iterative user studies.

Keywords: Large Screen Display · Haptic feedback · Control room

1 Introduction

Within industries such as nuclear, petroleum and chemical processes, monitoring and interaction is done from a centralized control room. In the past, information was presented to the crew through analogue wall panels, which offered feedback of process actions through physical buttons and knobs. Operators' physical proximity to the actual panel supported also transparency of crewmembers' actions, allowing other team members to see what the operator is doing. In recent years, technology has enabled digitalization of control rooms, introducing individual digital workstation displays. This has resulted in two challenges: i) lack of haptic feedback of actions, and ii) decreased transparency of team members actions.

One way of bringing back team transparency has been to introduce overview tools such as Large Screen Displays (LSDs) in the main control room. This technology has the potential to improve system performance by supporting operators in interaction and monitoring of complex and often safety critical processes. Industrial standards and guidelines suggest that LSDs can enhance situational awareness, and improve crew communication, through a shared view of the process state [1, 2].

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However, digital LSDs impose limitations in efficient interaction and also team transparency for individual actions. Firstly, interacting remotely through the LSD using mouse/keyboard is challenging, as the cursor disappears on the large surface. Secondly, when components are remotely operated from a workstation display, it is difficult for others to observe fellow crew members actions. Another aspect is that current interface technology used in control rooms only offer visual feedback, lacking the physical/haptic feedback provided by the legacy knobs and buttons. This has resulted in implementations that might not be exploring the full potential of LSDs, due to the lack of interaction features – the LSD is mostly used has a communication tool (shared awareness of plant status).

Recent technologies have opened the door to new ways of presenting haptic feedback, such as vibrations, as a form to convey information on the confirmation of tasks done directly on the display surface. The use of redundant sensory information (e.g. visual and haptic) is described in literature [3] and might contribute positively to new ways of interaction. There is evidence that the use of haptic feedback improves speed and accuracy in flat keyboard [4] and improve drivers' response accuracy and time [5]. And further, showing equivalent gains in virtual reality applications, with vibration being quite efficient as a cue [6]. Haptic feedback becomes even more relevant in environments that are visually/auditorily busy [7] and where vibration can enable quicker responses when transmitting for instance alarms [8].

This paper argues that innovative devices for haptic feedback can be a useful tool enabling LSD interaction in a more intuitive and efficient way. However, there is little advice for how to use haptic technology in industrial control rooms. We approach this topic through research and development focusing on: i) exploring LSD technology required for supporting haptic interaction, ii) selection of a haptic device for direct process interaction, iii) exploration of technology for connecting LSD to the haptic device, and iv) developing interaction menus for performing process actions.

2 Concept and Team

The approach of this project is to learn through the development of a working prototype. The prototype has a handheld haptic feedback device operated from a LSD, connected to a nuclear process simulator with functional objects such as valves and pumps. In order to reduce complexity, it was decided to only implement some of the most commonly used operations, like start/stop pump, open/close valve, set valve to automatic, and fine-tune manually a valve to a specific opening. The model is visually explained in Fig. 1.

The project first established a research team with complimentary skills and perspectives: two hardware/software experts; one interaction designer; one nuclear process expert and a human factors researcher with knowledge in haptics. The working prototype was then developed over a period of approximately 6–7 months. A small laboratory was available for the team to perform prototyping. In this period, the team had work meetings once a week, and performed local testing, learned, documented and improved the functionality iteratively. Toward the end of the project period, the team demoed the functionality to a larger audience of "in-house" researchers.

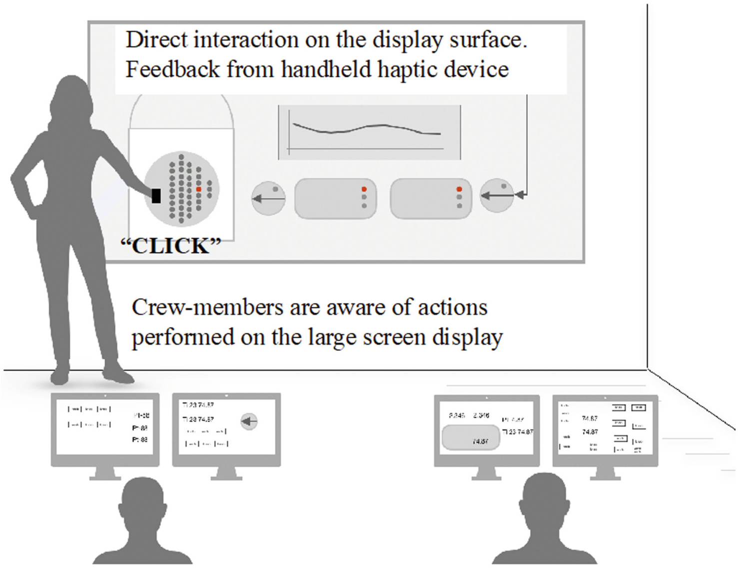

Fig. 1. Illustration of project concept of a working prototype

3 Technology Development for the Working Prototype

The following sections describe the development of the prototype, and lessons learned from this process. The work covers the display technology, the haptic device, and the connection technologies between the two and the nuclear simulator.

3.1 Display Technology

The requirements for the prototype are to offer position tracking on the LSD for the haptic device, as well as a method of giving haptic feedback and supporting interaction to the user. Looking at the state of the industry (process, petroleum, and nuclear) regarding LSDs, we identified how some used projected displays. However, an unwanted effect of using a front projected display is that the operators can block the LSD when standing in the path of the "light beam" from the projector. For haptic control and feedback, we therefore considered that a LCD panel with a scratch free surface is a reasonable solution. For our work, we used an multitouch-enabled 85" LCD display surface.

3.2 Haptic Device

The next challenge was to identify a suitable haptic device for performing process actions on the LSD surface. The requirements were that it should have low cost and robust, since it could be easily dropped. We focused therefore on game controllers which fulfil this requirement. Haptic devices used in the entertainment industry, especially video games, have haptic feedback as a standard functionality. They are also suitable in terms of reliability, charging solutions and affordance.

We determined that a suitable haptic device should at least have two channels: the first for selecting the desired operation, typically a button for “clicking” (e.g. selecting a pump or valve); and the second channel for fine tuning and adjusting levels (e.g. adjust valve opening), which we thought would be best supported by rotation motion.

The Nintendo Switch controller (shown in Fig. 2) fulfilled the requirements, since it supports easy to set-up communication with the process simulator and display through Bluetooth [9]. This controller had several input and output possibilities and the following were found useful for the prototype:

– X/Y-position on the LSD when the controller was held against the LSD;
– button press when the operator pressed the controller against the LSD; and
– the rotation of the controller.

Fig. 2. Nintendo haptic feedback controller for process actions

3.3 High Accuracy Positioning of the Haptic Device on the Display

The next challenge was to identify technology for high accuracy positioning of the haptic controller for performing process actions on the LSD. We considered using radio-frequency identification tracking. This required us to use a non-metallic display surface and to paste markers at all locations for process actions on the LSD. We found these limitations challenging. Vision based hand-tracking was also evaluated, but since it requires more advanced software and setup, it was not compatible with the project timeframe. Further advances in vision-based tracking are expected to give stable finger-level tracking, allowing for interaction in the form of pointing at the screen at a distance.

Considering utility and ease of implementation, the project found the LSD’s built-in touch functionality for position tracking useful. This technology was our choice, and is able to detect the Nintendo controller in close proximity to the display surface.

3.4 Nuclear Simulator and Haptic Feedback Actions

After selecting display technology and haptic device, the challenge was to find a suitable realistic simulator and to develop interaction possibilities. We started using the HAMlab BOiling water (HAMBO) simulator, which is a near full-scope simulator based on a late generation ABB plant Boiling Water Reactor [10]. The reactor thermal output is 3300 MW and the gross generator power is 1190 MWe. The simulator was found suitable for our purpose, and we selected one display which was then scaled up to fit the 85" screen. This process display includes the shut-down cooling system and the reactor water clean-up system.

After a series of trial and error and adjustments, the use of a four-step action process was selected for interaction with the simulator. The first is to hold the haptic device over the process object on the LSD to make contact. The system acknowledges this by presenting visual feedback in the form of a white ring around the component, as well as haptic feedback through a "click". The second action step is to push the device toward the object for an interaction menu, a "click" confirms the action. The third step is to rotate the device for selecting action: close, open, and adjust values, giving haptic clicks as feedback. The fourth stage is to confirm action by pushing the device toward the LSD, again with haptic click feedback. Figure 3 illustrates both the interaction menu and a user rotating the controller for manual adjustment of valve opening.

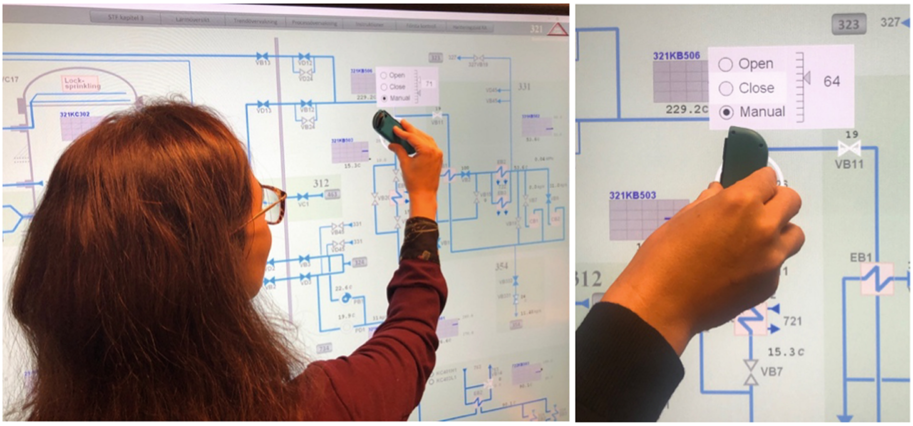

Fig. 3. Interaction menu (left) and adjusting valve opening by rotary wrist action (right)

We found that the haptic feedback strengthens the experience of "direct" interaction. These steps worked satisfactorily, with the exception of the rotational motion. This haptic fine-tuning by a rotational motion is typically manual control of a valve ranging from 0 to 100%. This proved to be challenging for two reasons: 1) the total rotation angle was too large, and 2) the accuracy was not good enough. These two conflicting problems are currently not solved satisfactorily. Contrary to fixed traditional rotary knobs, the operator using the haptic device cannot release and readjust their hands for operation. As the range for rotary wrist operation is limited, this needs further work.

For the haptic feedback during fine-tuning, we tried out a short "click" and a longer "rumble". The "rumble" was used when the operator was rotating the handheld controller outside the range of the menu. We decided to remove this rumble as it was perceived as exaggerated, confusing the user.

4 Summary

In this work we described a R&D project that focused on the development of a working prototype of a haptic feedback device to be used in interactive LSDs. The prototype was implemented for a full scope nuclear simulator, and the project learned both through the development and by using the working prototype. In this work, we present an approach that is rooted on principles from a transitional period in complex industries from analogue to digital controls. Our opinion is that digital interfaces represent the future through a higher flexibility for adjustments and modifications, as well as reduced maintenance costs. Nonetheless, some of the valued features from analogue interfaces of the past can be lost and even missed by users in this transition period, and as such, we argue that it is possible to digitally replicate some aspects such as the haptic feedback. Based on this, we find it reasonable to explore haptic technology using LSD applications.

We were able to explore and select existing available technological solutions both regarding the displays and the haptic devices, and were able to build a working prototype, connecting and positioning the haptic Nintendo Switch controller on the LSD. A challenging part in this was to offer high accuracy positioning on the LSD, the built-in position tracking on the LSD was useful for us to enable this. This prototype was linked to a nuclear process simulator which enable testing of the interaction in a realistic setting, where actions on components resulted in process parameters changes. The effort required to adjust the rotational motion control was unanticipated, both related to the accuracy and the allowed rotational angle.

5 Further Work

We find the concept of direct operation of complex processes through a LSD to be promising, but it needs to be further explored in user studies and matured in an iterative way. As described, there are several ergonomics and human factors aspects to be considered when exploring new solutions for interaction. Aspects such as the shape of the haptic device, differential feedback according to actions, or types of actions that can be supported can be further explored. In relation to the LSDs, enabling interaction will require new approaches to its design, since interactive components will need to be within reachable distance for operator. Likewise, from a more practical perspective, interactive components would need to be organized in such a way that the operator working on them would not occlude other relevant areas of the display.

We suggest that an analysis of usability aspects, possible safety implications, and a study of the impact of new interaction concepts on human performance should be investigated. Interesting topics to explore in user studies relate to the assumptions described in the introduction, that such new ways of interacting with LSD can increase team transparency. We suggest that the user studies focus on both individual and team aspects, simulating work environments where the technology could be deployed such as main control rooms for complex systems. We propose further to use the established technology platform to perform such studies.

Concluding, the concept for the prototype was based in previous research and knowledge on the current state of the industry. This paper presents the current state of the developed prototype. Next phases in the work will entail user studies to address the usefulness and usability of the haptic device, and later on to evaluate the impacts of this new interaction paradigm in control room performance.

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Piloting the Use of an Upper Limb Passive Exoskeleton in Automotive Industry: Assessing User Acceptance and Intention of Use

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Abstract. The exoskeletons are being developed and recommended worldwide as wearable devices that could be used by workers exposed to demanding working conditions, such as overhead work. Many studies, designed for laboratory research, have been carried out so far and most of them came to the same kind of conclusions. With these findings it is expected that user acceptance (UA) and intention of use (IU) would not be a concern. This study was designed to assess UA and IU of an upper limb exoskeleton, Skelex MARK 1.3®, in a group of workstations, where technical and organizational measures implemented were not enough to reduce the exposure risk to overhead work and/or work above shoulder level, from an automotive industry assembly line. The exoskeleton was tested in 6 workstations, by 88 workers, during 4 consecutive weeks, since UA and IU are influenced by factors which only exist in real working scenarios.

Keywords: Passive exoskeleton · Upper limb exoskeleton · Automotive industry · User acceptance

1 Introduction

Currently, the layout of many industrial plants, particularly in the automotive industry, is designed as continuous production assembly lines with several workstations. In each workstation, a combination of processes is planned to be performed each working cycle. As this can occur hundreds of times (e.g. for 8 h shift with breaks of 14 min and cycle of 1.3 min, there are 358 working cycles) workers are exposed to the risk of developing work related musculoskeletal disorders (WMSD) and therefore organizations try to improve the working conditions using ergonomics intervention approaches. According to the occupational safety and health European legal framework, prevention strategies should be primarily based on technical measures and whenever needed combined with organizational measures. In this sense, ergonomic interventions are

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about changing the working conditions in such a way that job demand falls within an acceptable risk level for the development of WMSD. Nevertheless, in some circumstances, the desired technical measures cannot be implemented (e.g. to turn overhead work into work below head/shoulder by redesigning the conveyor system, since they can represent an investment of millions of euros) and the organizational ones are not enough to decrease the WMSD risk.

Since 2015, exoskeletons began to be used in the industry [1]. Although this technology is quite mature in the healthcare industry – with complex, energized, full body exoskeletons that assist with rehabilitation – there is limited availability of simple, useful exoskeletons for targeted applications such as in automotive industry. According to Voilqué and collaborators [2], 30 passive exoskeletons are available in the market but the most relevant for the automotive industry are the ones designed to assist workers while exposed to demanding working conditions such as manual material handling and overhead work. Therefore, for automotive industry the exoskeletons of interest are mostly to shoulder and trunk and specially from passive and semi passive types. A passive exoskeleton can be described as a wearable, external mechanical structure that can reduce the impact of a movement on the human body [3]. This is achieved by redistributing forces; thus, protecting specific body regions.

Upper limb support exoskeletons may be considered the most mature and replicated design [1]. By introducing exoskeletons in workstations, the change in user performance results not from additional physical strength, but from the ability to sustain strenuous positions over longer periods, for example working overhead [4].

Laboratory studies show that the use of exoskeletons decreases the biomechanical load by, for example, reducing by more than 40% the muscle load [1, 5, 6] and increasing performance by an average of 30% [7]. These advantages, identified in laboratory settings, are supporting the marketing of such devices. However, there is a risk for organizations to base their decision making regarding the introduction of exoskeletons in manufacturing processes only on such criteria. In fact, the physical effects of exoskeletons can influence the worker; therefore, user acceptance (UA) is an important factor to study [4]. Discomfort is one of the most important factors that can influence the UA and intention of use (IU), affecting the implementation success in industry [4]. Therefore discomfort, usability [8] and perceived effort [7] are also factors to study. Thus, if exoskeletons are to be used for a long time, UA and IU should be analyzed [4], and the tests should be performed in real work environment [4, 7, 8].

Study findings can be quite different depending if they are performed in laboratory or in a factory plant where noise, heat and production-driven stress cause participants to experience frustration more quickly [3].

Hensel evaluated UA and IU through a usability questionnaire [8]. Spearman's rank correlation coefficient indicated which variables correlated with acceptance and intention of use, and the Wilcoxon signed-rank test revealed which variable differs between the initial and final condition. The results were used to suggest improvements to the exoskeletons' design in order to adapt them to the workers' needs and to verify in which workstations the workers recognized the benefits of its use while performing the tasks.

Present study assessed UA and IU regarding the upper limb exoskeleton, Skelex MARK 1.3®, used in a group of workstations of an automotive industry assembly line, where previous technical and organizational measures were not enough to reduce the exposure to risk from overhead work and/or work above shoulder level.

2 Materials and Methods

2.1 Participants' Selection

The initial sample size was 122 volunteer workers. After the medical evaluation, 88 workers were selected. The participants' selection were based in the following criteria:

– Experience/Qualification - volunteers must have more than three months of experience performing the task (errors are more likely to occur when operators are in the learning phase; in the study it is important to exclude any factors that may cast doubt on whether errors resulted from the use of the exoskeleton);
– Medical restrictions – volunteers must have no medical restrictions to perform the task of the workstation defined for the use of the exoskeleton;
– Anthropometry - volunteers must fit the exoskeleton's adjustments range.

2.2 Tested Exoskeleton Characteristics

The Skelex MARK 1.3, illustrated in Fig. 1, is a wearable technology engineered to support the arms of workers in tasks above the shoulder/head level, made by SKELEX.

The exoskeleton weights 3.7 kg and consists of arm cups, arm cover, arm strap, flex frame, height adjustment, hip belt, hinge, hinge cover, cable, shoulder strap and a chest strap. The maximum lifting capacity is 4.0 kg per arm. The arm cups, arm strap, height, hip belt, shoulder strap and chest strap are adjustable. The range of adjustments is presented in Table 1.

Fig. 1. Skelex MARK 1.3

Table 1. Skelex adjustment range by body part

Body part dimension	Adjustment range (cm)
Shoulder width	43–54
Torso length	44–54
Pelvic circumference	84–124
Upper arm circumference	20–42

Before operating with the Skelex MARK 1.3, it is important to ensure that it is properly set in the workers' body. According to the manufacturer if worker's body part dimension is outside the range presented in the Table 1, Skelex MARK 1.3 does not provide a comfortable use.

2.3 Workstations' Selection

Exoskeletons are not suited to all types of workstations. Therefore, the selection of the workstations for testing the device was based on the criterion that more than 30% of the activity was performed above the shoulder/head level. The Ergonomic Assessment Worksheet (EAWS) method was used to identify such workstations.

Six workstations with a high percentage of work activity above shoulder/head level were selected: Tailgate wiring loom routing (workst. 1), EPB/Brake pipes connection (workst. 2), Noise shield tightening (workst. 3), Rear end fit (workst. 4), Tailgate pre-fit (workst. 5) and Tailgate trim panel assembly (workst. 6).

2.4 Testing Protocol

The first step was to present the exoskeleton and the test procedures in meetings with the teams working at the selected workstations. The workers had the opportunity to ask questions and after that, the volunteers signed an informed consent.

Before starting the pilot study, each volunteer was subject to an initial evaluation in the medical department, which issued a certificate that he/she had no restriction to perform the tests. On the first day of the test, the participants learned how to use and adjust the exoskeleton. The participants initially used the exoskeleton for 30 min, and in each new day this duration was increased by 15 min until a maximum of 2 h per day was reached. At the end of each period of exoskeleton use, the participants completed a questionnaire. After the first and the last use participants were requested to answer a different questionnaire aimed to assess the exoskeleton performance and user acceptance based on subjective indexes. After completion of the test period all participants were subject to a final evaluation in the medical department.

2.5 Survey Tool

As referred, two questionnaires were used: a daily questionnaire (completed after each usage, except the first and the last test days) and a usability questionnaire (completed in the first and in the last days of use). The daily questionnaire included four questions related with the main and the secondary tasks, asking if the workers perceived the use of the exoskeleton as helping or disturbing. The usability questionnaire gathered the workers' opinion regarding perceived effort, discomfort, perceived utility, perceived ease of use and intention of use. The workers also classified the perceived effort for each body regions, considering the work with and without exoskeleton. The classification was based on Borg rating of perceived exertion scale (RPE scale). The reported discomfort might refer to heat, pressure, perspiration, skin irritation, among others. The scale used to classify discomfort was "1 - minimum discomfort" to "7 - maximum discomfort", based on 7-point Likert scale. The user acceptance (UA) was investigated with three questions (Q1 - The features of the exoskeleton satisfy my needs, Q2 - The exoskeleton is easy to use, Q3 - The exoskeleton is easy to dress and undress). The one about perception of utility was based on the UMUX-LITE model. The other two questions were about perception of ease of use: the first concerns ease of use and the second refers to the ease of dressing and undressing, which consists of an issue that was considered important according to the usability of the equipment, related to its use in the workplace. The questions were based on the System Usability Scale model. The intention of use (IU) questions (Q4 - I would like to have access to the exoskeleton, Q5 - I would use the exoskeleton) were based on the Technology Usage Inventory model. An agreement scale was used to assess the perception of utility, ease of use and intention of use, based on the 7-point Likert scale, from 1 (Don't agree) to 7 (Totally agree). Both surveys were adapted from (Hensel & Keil, 2019). Also, in both questionnaires the participants could express their complains and/or opinions. The analysis of the comments was made by separating the different topics and checking the frequency with which they were mentioned.

3 Results and Discussion

Since the exoskeleton was used during the whole cycle time, the differences of performance were studied by asking the workers opinion regarding the ability of the exoskeleton to support the shoulder postures and movements during the main and secondary tasks. In workstation 1, 87% of the workers reported that the exoskeleton helped performing the tasks above shoulder level and 74% in performing other tasks. Considering the tasks above shoulder level as main tasks, and the others as secondary, the perception that the exoskeleton helped was less for the secondary tasks in all workstations, except workstation 5, as shown in the left columns of Table 2. In workstation 5 the participants didn't recognize the benefit of using the equipment due to the complexity and dynamics of the main task performed.

The usability questionnaire allowed assessing the participants intention of use. Table 2 (right columns) shows the percentage of participants who agreed that they would use the exoskeleton, considering the initial and final questionnaire. In all workstations the IU decreases. Beyond the perceived effort and discomfort, the parameters that could influence the results are the increase of the duration of the test and the period of usage.

Table 2. Daily questionnaire and Intention of use (IU) results

Work-station	Daily questionnaire results		Intention of use (IU) results	
	Participants agreeing that exoskeleton helped performing the task (%)		Participants agreeing to usethe exoskeleton (%)	
	Main	Secondary	Initial	Final
1	87	74	76	53
2	69	43	83	33
3	58	52	44	39
4	23	2	40	10
5	0	39	25	13
6	38	35	35	26

Through the application of Spearman rank correlation coefficient, the perceived effort and the discomfort in different body regions are correlated with the UA and IU in all workstations. The variables most correlated with the UA and IU are the shoulder perceived effort and the back perceived discomfort. Table 3 represent the questions where there is a strong correlation between the variables, in the different workstations. When the coefficient is negative it means that the higher the discomfort or perceived effort of using the exoskeleton, the lower the intention to use. The variables of UA and UI are positively correlated with each other, and the perception of effort and discomfort are negative correlated with UA and UI.

The Wilcoxon signed-rank test provides the differences between the initial and final conditions. In workstation 1 only the neck perceived effort was significant. In workstations 2 and 3 the back and low back discomfort were significant. In workstation 4 the neck, back, low back, and left shoulder perceived effort were significant. In workstation 6 the back, low back, core, arms and hip discomfort were significant. The difference between intention of use was significant in workstations 2, 4, 5 and 6.

Despite the general recognition of the exoskeleton support in the comments made on the questionnaires, the participants expressed several complaints and the most frequent were related with heat and limited range of motion. Workers also mentioned the relief felt when removing the exoskeleton due to its weight. Throughout the study, it was noticed that in addition to the variables under analysis (i.e., perceived utility and discomfort) the type of tasks also influences the user acceptance and intention to use.

Table 3. Spearman's rank correlation coefficient

Workstation	Shoulder perceived effort (ρ)	Back perceived discomfort (ρ)
1	Q1 (−0,7629)	Q1 (−0,5036)
2	Q4 (−0,6575)	Q2 (−0,6185) Q4 (−0,6799)
	Q5 (−0,6202)	Q3 (−0,8076) Q5 (−0,5954)
3	–	Q2 (−0,6024)
4	Q3 (−0,6321)	Q2 (−0,6660)
5	–	–
6	Q1 (−0,5995) Q5 (−0,6202)	Q1 (−0,6351)
	Q2 (−0,6140)	Q2 (−0,6338)

Based on the tasks' characteristics, it was found that the longer the tasks above shoulder and the static levels of the task, the higher is the perceived utility and the lower is the discomfort of using the exoskeleton. A priority matrix was created to map usage recommendations against the type of tasks involved in the workstation. Figure 2 depicts this, relating the perceived utility and the discomfort with the type of tasks, and the recommendation of exoskeleton usage. Figure 3 shows where each studied workstation lays according the type of tasks performed there.

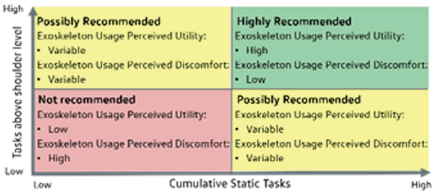

Fig. 2. Recommendation of exoskeleton usage according the type of tasks

Fig. 3. Type of tasks performed in each workstation

Considering the cumulative static tasks that the workers elevate the arms above the shoulder level per cycle, workstation 1 is the only that is considered as recommended the use of the exoskeleton. However, several factors influence the user acceptance and intention of use, for example, heat, noise and stress. The Spearmans' rank correlation coefficient revealed that perceived effort and discomfort are negatively correlated with UA and IU, i.e., the higher the perceived effort or the discomfort, the lower is the UA and IU. The Wilcoxon test indicated that UA and IU can change and perceived effort and discomfort in some body regions also change over time and the length of usage duration. One reason might be due to organizational reasons, since participants could change the work shift, implying the non-use of the exoskeleton when scheduled. A second reason might be related with the existence of environmental conditions preventing a comfortable use of the exoskeletons (e.g., excessive heat). A third reason was volunteers evidencing symptoms of difficulties to perform the tasks, forcing the test to be stopped and requiring an evaluation at the medical department. This information was very useful, allowing the formulation of improvement proposals to the SKELEX.

4 Conclusions

According to the results, the workstation where the use of exoskeleton is most suitable according to the usability is workstation 1. Despite the fact that in five of the six workstations the use of exoskeleton was not recommended, it was deemed that applying some changes, suited to the needs of each workstation, the results of usability could change, and the exoskeleton usage may become recommended.

It was found that user acceptance and the intention of use tend to decrease over time.

Based on the comments made by the participants and the results obtained, it were proposed some improvements to the equipment, to make it lighter (after one hour of use, participants tended to report relief by removing the exoskeleton), to reduce or modify back and lower back area (the straps made pressure while performing some tasks and caused heat), and to increase the range of motion (participants need to perform various movements during work cycles and the exoskeleton restricted movement in some tasks). Once these changes are made, the exoskeleton will better meet the needs of the workers and UA and IU of the exoskeleton may increase.

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Reliability in Extreme Isolation: A Natural Language Processing Tool for Stress Self-assessment

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Abstract. Life in isolation is a condition that affects more people every day. From isolation of people in case of an epidemic (Ebola, Coronavirus, ..) to mineworkers or scientist in the Antarctic environment, it is currently well established that extreme isolation is a stressor element which negatively affects human creating stress and social conflict. Living in outer space is one of the most extreme forms of isolation that can be used as a test bench for isolation research. Crews in space are expected to be able to manage independently stress and social conflict problems to be highly reliable and autonomous. Human natural language (NL) has the potential of being a valuable source of information on crew-members stress and reliability in isolation. Based on the use of NL, the PSI (Performance and Stress in Isolation) research group is developing an Artificial Intelligent tool for the autonomous monitoring of stress and reliability. In order to develop this tool, the first step (here presented) is to investigate the correlation of NL with stress and reliability within the PSI experiment. The experiment consisted of three tasks to be performed periodically during the isolation: 1. Analysis of free written communication (NL); 2. Short self-reference questionnaire; and 3. Detection of heart rate and blood pressure values. In this paper we present the preliminary data collected from 29 participants (17 males and 12 females) to 6 space analogue missions accomplished in Europe, the USA and Israel in the 2016 – 2019 time frames. That is, so far, the largest database ever analyzed of this kind. The results are coherent with what is described in the literature about NLP content and style analysis, with the novelty of the correlations found with the cardiovascular parameters, thus reinforcing the

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perspective of applying a NLP AI system for supporting stress management in extreme isolation contexts from Space to Earth spin off.

Keywords: Human factors · Human-systems integration · Cognitive neurosciences · Natural language processing · Artificial intelligence · Space psycho-physiology · Space spin off

1 Introduction

In every mission isolation is a stressor element which negatively affects human behaviour, mood and cognitive performances, creating stress and social conflict. Living in outer space is one of the most extreme form of isolation that can be used as test bench for spin off of isolation research on Earth. Future crewed long lasting space missions Beyond Low Earth Orbit (BEO) pose danger and challenges not previously faced by any human explorer. Not only would the trip's length far exceed any previous mission but the crew members would also experience significant communication delays, endure lengthy periods of inactivity punctuated by crises and they would lose sight of the Earth as they journey towards deep space. The effects of these unique circumstances on astronauts are still not completely described but they will likely test human psycho-physiological limits like never before and the importance of being able to self-monitoring the psychological and physiological factors will be crucial to their success [1].

In particular the relative lack of human factors data Behond Eath Orbit (BEO) creates a significant difficulty in understanding what the problems are and how to address them in the context of a crewed mission with associated constraints. What is already well described into the scientific literature is how "extreme" environmental stimuli give origin to an adaptive response, which comprehends systemic and behavioural changes aimed to develop the best homeostatic capability of the individual, thus increasing his survival chances. These adaptive changes are produced by chemical mediators, such as adrenalin, glucocorticoids, growth hormone and cytokines, that act on specific receptors localized in different organs. Chronic stress can produce the so called allostatic state, characterized by an increased activity of the mediators on their target cells that leads to receptor desensitization and tissue damages, thus connoting the allostatic load [2]. This may cause dramatic consequences, all detrimental in the operating scenario of a crewed space mission that include insomnia, depression, cognitive impairment and various cardiovascular diseases.

Because of all those assumptions it is now well established that crewed missions BEO are expected to be highly autonomous and automated in order to improve the human factor on the overall outcome of the mission and also, because of the communication delay with the earth station that imposes the spacecraft to be as self-reliant as possible in the accomplishment of its tasks. From these findings comes the need to design and implement more advanced systems of Artificial Intelligence (AI) and human-computer interfaces on board future spaceships. An effective and innovative human-computer interface cannot do without the implementation of the possibility of making astronauts communicate with AI in the most spontaneous way for humans:

natural language. The branch of computer science that deals with “teaching” AI machines how to effectively communicate in the natural language of humans is called Natural Language Processing (NLP).

Other than just potentially being a very effective human-machine interface, human natural language has the potential of being a valuable source of information regarding crew-members psycho-physiological well-being, stress and reliability. In fact, it has been well known for more than a century that psychological states and processes are encoded in verbal behavior and psychological constructs may be reliably explored by text analysis [3, 4]. A multitude of studies indicate the existence of a strong correlation between the variation of the word spectrum used in an individual’s daily vocabulary in a given period and the variation in his level of physiological and psychological stress [5–7]. The aim of this study was to investigate the prospect of using NLP to monitor the psychological wellbeing and stressful conditions of personnel undergoing prolonged missions in Isolated and Confined Environments (ICEs). NLP is a theory-motivated range of computational techniques for the automatic analysis and representation of human language [8]. The history of NLP began in the 1950s as the intersection of artificial intelligence and linguistics [8]. In recent years, increases in computing power have led to the development of sophisticated machine learning algorithms that allow researchers to analyze enormous quantities of biomedical data to detect covered patterns [9]. These developments have brought back the growing of the studies of human Natural Language from a psychometric perspective, consequently directing the progression of NLP algorithms as a diagnostic tool for psychiatric and psychological disorders based on the analysis of written and spoken language [10].

The studies of potential space applications of Natural Language Processing (NLP) have been pioneered by the Russian IBMP research group led by Prof. Vadim Gushim, who analyzed texts extracted from Space Stations (MIR and ISS) and Analogue Missions (MARS500 and MARS105) crews communications with the respective ground controls. A computerized content analysis of written daily reports of the MARS105 experiment crew (IBMP, Moscow, 2009) revealed different tendencies in communicating behaviour. A stress-related strategy was “closing the communication channel” [11], which was found to correlate with elevated urinary cortisol level. These results suggest as both language use and somatic markers can have a diagnostic value in identifying stressful conditions and changes thereof.

Current NLP analyses typically consist of both a content analysis assessing what a subject says and a style analysis evaluating how subjects express themselves. So far, the strongest associations according the scientific literature regarding content analysis have identified in the first-person singular personal pronouns the strongest NLP content indicator of depressive mood [12]. Adjectives and adverbs expressing negative emotions are found to be strongly linked to depressive mood and suicidal thoughts [13, 14]. Regarding style analysis, it has been found that individuals with suicidal thoughts, anxiety or depressive mood tend to use more absolutist words than the general population, thus expressing ideas of certainty [12].

This study explores the possibility to use the NLP to identify language markers that could be of diagnostic value in assessing crew-members psychological wellbeing and stress. Moreover for the first time in literature, it looks for new correlations among: NLP-markers and known stress related cardio-vascular parameters such as Heart Rate, and NLP-markers and a self-reference psychometric short questionnaire. Those findings could prospectively lead to the development of an AI learning tool to monitor remotely and non-invasively not only the astronauts' wellbeing and cognitive performance status in future missions BEO but also on different spin off isolation context on Earth.

2 Materials and Methods

The PSI (Performance & Stress in Isolation) experiment aims to analyze stress levels during extreme missions without intrusive instruments. It has received the approval of the Ethics Committee of the Pope Giovanni XXIII Hospital in Bergamo on 11 August 2017. In this paper, the preliminary data collected from 29 participants (17 males and 12 females) to 6 space analogue missions (Figs. 1 and 2) accomplished among Europe, the USA and Israel in the 2016–2019 time frames, are presented. That is, as yet, the largest database ever analyzed of this kind.

Fig. 1. Astronaut simulation, Female crew mission. (c) Dr. M. Musilova, EMMIHS 2019 (ILEWG EuroMoonMars-International Moonbase Alliance- HISEAS)

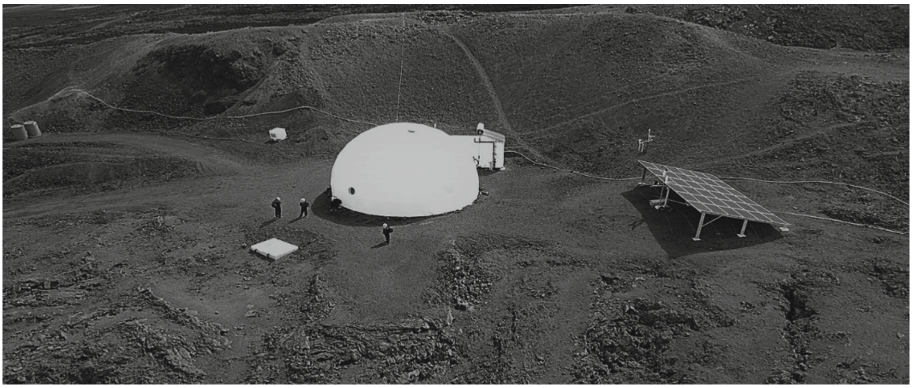

Fig. 2. HI SEAS space simulation base in Hawaii. (c) EMMIHS 2020 (ILEWG EuroMoonMars-International Moonbase Alliance- HISEAS)

The core of the PSI experiment consisted of three tasks to be performed periodically during the isolation:

1. Short text collection, to be analyzed through a NLP software. Every crew member was asked to write in a maximum of 30 min a text with a maximum of 500 words in his mother tongue (e.g. diary collection or daily and official mission report if not affected by a strong imposed structure).
   a. Short self reference questionnaire, to assess subjects' perceived psychological stress levels. It consisted of the following three questions:
   b. Q1: "How stressed do you feel today?" (from low:1 to high:10);
   c. Q2: "How well were you able to perform today?" (from low:1 to high:10);
   d. Q3: "How comfortable do you feel today?" (from low:1 to high:10).
2. Detection of Heart Rate (HR) and Blood Pressure (systolic, diastolic and mean arterial pressure) values, as markers of subjects physiological stress levels. The measurements were taken using an OMRON M3 device, provided to every crew, and crew members were instructed to measure the parameters according to the latest American Heart Association recommendations that at least two readings be taken, with a one-minute interval between them and the average of the measurements recorded.

For each subject the written texts were categorized based on the editing date and time spent in isolation and according to the subject's gender and mother tongue as well. This research relied on the use of two content analysis software tools. One is an Italian tool specifically tailored to this scope. The second tool is LIWC (Linguistic Inquiry and Word Count), developed by the Pennebaker Lab [15].

The data was analyzed using standardized z-score output of linguistic markers from LIWC software as well as using our own specifically tailored software which provides two variables not considered by the LIWC software: the number of Different Words in a text (DW, assumed to be an index of verbal fluency) and the number of Average Characters per Word in a text (CW, assumed to be an index of verbal and cognitive complexity). A Pearson's correlation analysis was run to assess the strength of relationships between linguistic markers.

3 Results

Statistical analysis correlations were searched between the NLP parameters and the answers to the self-reference psychological questionnaire and the cardiovascular parameters. Numerous novel correlations were identified; those lead an interest for a confirmation with a larger number of subjects. Here will be illustrated the most relevant correlations (Fig. 3).

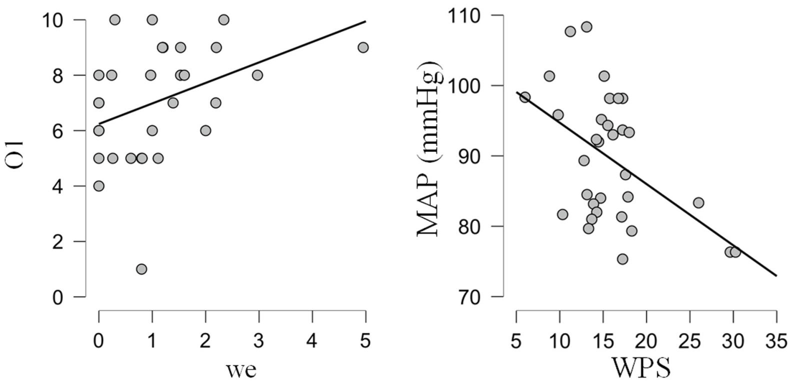

Fig. 3. Left: Scatter Plot of the First Person Plural Pronouns usage (we) and the average scoring at the first question of the self reference test (Q1) (p = .002, r = .490). Right: (right) Scatter Plot of the average number of Words per Sentence (WPS) and the Mean Arterial Pressure (MAP) values (p = .013, r = −.393).

3.1 NLP Parameters and Perceived Stress

A strong direct correlation emerged at the Person Regression analysis (R = 0.490, p = 0.002) between the frequency of *first person plural* pronouns in a text and the scoring at the first questions of the self-reference psychological test (*"How stressed do you feel today?"*). Perceived stress is thus directly correlated to the subject's tendency to express using the *first person plural pronouns*, which is linked to a feeling of detachment, selflessness and isolation [15].

3.2 NLP and Cardiovascular Parameters

A moderate negative correlation was found between the average number of *Words per Sentence* (WPS) and the Mean Arterial Pressure (MAP) values (R = −0.393, p = 0.013). WPS is considered as an indicator of subjects' cognitive complexity [15], while the MAP is an estimation of the average blood pressure in an individual during a single cardiac cycle. It is widely described in the scientific literature the link between higher blood pressure values and chronic [16, 17], allowing us to assume that in individuals in extreme isolation higher MAP values are an physiological indicator of stress and that are negatively correlated to subjects' cognitive performances.

4 Discussion and Conclusion

The results confirm the literatures about NLP content and style analysis, with the important novelty of the correlation hypotheses between the NLP and cardiovascular parameters. Being well assessed in the scientific literature [15, 16] how higher blood pressure values are linked to chronic stress and its complications, this finding open up the perspective of developing a NLP AI system to self-monitor not only astronauts' psychological and cognitive well being but also of their overall psycho-physiological status with spin off applications in different isolation contexts on Earth.

Furthermore we know that the literature review is coherent in assessing that human NLP-psycho-physiological parameters correlations do not always follow the same trends within every subject, like on most parts of the human psycho-physiological phenomena [10–15]. The reason is that NLP and stress-related parameters are highly influenced by many factors such as subjects' age, cultural background, education\-training, gender and length of the isolation. The implementation of NLP in a software designed to let crew members to monitor their wellbeing in isolation, cannot be based on a single rigid algorithm but should be based on a machine learning tool trained to identify the peculiar pattern followed by each parameter in a given subject.

Finally, due to the restricted number of subjects enrolled in this study, the statistical power of this analysis is low and further research is needed to confirm specific linguistic indicators of functionally prohibitive stress responses.

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Occupational Hazards in a Pathological Anatomy Service

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Abstract. Based on an Ergonomic Work Analysis the objectives of this study were to assess and evaluate the working conditions of a Pathological Anatomy Service (PAS) in a Private Portuguese Hospital. Twelve workers participated in the study and six tasks were analyzed and assessed with the RULA method. The main results of this study have highlighted that the work done in this PAS entails risk factors probably responsible for the prevalence of musculoskeletal symptoms and the high levels of eyestrain. According to RULA results, the risk for the development of MSDs is present in almost all tasks suggesting that investigation and adjustments in the work situation are required. Considering the chemical risk assessment, several nonconformities were found in terms of labeling, storage, workplace and worker's training. Globally, the obtained results are in accordance with those reported by other studies.

Keywords: Musculoskeletal Disorders (MSDs) · Ergonomic Work Analysis · Visual fatigue · Pathological Anatomy Service · Rapid Upper Limb Assessment (RULA) · Binocular microscopes · Microtomes · Embedding centers · Digital pathology · Chemical risk

1 Introduction

Work-related musculoskeletal disorders (WRMSD) represent an important cause of occupational disability in developed countries and are responsible for high absenteeism rates. They are among the most costly health problems that society is facing today affecting millions of workers in Europe and cost employers billions of Euros [1, 2].

Musculoskeletal Disorders (MSDs) are injuries and illnesses that affect muscles, nerves, tendons, ligaments, joints, spinal discs, skin, subcutaneous tissues, blood vessels, and bones. Therefore, WRMSD are MSDs to which the work environment and the performance of work contribute significantly, or MSDs that are aggravated or prolonged by work conditions [3].

World Health Organization (WHO) attributes a multifactorial etiology to WRMSD. These disorders seem to be a consequence of the worker exposure to the different

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number of work-related risk factors. “A risk factor is any source/situation with the potential to cause injury or lead to the development of a disease” [4]. WRMSD are associated with a diversity of risk factors such as: a) Physical factors – involving repetitive movements, sustained awkward and uncomfortable postures, static muscular constraints, strained hand and arm movements, the combination of strain and repetitiveness, sudden muscular effort, exposure to vibrations, low temperatures in the work environment, mechanical compression on tissues b) Psychosocial factors known as Work Stress: including long work-shifts, lack of work-pauses, short work cycles, task invariability, short deadlines, work pace, high cognitive demands, lack of autonomy over work, task demands, negative psychosocial situations such as a weak social support from colleagues and management and job uncertainty c) Individual factors: including age, gender, professional activities/skills, sports activities (workers’ fitness), domestic activities, recreational activities, alcohol/tobacco consumption and, previous WRMSD [4, 5].

In a Pathological Anatomy Service (PAS), it is recognized that the main tasks performed expose the pathologists and other technicians to awkward and uncomfortable postures that, in combination with others risk factors, may be responsible for the development of eyestrain and chronic pain syndromes [5–8]. Despite of the recognition of the association of prolonged microscope use with the development of chronic pain syndromes for nearly 3 decades [7], this problems remains present. Some of the tasks’ particularities are known as responsible for WRMSD such as: sustained awkward posture while using binocular microscopes, turning knobs repeatedly while using microscopes, microtomes and embedding centers, etc. [5, 6].

In addition to the risk of WRMSD, the constant handling of chemical substances and their presence in SAP is also a concern. According to Ferro et al. [9], the perception of professionals, who work in pathological anatomy laboratories, regarding the hazardousness of chemical products handled/stored is not high enough to ensure the desirable levels of safety and health at work. The absence and/or devaluation of the implemented protection measures are one of the problems recognized in some studies as being associated with this type of services [10].

An Ergonomic Work Analysis was required to assess and evaluate the working conditions of a PAS in a Private Portuguese Hospital. The mains objectives of this study were:

- to investigate possible relationships between the working conditions and the complaints reported by workers;
- to characterize the most painful tasks/workstations in terms of the associated musculoskeletal disorders (MSD) development risk;
- to characterize the PAS in terms of chemical risk;
- to propose some preventive measures.

2 Materials and Methods

This study was carried out at a pathological anatomy service (PAS), in a Private Portuguese Hospital, from September 2018 to May 2019. Eighty percent out of fifteen workers involved in this service were invited to participate and an informed written consent was previously obtained. The confidentiality of data was always guaranteed.

This study comprised 3 fundamental stages which integrate different kinds of objectives and materials: Global Characterization of the Work Situations; Risk Characterization (MSDs and Chemical risk assessment) and Risk control, following the methodology adopted by Costa et al. [6]. The first stage integrated three objectives: the characterization of both the operators and tasks: the prevalence of complaints (musculoskeletal or visual fatigue) among PAS professionals, based in a self-reported symptoms questionnaire, organized by body regions; the associations between variables (individual/work-related characteristics) and the prevalence of complaints reported and the identification and selection of the most painful task/workstation. The second stage integrated the characterization of the selected task/workstation in terms of the associated MSD development risk. Additionally, the chemical risk assessment of PAS was integrated. The third stage integrated the proposal of several preventive (technical and organizational) measures.

2.1 Data Collections and Procedures

Different methods, tools and equipment were used according to the specificity of each stage of the study. For the first stage, the data were collected through free/systematized observations, conversation with workers and a questionnaire specifically developed for this purpose. The questionnaire intended to identify key parameters for the workers' characterization, evaluate their perception of the real working conditions, identify self-reported musculoskeletal and visual symptoms, as well as to evaluate the workers' risk perception. The questionnaire was based on the adapted version of the Nordic Musculoskeletal Questionnaire (NMQ), proposed by Serranheira et al. [11] and others available in the literature [6, 10], and information provided by the PAS' workers. The questionnaire comprises 42 questions distributed in four sections (A, B, C and D). The main objectives and associated items can be found in Martins et al. [5].

For the second stage video recording allowed to collect images related to work activity. For this purpose, a digital camera of a mobile phone was used. To characterize the associated risk of MSD development, by each task selected, the Rapid Upper Limb Assessment (RULA) was applied following the methodology adopted by Carvalho et al. [6]. A complete description of the RULA method can be found in the article written by McAtamney and Corlett [13]. RULA was applied considering the following criteria: a) tasks selected by workers as more difficult; b) tasks previously related to accidents; c) tasks requiring risky postures and repeatability. At the end the average scores obtained for each analyzed task/subtask were considered. For the Chemical Risk Assessment a checklist was developed (adapted from [14]) and a matrix-based risk assessment method, proposed by Pité-Madeira, was applied [15]. The checklist was organized in four parts: a) Packaging, Labeling and Safety Data Sheets; b) Storage; c) Workplaces and Workstations, and d) Training and Information for Workers. The Pité-

Madeira matrix-based risk assessment method was applied considering that it is easy to apply; makes it simple to classify the risk according to the level of risk found, proposes a clear and objective action plan (action measures) and finally, it was adopted by the Department of Public Health (2010) of the Ministry of Health in Portugal, to assess the chemical risk associated with situations in which risk factors do not have reference values assigned. The risk level (R), in percentage, is obtained by the application of Eq. 1. It should be noted that in the presence of more than one index (Table 1), in the variables under study, the one with the greatest severity should be selected. This means that the application of this method does not only evaluate the risk for the Health of the professionals, but also evaluates the risk in terms of system Safety.

$$R[\%] = \frac{\log P \times \log G}{\log N_P \times \log N_G} \times 99 + 1 \quad (1)$$

where,

P – Probability index = Q x T (1 to 4 levels); Q = Quantitate index of substance used;
T – Task characteristics (see Table 1)
G – Gravity index = F x To (1 to 4 levels); F = Substance' Physical characteristics;
To – Substance' toxicity, based on Safety Data Sheets (SDS) (see Table 1)
N_P – Probability Index Scale*; N_G – Gravity Index Scale*
* the maximum obtained level available considering the scale used by each variable, in this case = 16)

Table 1. Index by variable used in Probability and Gravity. (adapted from [15])

	Probability (P)		Gravity (P)	
Index	Q	T	F	To
1	Solid > 100g Liquid > 1000 ml	Open system with long duration or task made frequently;	Oxidizing Corrosive Explosive Flammable	Acute toxicity
2	Solid: 11- 100g Liquid: 501-1000 ml	Open system with task made in moderate duration;	Very volatile liquid (p.e <50°C) Aerosols Gases	HAZARD Serious health hazard
3	Solid: 1- 10g Liquid: 100-500 ml	Open system with short duration or task made rarely;	Volatile liquid (p.e 50-100°C) Powdery solid Lyophilized solid	ATENTION
4	Solid < 1g Liquid < 100 ml	Closed system	Non-volatile liquid Dense solid	ATENTION

The relationship between Risk Level, Risk Classification and corresponding Action Level is showed in Table 2.

Table 2. Risk Level (R), Risk Classification and respective Action Levels (adapted from [15]).

R [%]	Risk Classification	Action levels
R ≥91	Unacceptable risk	work cannot be started without reducing risk
81 < R ≤90	Significant risk	needs immediate intervention to reduce risk
66 < R ≤80	Moderate risk	corrective and preventive measures must be implemented within a specified period to reduce the risk
41 < R ≤65	Acceptable risk	only requires prevention since the risk has been reduced to the ALARP level
0 < R ≤40	Negligible risk	does not require any measure, the risk is controlled

Data processing was performed with the Statistical Package for the Social Sciences (SPSS©) (version 24). Descriptive analyses were made to summarize the socio-demographic data, job characteristics and the prevalence of complains.

The Chi-square test was used to identify possible associations between variables and the prevalence of complaints. The nonparametric Mann Whitney and Kruskal-Wallis tests were used to compare RULA results by shifts (Morning (M)/Afternoon (A)) and by task. In all cases, a significance level of 0.05 was adopted. Whenever the null hypothesis was rejected the Pairwise Comparison Test was used. The Action Level 2 of RULA method, which corresponds to a RULA Grand Score (RGS) equal to 3 or 4, was considered the level above which a high-risk level of MSD development is present.

Twelve (80%) workers (5 Pathologists/6 Technicians/1 Administrative) agreed to participate in the study answering the questionnaire. Six tasks (Inclusion, Macroscopy, Thinning, Microtomy, Microscopy and Digital Pathology) were analyzed and assessed with the RULA method. The first four tasks are accomplished by Technicians and the last two tasks by Pathologists. The Administrative is responsible for all Lab secretarial work. 162 postures distributed by 6 tasks were used to apply RULA. The tasks assessed were performed by one or two out of four workers (#1, #2, #3 and #4) and during one or two shifts (M/A). Five chemical products were selected to integrate in this study: *Formol, PreservCyt, Cytolyt, Ethanol 96%* and *Xylol*.

3 Results and Discussion

The body regions with the highest percentage of complaints were the cervical (83%), the dorsal (75%), and the lumbar (58%) spine, plus the right hand (67%) and the right shoulder (50%) corroborating the results showed in others studies [6, 7, 12, 16, 17]. The repetitiveness of the arms movements; the flexion/rotation of the head and prolonged sitting were the main reasons, related with characteristics of the tasks, pointed out by the workers to present some of these complaints. Eighty three percent of the workers reported visual fatigue; 40% out of these considered that the symptoms had some impact in the perception of information. The Chi-square test revealed that there were no statistically significant associations between the MSD symptoms/Visual Fatigue and the variables (individual/work-related characteristics) ($p > 0.05$). The risk level for the development of MSD, for all the evaluated tasks, is between the Moderate (67.3%) and High (29%) suggesting that adjustments in the work situation are relevant for 97.5% of the observed postures (Risk Level $\geq$ 2) and further investigation is needed. For the tasks Digital Pathology, Microtomy, Microscopy and Inclusion the Biomechanical loading at the "Neck+Trunk+Legs" was the most important for the final results corroborating the results shown by Maulik et al. [16]. Considering the average values of RULA the riskiest tasks were identified: Inclusion (Risk Level = 2.7), Microtomy (Risk Level = 2.4) and Macroscopy (Risk Level = 2.2). Digital Pathology and Microscopy have the same average value (Risk Level = 2). There are statistically significant differences on Score B in the Microscopy task ($p = .038$) and on RGS in the Macroscopy task ($p = .034$) between shifts. The differences found may be due to: specificities of the body pieces being analyzed at the lab or to the operative modes of each technician. Considering the results obtained by task, the Kruskal-Wallis test suggests that there are statistically significant differences among results from all variables assessed ($p < .00$). The Pairwise Comparison Test did not reveal a pattern in difference found on variables Score B, RGS and Risk Level. On the other hand, the differences found for Score A were between the Microscopy and all other tasks, except Digital pathology.

Considering the Risk level obtained by matrix-based risk assessment method the *Formol* presented the highest (R = 82.18) followed by *PreservCyt, Ethanol 96%* and *Xylol* (R = 75.25), and *Cytolyt* (R = 57.43) which means that corrective and preventive measures must be implemented within a specified period to reduce the risk. Considering the chemical risk assessment, several nonconformities were found in terms of:

- Labeling –Safety Data Sheets (SDS) not available;
- Storage - absence of impounding basins, substances storage without ventilation system, dangerous substances are not stored in their own compartment, storage without taking into account incompatibility and reactivities, storage is not done in signposted areas, materials stacked and ordered inappropriately;
- Workplace – without signs for the use of personal protective equipment (PPE's), without fire extinguisher, the PAS has no means of natural air renewal; there is no emergency plan and emergency numbers are not accessible/visible;
- Worker's training – workers not trained to read labels, to work with hazardous substances, nor to evacuate workplaces;

Globally, the obtained results are in accordance with those reported by other studies [9, 10].

4 Solutions Proposed

To reduce the risk of developing MSD and complaints presented by workers some technical and organizational solutions were proposed: a) rearrangement of the Digital Pathology workstation; b) if possible, acquire adjustable microscopes with tilting and telescoping eyepieces, or adapt existing microscopes with longer ocular tubes and platform adapters; c) select adjustable chairs, desks and other equipment and provide footrests to help workers to support lower limbs; d) workers should become aware of their posture and better understand the MSD risk factors; e) whenever possible workers should take pauses or rotate among tasks and learn how to fit the workstation to their needs; f) Promote awareness training for Chemical Risk (hazards, consequences, correct use of appropriate PPE's, storage, interpretation of SDS).

5 Conclusions

This cross-sectional study was conducted in the pathological anatomy service of a Private Portuguese Hospital. The main results of this study have highlighted that the work done in this PAS entails risk factors probably responsible for the prevalence of musculoskeletal symptoms and the high levels of eyestrain such as: high work intensity, awkward postures, turning knobs repeatedly, high cognitive and visual demands.

According to RULA results, the risk for the development of MSDs is present in almost all tasks suggesting that investigation and adjustments in the work situation are required. Considering the chemical risk assessment, several nonconformities were found in terms of labeling, storage, workplace and worker's training. Globally, the obtained results are in accordance with those reported by other studies.

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Architecture for a Services System Based on Sharing Economy

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Abstract. The high rate of unemployment in Ecuador requires new opportunities to create job offers. We have observed the business model of Uber and Airbnb, there is still many opportunities to create the sharing economy. In this document, we present a clear and innovative architecture to build a business including sharing economy. A system for applying our proposed architecture was developed. Our system monitors and channels the activities of the participants, both the provider of the service and the users of the service. Finally, we evaluate our proposal through a survey aimed to providers and users.

Keywords: Systems engineering · Uber architecture · Cloud computing

1 Introduction

Actually, Uber and Airbnb utilize a compelling vision for the future of mobility as a service going hand a hand [1]. This type of transportation service is called “Transportation network companies” [2] and “Mobile service providers” [3] has been a start to new forms of stablished business. This business applies sharing economy also called on-demand economy or gig economy [2] or collaborative consumption, and collaborative economy [3].

The sharing economy refers to a set of techniques and practices that facilitate trusted transactions between strangers on a digital platform, today the services are the wide spread available of smartphones and other connected devices, as well as technologies like rating systems, that facilitate trust among strangers [4]. Sharing economy firms are disrupting traditional industries across the globe [5, 6]. Actually, the current regulations are the most significant barrier to future growth for sharing economy firms [5, 6].

The virtual platform takes the role of the facilitator and the intermediary of the transactions made among its users. This new business model where trade is carried out on digital media is known as marketplace. We are sure that sharing economy model opens doors to expose many other businesses. We propose the service system

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architecture, with current tools and service-oriented, that facilitates both the marketplace and the sharing economy. Our system focuses on the "domestic service in Ecuador" activity.

The remainder of this work is organized as follow. In Sect. 2, the architecture proposal is presented. In Sect. 3 the evaluation is presented. Finally, in Sect. 4, conclusions and future work are discussed.

2 Architectural Proposal

To demonstrate the use of the proposed architecture, we have developed an application that offers domestic services to be used for homes, offices or others. It is a web and mobile application, where registered users can have the role of workers who offer their work or customers who demand a service. We have set our own conditions in order to optimize the mobility time of workers, the task is assigned to those who are in areas close to where they must work. We have adopted the payment systems imposed by Ecuador government and we have included payment to the country's internal revenue services.

Figure 1 shows the system architecture. A service-oriented architecture (SOA) was used, and specifically RESTful web services. Our architecture consists of providers and service applicants. Providers and applicants communicate through standard protocols.

The backend was developed using Node.js[1], using the Sails.js[2] framework. Sails allows the definition of required data models, along with their attributes and integrates these models into the database for storage. The deployment and configuration of the backend services were executed on the Heroku platform[3]. Heroku provides a public IP. The client HTTP called Postman executes the request to the backend in order to view all registered users. Next, the architecture is detailed:

- Send grid[4] is integrated to Node.js in order to communicate with the applicants through email.
- Firebase cloud messaging[5]is a cross-platform messaging and notifications solution, manages messages sent from the server to the client, in order to facilitate interaction between platform users.
- Angular Google maps[6] provides integration solutions for the official Google maps API. Geolocation coordinates and Google maps visualization are managed.
- PayPal API[7]for secure payment management guarantees collections, payments or payments refunds.

1 https://nodejs.org/en/.

2 https://sailsjs.com/documentation/reference.

3 https://devcenter.heroku.com/articles/platform-api-reference.

4 https://sendgrid.com/.

5 https://firebase.google.com/docs/cloud-messaging.

6 https://angular-maps.com/guides/getting-started/.

7 https://developer.paypal.com/docs/api/overview/.

- Amazon Elastic compute cloud server[8] (EC2) provided by AWS hosted MongoDB - NoSQL database. EC2 provides secure and resizable computing capacity in the cloud.
- Amazon S3[9] is used as a storage service for online multimedia computing resources, we store profile images and documents.

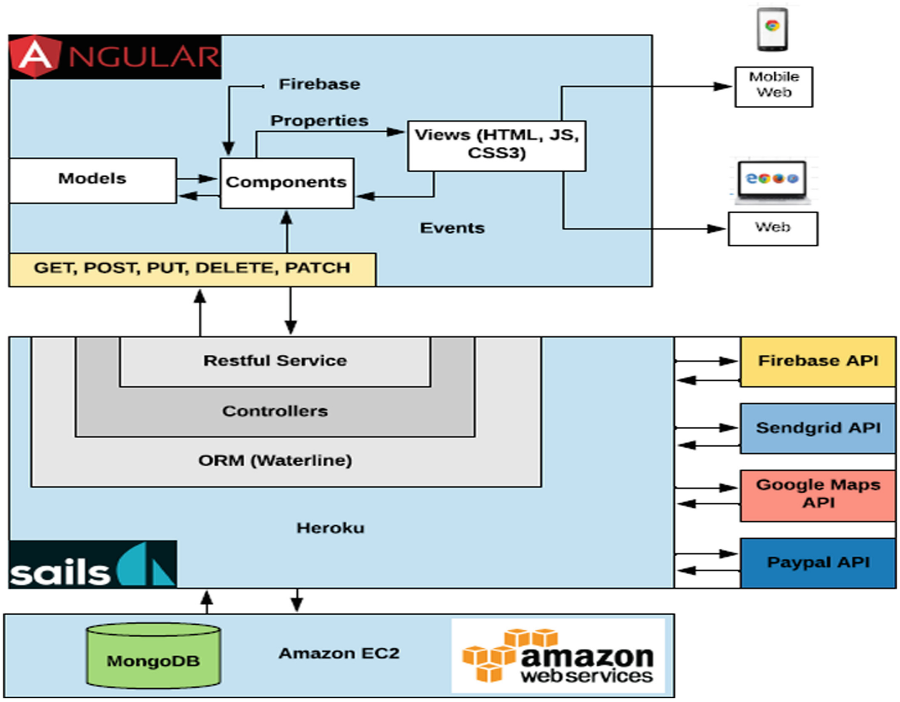

Fig. 1. Services system architecture proposal

The client, which was implemented in Angular, consumes web services exposed in the backend using the standard verbs of the HTTP protocol (GET, POST, PUT, DELETE, and PATCH) and generates the views for mobile and web applications. Finally, the application was deployed using the Firebase hosting service.

Our architecture facilitates the comprehension of our system, and improves maintainability of the system.

[8] https://aws.amazon.com/es/ec2/.

[9] https://docs.aws.amazon.com/es_es/AmazonS3/latest/API/Welcome.html.

3 Evaluation

The final product tests were performed with a total of 20 people where 10 of them took the role of service provider and the remaining 10 took the role of service applicant. The perceived utility and ease of use was evaluated when using the digital platform according to the Technology Acceptance Model (TAM) [7].

Table 1 presents a group of questions, which were answered by both the user and the service provider. The items were measured through a Likert scale with five points (1 → disagree and 5 → agree).

Table 1. Questions on survey

Participant	Perceptions	Code-question	Questions
User	Perceived usefulness	User-usef-1	Did the application help you solve your service-contracting requirement?
		User-usef-2	Do you agree with the opportunity to approve or refuse the service?
		User-esef-3	Do you agree with the hourly prices assigned to the required service?
		User-usef-4	Would you suggest this application to other people?
	Perceived ease of use	User-ease-1	Was the hiring of the service reliable?
		User-ease-2	Was clear and understandable the interaction with the services system?
		User-ease-3	Was the payment of the service easy and reliable?
Service provider	Perceived usefulness	Provi-usef-1	Did the services system help you find a job?
		Provi-usef-2	Did the offered jobs meet your expectations?
	Perceived ease of use	Provi-ease-1	Was the system clear and understandable at the time of registration?
		Provi-ease-2	Was the system clear and understandable when offering the service? Is the calculation of your profit clear and understandable?

Figure 2 shows the frequency of responses to each question related to perceived usefulness, and Table 2 indicates that the median plus one standard deviation always produces results greater than 3. Therefore, the results on perceived usefulness were positive.

Table 2. Statistical summary of web survey responses to items measuring User - perceived usefulness

Item	Min	Max	Median	Std. Deviation
User-usef-1	3	5	5	0.707
User-usef-2	2	5	4	0.876
User-usef-3	2	5	4	0.994
User-usef-4	3	5	4.5	0.699

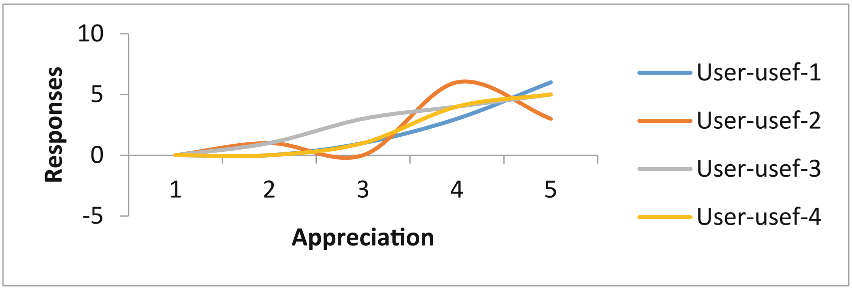

Fig. 2. User - perceived usefulness

Figure 3 shows the frequency of responses to each question related to perceived usefulness, and Table 3 indicates that the median plus one standard deviation always produces results greater than 4. Therefore, the results on perceived usefulness were positive.

Table 3. Statistical summary of web survey responses to items measuring User - perceived ease of use

Item	Min	Max	Median	Std. Deviation
User-ease-1	4	5	4.50	0.527
User-ease-2	3	5	4.00	0.789
User-ease-3	4	5	4.00	0.516

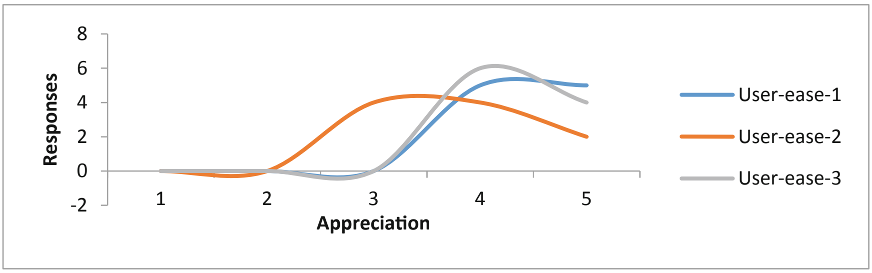

Fig. 3. User - perceived ease of use

Figure 4 shows the frequency of responses to each question related to Service providers - perceived usefulness, and Table 4 indicates that the median plus one standard deviation always produces results greater than 4. Therefore, the results on perceived usefulness were positive.

Table 4. Statistical summary of web survey responses to items measuring Service providers-perceived usefulness

Item	Min	Max	Median	Std. Deviation
Provi-usef-1	3	3	4	0.5
Provi-usef-2	4	4	4	0.5

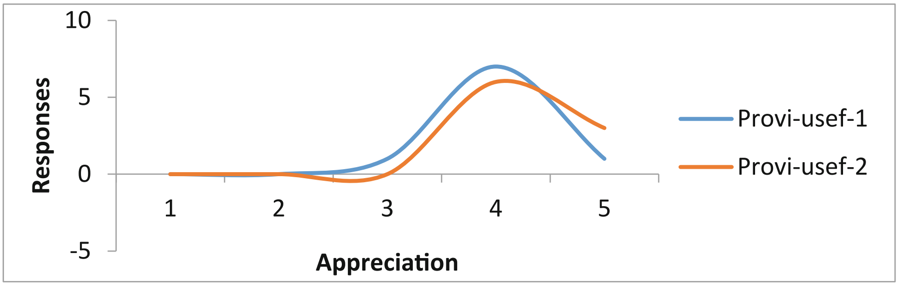

Fig. 4. Service provider - perceived usefulness

Figure 5 shows the frequency of responses to each question related to Service provide-perceived ease of use, and Table 5 indicates that the median plus one standard deviation always produces results greater than 4. Therefore, the results on perceived ease of use were positive.

Table 5. Statistical summary of web survey responses to items measuring Provide of service - perceived ease of use

Items	Min	Max	Median	Std. Deviation
Provi-ease-1	4	5	5.00	0.500
Provi-ease-2	3	5	4.00	0.601
Provi-ease-3	3	5	4.00	0.782

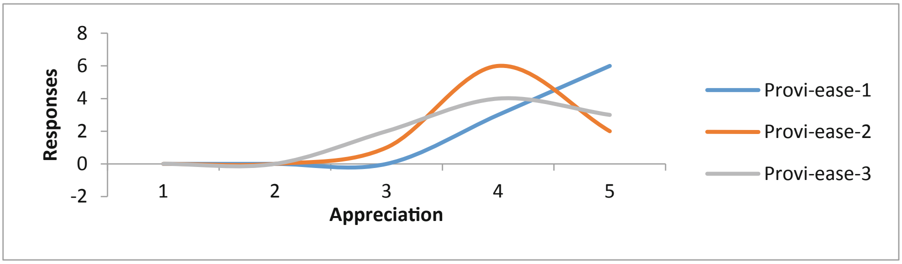

Fig. 5. Service provider - perceived ease of use

4 Conclusions and Future Work

The modularity and flexibility of our proposal architecture improved performance of the services system. We observed new paradigms of the software engineering. The architecture proposal is original and we use contemporary design tools.

To adopt the sharing economy in a country like Ecuador as a novel form of technology-enabled commerce is to create new sources of work, to which a large number of people have access. We solve a problem that many families have, as we allow them to be hired by activity.

Also, in many countries, the criticism of the sharing economy or collaborative economy has generated a concern. In our case, we do submit to the rules imposed by the internal revenue service of our country.

In this type of shared economy companies, an important point is the ability to monitor and channel the behavior of the participants, we also do the relevant monitoring, and we also do activity statistics.

We have used appropriate technology and techniques attached to the work context, we are offering our own architecture that can be useful to anyone who wants to create new shared businesses.

Our future work will develop an architecture based on micro services.

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The RENAULT Ergonomic Assessment Method V3: Comparing Results with the OCRA Checklist and the Strain Index Methods

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Abstract. Work related Musculoskeletal disorders affect millions of workers in Europe and cost employers billions of Euros. Concerned about this problematic, the Renault Group has developed methodologies to assess the risks associated with jobs that integrate repetitive tasks such as the Ergonomic Assessment Method V3 (EAM-v3). Bearing in mind that the assessment of certain jobs by the EAM-v3 does not seem to fully reflect the concerns and the complaints reported by the operators performing them, it seemed appropriate to evaluate these jobs with other methods available in the literature. The main objective of this study was to compare the EAM-v3 results with those obtained with the OCRA Checklist Index (OCRA) and the Strain Index (SI). Five workstations were selected and assessed with the three methods aforementioned. The results obtained showed that in 60% of the evaluated cases, the EAM-v3 was robust enough to reflect the concerns of the respective workers, since the results obtained were, at least, similar or even higher than those obtained by the OCRA and SI methods. In 40% of the cases, the EAM-v3 was less protective resulting in lower risk levels.

Keywords: Musculoskeletal disorders (MSDs) · Ergonomic work analysis · Ergonomic Assessment Method V3 (EAM-v3) · OCRA CHECKLIST index (OCRA) · STRAIN Index (SI)

1 Introduction

Work related musculoskeletal disorders (WRMSD) fall under rheumatic diseases and are characterized as a group of musculoskeletal dysfunctional symptoms and signs that may involve muscles, ligaments, tendons, joints, fascia, synovial bursa, peripheral nerves and supporting blood vessels [1, 2]. These disorders, with a cause associated with work, have heavy economic consequences, cause suffering, and often lead to

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permanent disability [2]. It is known that WRMSD have a multifactorial nature, not depending solely on occupational factors [2, 3]. However, these factors play an important role in the onset, development, or aggravation of musculoskeletal problems [3]. WRMSD represent an important cause of occupational disability in developed countries and are responsible for high absenteeism rates. They affect millions of workers in Europe and cost employers billions of Euros [4]. WRMSD are the main occupational diseases, affecting over 1/3 of the workers in Europe [2]. Several epidemiological studies have demonstrated that a number of risk factors are likely to cause WRMSD problems [5] such as [2]: Physical – awkward joint postures (e.g., bending and twisting), unsupported positions that workers hold for long periods, static postures, excessive movements' repetition, excessive force exertion, direct compression (resulting, for instance, from grasping sharp edges), repetitive materials handling (e.g., carrying and lifting heavy loads), excessive vibration, and cold working environment; Psychosocial - inadequate recovery time due to overtime, lack of breaks, failure to vary tasks, high job demands, time pressure and lack of control; Individual - involving age, gender, professional activities/skills, sports activities (lack of fitness), domestic activities, recreational activities, alcohol/tobacco or drug consumption and, previous WRMSD or disease, genetic factors, among others. In other words, all risk factors that could affect the vulnerability to injury.

Concerned about this problematic, the Renault Group has developed, long time ago, methodologies to assess the risks associated with jobs that integrate repetitive tasks such as the Ergonomic Assessment Method V3 (EAM-v3). EAM-v3 applies to repetitive tasks, with cycle times lower than 10 min, and allows to assess the risk of WRMSD in these jobs, according to the following criteria: Posture, Effort (or Strength), Repeatability or Duration, which are among risk factors that contribute for development of these injuries. In addition to the variables mentioned, this method also takes into account exposure to vibrations, as an aggravating factor for this type of injury. With regard to other factor, Stress, it can also aggravate the appearance of WRMSD and although EAM-v3 allows a specific assessment to be made on this topic, it wasn't considered in this study.

Bearing in mind that the assessment of certain jobs by EAM-v3 does not seem to fully reflect the concerns and the complaints reported by the operators performing them, it seemed appropriate to evaluate these jobs with other methods available in the literature. Therefore, the main objective of this study was to compare the EAM-v3 results with those obtained with the OCRA CHECKLIST Index (OCRA) and the STRAIN Index (SI). So, this study intend to conclude whether or not there is a gap between the results obtained, but also if those obtained by other methodologies are closer to the complaints reported by operators in order to identify its importance and the possible need for their integration in a future revision of the method adopted by the Renault Group.

2 Methodology

2.1 Selection of Workstations

Five workstations were selected and assessed with the three methods aforementioned: two related with machining workstations (with lower cadences), identified by #1 and #2, and three related with assembly workstations (with higher cadences), identified as

Table 1. Main characteristics of the workstations.

Workstations	#1	#2	#3	#4	#5
Time/cycle/machine [min/cycle]	5	7.1	0.28	0.55	0.26
Number of parts machined/machine per hour	12	8	n.a	n.a	n.a
Nº of machines used	2 (without conveyor ahead) 4 (with conveyor ahead)	3	1 assembly workstation	1 assembly workstation	1 assembly workstation
Number of parts machined per hour	72	24	n.a	n.a	n.a
Number of parts assembled per hour	n.a	n.a	94	86	86
Planned breaks (duration in min)	2 (10; 20)	3 (5;10; 20)	4 (3*5; 1*15)	4 (3*5; 1*15)	4 (3*5; 1*15)
Part weight before being machined [Kg]	6.30	8.20	n.a	n.a	n.a
Part weight after being machined [Kg]	6.25	8.10 7.55	n.a	n.a	n.a
Weight of assembled parts	n.a	n.a	[0.1 – 0.7]	[0.1–1.2]	n.a **
Type of work	Dynamic*	Dynamic*	Dynamic (UB) Static (LB)	Dynamic*	Dynamic***
Other Risk factors	n.a	n.a	n.a	Exposure to vibration	n.a

Legend:
n.a - Not applicable; UB – Upper Body; LB – Lower Body;
* - The work is carried out standing with movements between machines;
** - The operator moves a lever similar to that used in light motor vehicles;
*** - Work is performed sitting or standing (the operator can alternate this posture)

#3; #4 and #5. Table 1 summarizes some of the main characteristics of the workstations.

The main reasons to select these workstations were:

- in all of them operators perform tasks that involve various movements with the body, especially the upper limbs;
- at #1 and #2 the heaviest pieces in production are manipulated;
- in 4 out of the 5 jobs (#1, #2, #3 and #4), workers often complain about the associated workload, concerning: the postures adopted, the excessive force exertion and the repetition of the movements;
- finally, the reason for choosing #5 is not related to the existence of complaints of the workers, but because the EAM-v3 does not seem to be adequate for the analysis of this job, due to the difficulty in measuring effort of the worker when carrying out the task (the operator manipulates a lever, back and forth, to test gearboxes).

2.2 Methods Selected, Procedures and Data Processing

MSDs developing risk assessment relied on three methods: a) the EAM-v3, developed by the RENAULT GROUP [6]; b) the OCRA CHECKLIST Index (OCRA) [7] and c) the STRAIN Index (SI) method [8]. A complete description of the EAM-v3, OCRA and SI methods can be found in articles written by da Silva [9], Occhipinti and Colombini [7] and by Moore and Vos [8], respectively. The main reasons to select these methods are summarized in Table 2.

Table 2. Main reasons to select the OCRA and the SI methods.

OCRA	SI
• is a method that focuses on the study and evaluation of the upper limbs, the main part of the body requested in the selected jobs • is a method that emerged and was accepted by the International Ergonomics Committee in 2001 [7], one year before the appearance of the EAM-v3 • the EAM-v3 was based on French and Spanish National Regulations, European standardization and two international methods: RULA - Rapid Upper Limb Assessment and NIOSH - National Institute for Occupational Safety and Health (United States of America), different from OCRA [6], making it interesting to compare the results obtained by these two methods • was the first, most analytical and most reliable method developed and is generally used for (re) design or in-depth analysis of jobs and tasks [7]	• is a method that assesses the risk of WRMSD, especially associated with distal extremities, one of the main parts of the body requested in the workstations studied • the EAM-v3 had in its genesis different methods from the SI, so it is interesting to apply this method and compare the results obtained with those of the EAM-v3, in order to ascertain the pertinence of integrating other risk factors in the calculation process of the method used by the Renault group

Finally, due to repeated movements of the upper limbs, OCRA and SI are among the most recommended methods [10] in the literature. The three methods used are based on the observational analysis of the work activity. The main parameters used by each method are summarized in Table 3.

Table 3. Main parameters considered by methods used.

Parameters	OCRA	SI	EAM-v3
Force applied/Intensity of exertion (Borg scale or %MVC)	x	x	x
Posture (awkward or uncomfortable)	x	x	x
Portion of the cycle time or Duration of exertion	x	x	x
Repetition of the same movement (technical actions)	x		
Frequency (efforts/minute) (frequency/hour)		x	x
Additional factors (I.e.: vibration tools, gloves, gestures implying countershock, exposure to cold surfaces, …	x		x
Recovery period (rest)	x		
Duration (the total time of repetitive tasks during the shift)	x	x	
Speed of Work		x	

OCRA and SI were applied to both sides (right and left) as proposed in the literature. EAM-v3 analyzes the worst member involved in carrying out the task.

As a reference, OCRA and SI use a 4 level-scale to determine the needs for actions [7, 8] whereas EAM-v3 uses a 3 level-scale [6, 9]. To facilitate the comparison between all approaches, OCRA and SI Scores were reclassified into a 3 level-scale. The two intermediate categories were regrouped under the single “moderate” heading, following the methodology adopted by Chiasson et al. [11]. The OCRA, SI and EAM-v3 Risk Level and their interpretation are shown in Table 4.

Table 4. OCRA, SI and EAM-v3 Risk Level and respective Action Level.

Risk level	OCRA	SI	EAM-v3	Action level
Low risk	≤ 6	≤ 3	$\leq 3/3$	Workstation with no risk
Moderate	6.1–18.9	3.1–6.9	4/3 or 3/4	Workstation with moderate risk of WRMSD
High risk	≥ 19	≥ 7	4/4 or Posture or Effort level = 5	Workstation with high risk of WRMSD. Preventive measures must be implemented

In order to reduce the sampling error in relation to the individual factors of the workers and, to ensure that the tasks observed and the way they were performed were representative of the aforementioned posts, the following prerequisites were established: a) the workers observed had to have more than 1 year of experience in the daily performance of the job under analysis; b) workers should not suffer from any pathology or disease that could affect or influence the way in which the job is performed; c) workers should be of medium height and their physical shape should not affect the way the gestures were performed; d) workers should perform their jobs as other operators, i.e. in a standardized way.

The observed workers were aged between 25 and 40 years and 13% were female. 20% of the workers had 10 years of seniority in the job, 40%, 4 years and 20%, 2 years.

During image recording, all machines and peripheral equipment were in normal operation. For images collection a digital camera of a mobile phone was used and a verbal consent of the workers was previously obtained. To apply the selected methods, 3 cycles and 3 operators per station were observed. In order to compare the risk levels of WRMSD existing in the different jobs, by different methods, an 8-h workday was considered. To collect the data related to the efforts, a Chantillon - Ametek DFX II, 100LBF or 500 N dynamometer was used.

For data processing the SPSS© software was used and descriptive analyzes were performed using measures of location (means). The nonparametric Friedman tests was used to compare the results obtained with different methods (inter-method assessment). A significance level of 0.05 was adopted. In addition, the results obtained by the different methods and for each workstation evaluated were compared, depending on their specificities (direct analysis of the results). The most relevant parameters that influenced or were responsible for these results were analyzed and highlighted.

3 Results and Discussion

Table 5 shows the different results obtained (average values), by the different methods, for the five workstations. Considering the Friedman test results, there were no statistically significant differences among the results obtained by different methods ($p > 0.05$) suggesting being indifferent the used method. Despite these results only two tasks (#2 and #4) obtained the same results with the three methods used considering that the majority of differences found are in accordance with other studies [12, 13].

Table 5. Results (average values) obtained by workstation and method.

Workstation ID →	#1	#2	#3	#4	#5
OCRA	RUL – 9.5 LUL – 8.5	RUL – 10 LUL – 7	RUL – 25 LUL – 25	RUL – 26 LUL – 26	RUL – 21 LUL – n.a
SI	RUL - 6 LUL - 3	RUL – 4.5 LUL - 3	RUL - 6 LUL - 6	RUL - 27 LUL - 36	RUL – 13.5 LUL – n.a
EAM-v3	4/4	3/4	4/2	5/4	4/3

Legend:
RUL – Right Upper limb; LUL – Left Upper Limb, n.a – not available

An in-depth analysis of the results obtained revealed the main parameters that contributed for the results obtained by each method and each task. The main results are summarized on Table 6. As reported in other studies the different calculation algorithms associated for each method, which consider a number of different variables to determine the risk, and the different risk limit values within each algorithm could be responsible for the obtained results.

Table 6. Most valued parameters by each method.

Workstation ID	#1	#2	#3	#4	#5
OCRA	Force Posture	Force Posture	Recovery period Repetition Posture	Recovery period Repetition Posture Additional factors	Recovery period Force Posture
SI	Intensity of Efforts	Intensity of Efforts Posture (hand/wrist)	Posture (hand/wrist) Speed of Work	Frequency Duration Posture (hand/wrist) Speed of Work	Frequency Posture (hand/wrist)
EAM-v3	Posture Efforts	Efforts	Posture	Posture Efforts	Posture

4 Conclusions

This study compares 3 methods for assessing risk of WRMSD. The main objective was to compare the EAM-v3 results with those obtained with the OCRA and the SI methods. Five workstations were selected and assessed with the three methods aforementioned.

The results obtained showed that in 60% of the evaluated cases, the EAM-v3 was robust enough to reflect the concerns of the respective workers, since the results obtained were, at least, similar or even higher than those obtained by the OCRA and SI methods. In 40% of the cases, the EAM-v3 was less protective resulting in lower risk levels. As a limitation of this study we can highlight the sample's dimension which can explain some of the results, in particular the non-statistically significant difference found between methods which contradicts the results showed. Plus, if the comparison of the results obtained was based on a 4-level scale, as in the OCRA and SI methods, it could, eventually, produce larger differences among the results obtained by the methods considered, applying the same non-parametric test.

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Ergonomics in Mobile Fingerprint Recognition Systems: A User Interaction Evaluation

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Abstract. Fingerprint recognition represents the most installed recognition modality in modern mobile devices. Currently, there are thousands and thousands of smartphones equipped with fingerprint sensors; the type of sensor and its position on the device changes depending on the model. The fingerprints sensors are typically positioned in the home button (front side), even if sensors embedded on the backside or on the lateral side are equally common. In this paper, we research how the ergonomics of the mobile fingerprint systems influences the user experience and consequently the outcome of the identification. For this reason, we assessed the user interaction with a fingerprint recognition system installed in 3 smartphones (differentiated by the position of their fingerprint sensors). Data collected during the experiment let us analyse how the position of the sensors changes the recognition system's performance and the user feelings while completing a biometric authentication.

Keywords: Biometrics · Mobile biometrics · Fingerprint recognition · User interaction · Ergonomics · Performance · Usability

1 Introduction

Biometrics is the discipline that studies how a human being can be authenticated based on his behavioral and physical traits. Since the very beginning, biometric recognition has been applied in critical contexts where the security and the privacy of citizens must be stabilized (e.g., airport gates, police checks).

During the last decades, the mobile phones have completely revolutionized the use of biometrics. In facts in recent years, we have witnessed a transition from the traditional use of biometrics (forensics) to more private applications of it. This change has been possible since fingerprint sensors are widely embedded on mobile devices.

Thus, thanks to a biometric approach, many users can now access their phone and perform different web transactions in a more efficient and secure way. Nowadays, there are many mobile phone manufacturers that supply their devices with fingerprint sensors to increase the privacy of their customers. Since there are many mobile phone models, there are also different types of fingerprint sensors. The differences between the various

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kinds of sensors do not depend just on the technology (e.g., thermal, capacitive or optic), but also on their location on the device itself. For example, there are some devices that have the fingerprint scanner on the front, others laterally or even in the back. These differences in location can influence the way in which users interact with mobile recognition process, considering that each user has specific characteristics and different levels of hand-dexterity. Hence, can we establish how the user interaction changes as the sensor position changes? How the position of the sensor influences the outcome of mobile fingerprint recognition processes?

In this work, we present a user interaction study in which we investigated how the ergonomics of the fingerprint sensors could influence the outcome of the biometric process in smartphones. In order to accomplish this goal, we recreated a scenario evaluation (according with the ISO/IEC 19795 [1]) in which the user must identify himself by means of fingerprints using mobile phones to finalise retail payments. The transaction could be carried out by an Android application that required the user to present his fingerprint traits. During the evaluation we asked participants to test the app with 3 different mobile devices; all of those smartphones had the fingerprint sensor placed differently (1 frontal sensor, 1 in the back and 1 lateral).

Analyzing the previous results obtained in terms of performance and usability it is possible to address specific typology of sensors to specific classes of users and understand advantages and disadvantages of one or other sensor positions.

We are going to start this paper presenting the previous studies done in this area (Sect. 2), and then we describe the experiment (Sect. 3) and its results (Sect. 4). Finally, the conclusions are showed in Sect. 5.

2 Related Works

"Ergonomics is the study of how equipment and furniture can be arranged in order that people can do work or other activities more efficiently and comfortably" [2]. In the biometric environment, ergonomics refers to the design of scenarios and systems thanks to which the user can easily authenticate himself. As specified by authors in [3], ergonomics helps to establish the best interaction between user and biometrics systems. For this reason, in the previous studies that assessed different ergonomic solutions of biometric systems, researchers were mostly focused on the usability [4] metrics (efficiency, effectiveness and satisfaction).

Until now, there is a poor literature about the ergonomics in biometrics and the majority of these studies were carried out since long ago. In 2013 and 2014, authors in [5, 6] tested signature recognition on mobile devices asking participant to change their posture or using different stylus during the evaluations. Their findings shown a clear correlation between user's position, digital pens and the outcome of the signature recognition process. The same authors, studying the user acceptance of 3 planar fingerprint sensors [7], found out that user preferences could depend on the design of the devices. Most of the participants, enrolled in the experiment, declared their predilection especially for 2 of fingerprint sensors provided. This because those 2 were lighter than the other one and, according to users' feedbacks, this specific feature let them feel more comfortable while performing fingerprint authentications.

Considering that till now the state of the art about ergonomics in mobile biometrics is quite limited, we focus our study on exploring how the fingerprint recognition procedure could be influenced by changing the sensor's position in smartphones.

3 The Experiment

In order to assess how ergonomics factors could influence the biometric process in smartphones, we developed a mobile fingerprint recognition system for performing retail payments. The ISO/IEC 19795 [1] had been followed to design a scenario evaluation in which we tested the biometric system.

The aforementioned system consists of an Android application that allows making money transition once the user has authenticated his fingerprints. We installed this application in 3 models of smartphones, with different fingerprint sensors in terms of shape and location (Table 1).

Table 1. Characteristics of the devices used during the experiment.

Device	Sensor position	Sensor shape	Device Size (Width × Height)	Device weight
Smartphone 1 (**S1**)	Lateral side	Rectangular	72 × 146 mm	161 g
Smartphone 2 (**S2**)	Front side	Rectangular	74,7 × 152,7 mm	158 g
Smartphone 3 (**S3**)	Back side	Circular	70,9 × 146,5 mm	145 g

More details regarding the protocol, the workflow of the experiment and the evaluation crew are provided in the next paragraphs.

3.1 The Protocol of the Experiment

During the experiment, all participants interacted with a fictitious payment application. In order to simulate its context of use, we recreated the most typical scenario in which retail payments are required: supermarket checkout.

In this scenario when the user arrives a supermarket's check-desk and the casher scans items, a payment request is sent to the user's smartphone. Thought our app, the user can accept the payment and complete it after authenticating his fingerprint. The connection between the smartphone and the checkout is established via Bluetooth.

In order to understand how this system could improve the users experience while performing retail payments, we evaluate the user interaction with the 3 devices through performance and usability scores.

In our evaluation the fingerprint authentication process was carried out by the Android security tool, which returns the matched or not-matched result of each verification attempt. Thus, we stored the performance scores as the percentage of successful recognition attempts.

Regarding the usability we reported the efficiency as the time spent for each user in completing the task required them; the effectiveness as the percentage of successful verification attempts and, finally, we assessed the users' satisfaction analysing the feedbacks received from the participants at the end of the experiment.

3.2 Experiment Workflow

Before starting the test, the volunteers were informed about the purpose of the experiment and they signed a consent form for the collecting of personal and biometric data. Additionally, they filled an initial questionnaire in order to store their demographic data and the information about their experience with biometric system and mobile technology. After the informative part, users were asked to perform the first verification phase. After one week-time, they came back to complete a second verification phase and they, finally, fulfilled a last survey to collect their feedbacks and suggestions.

During the verification phases, the user was required to complete 5 verification attempts with the 3 smartphones. Since the fingerprint verification system is blocked by Android Security tools (which allows the storage of only 5 fingerprints at a time) before each verification phase users were asked to enroll their fingerprint traits on the 3 devices that we provided them.

3.3 Evaluation Crew

For this experiment, we recruited to date a population of 21 users belonging to different age groups (between 18 and 64 years old) and with different experience in term of technology and biometrics recognition process. Demographic data and general characteristics of the users are showed in the figure below (Fig. 1).

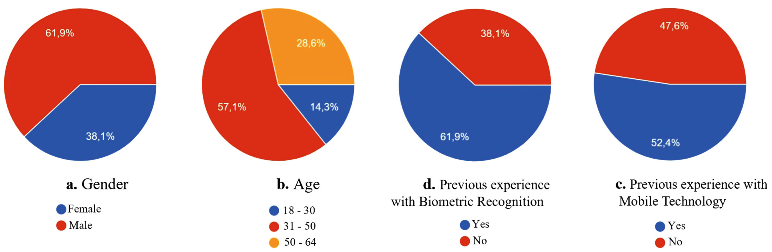

Fig. 1. Demographic data of the 21 volunteers.

4 Results

In this section we report the previous results obtained from our experiment. In order to draw clear and useful considerations regarding user interaction with the proposed biometric system, the results were grouped according to the device (S1, S2, S3) and the phase of the experiment (first and second session).

4.1 Performance Results

In Table 2 are provided the performance results using the 3 smartphones during the first and the second session. It's remarkable the low values obtained analysing the outcome of the S3. During the first visit, just in the 29,3% of the interactions the user was recognized by the system. The result increases during the second visit, even if it remains lower than the values reached with other 2 smartphones.

Table 2. Percentage of successful verification attempts during the experiment.

Device	First session	Second session
Smartphone 1 (**S1**)	78,12%	80%
Smartphone 2 (**S2**)	88,76%	88,54%
Smartphone 3 (**S3**)	29,3%	44,26%

4.2 Usability

The efficiency had been measured as the time needed to each user for completing the two verification phases. Table 3 shows the mean and the standard deviation of times (in seconds) recorded by each user during the experiment's sessions.

Table 3. Efficiency scores: time (in second) spent in completing the verification process during the experiment.

Device	First session (mean and standard deviation)	Second session (mean and standard deviation)
Smartphone 1 (**S1**)	43,6 ± 9,7	44,1 ± 21,8
Smartphone 2 (**S2**)	43,3 ± 11,2	46,5 ± 15,6
Smartphone 3 (**S3**)	59,9 ± 35,1	47,8 ± 11,6

Users almost spent the same time completing the recognition process while interacting with the S1 and S2 during the two session. Regarding the S3, there is a decrement of time between the two verification phases probably because during the first visit user took more time in finding the sensor on the backside of the devices. The standard deviation values especially regarding the second session of S1 and the first session of S3 are quite high, this because there was a high fluctuation between the samples obtained from the limited population we analysed.

All the mistakes made by the participants during the verification phases were considered as incorrect interactions. This means that we have recorded each time that a user has positioned his finger incorrectly (too fast or too far from the biometric sensor); or each time participants had pressed another button of the smartphone rather that the fingerprint one. The percentage of errors made using each smartphone in the first and second verification are shown in the table below (Table 4).

Table 4. Effectiveness scores: percentage of incorect interaction with the system during the verification process.

Device	First session	Second session
Smartphone 1 (**S1**)	10,41%	19%
Smartphone 2 (**S2**)	16,45%	8,23%
Smartphone 3 (**S3**)	33,3%	24,6%

The third device is the one with which the users made more errors, this probably due to not being able to see the sensor while presenting fingerprint. This also explains the increasement in the interaction time with this device compared to the times with which the user interacted with the other two smartphones (Table 5).

Table 5. Users feedbacks about the comfort and the speed of the devices.

Device	Comfort	Time
Smartphone 1 (**S1**)	2,9	2,9
Smartphone 2 (**S2**)	3,8	4
Smartphone 3 (**S3**)	2,9	2,8

Regarding the satisfaction, we asked participant about their favorite payment method once they experienced our system (Fig. 2.). The 54% of the entire population declared the predilection for the biometric-based application instead of cash or credit cards. Half of the volunteers (53%) stated their preference for the second smartphone rather than S1 (20%) and S3 (13,3%).

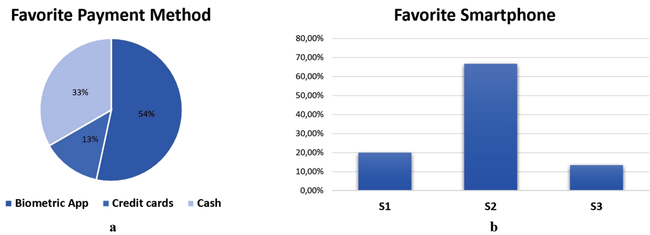

Fig. 2. Results from the final survey.

Besides these general questions, we also asked participants to rate devices in terms of comfort and time choosing values from 1 to 5 (where 5 indicates the most comfortable and the faster device).

Even in this case the best scores were obtained by the second device (S2) which obtained an average of 3,8 for the comfort and 4 for the time required to perform a recognition. Moreover, interviewing the participants at the end of the experiment, we noticed that users' opinions resulted quite different depending on their age and experience. The younger group (composed by people between 18 and 30 y/o) declared the S3 as the device that required less interaction time and stated that they would prefer this design (back-side fingerprint sensor) because is the easier way to approach the sensor while holding the device. On the other hand, the older groups of users still preferred the S2 because reaching the front-side sensor was more intuitive and required them less effort compared with the S1 and S3. Additionally, while the users with previous experience with technology and biometric recognition declared they willingness to use mobile biometrics to perform retail payments, participants without experience said they would not use it because they not feel comfortable.

5 Conclusions

In this paper we have presented the results obtained assessing a biometric-based Android application thanks to which users can complete retail payments. Taking into account our findings, we have proved that the location of the fingerprint sensor on mobile devices influences the user experience and the outcome of the recognition process. The best device in terms of performance was the S2 (front-side fingerprint sensor) followed by the S1 and the S3. This result could be addressed to the intuitiveness of finding the sensor embedded in the home button. Besides, we also noticed that users' preference on sensor design could change according to people's age or experience. Basically, young people were more willing to use the S1 and the S3, while older participants remained convinced to use the S1 using the more traditional home button-fingerprint sensor. Next mobile biometrics evaluations should investigate how other factors related to the characteristics of the users (e.g., any mobility or cognitive issues) could influence the recognition process considering different ergonomic solutions.

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A Life Cycle Assessment Framework-Based Method for Ergonomic Indicator Selection for Complex Human-Machine Systems

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Abstract. To guide the implementation of an ergonomic evaluation in the life cycle of complex human-machine systems, it is necessary to choose suitable indicators for the evaluation. In the present research, we establish an ergonomic indicator evaluation system based on a life cycle assessment framework. Within the structural framework, we propose midpoint and endpoint impact categories for ergonomic evaluation. Taking the evaluation goals as endpoint impact categories, a midpoint impact category groups different indicators into one effect in the evaluation goals. We score the indicators by measuring the relationships between the indicators and the impact categories. Based on the scores of the indicators, the representative ergonomic indicators can be selected. At the end of the manuscript, we use the framework to conduct the selection of ergonomic indicators for a train dispatching command system. This study proposes a structural framework that ensures the validity of the selected indicators.

Keywords: Ergonomic indicators · Human-systems integration · Ergonomic evaluation · Life cycle assessment framework · Dynamic ergonomic indicator selection

1 Introduction

Conducting an ergonomic assessment can effectively identify ergonomic risks in complex human-machine systems. To be efficient and less costly, the assessment activities should start at the initial phases of the system [1]. Within the context of the human-system integration process, this work can also be undertaken during the phases of manufacturing, in-service and disposal. Ergonomic design and evaluation for complex systems in different life cycle phases should be different and specific according to changing requirements [2]. An ergonomic indicator is a measurement index required for ergonomic design, analysis, and evaluation. Ergonomic indicators can represent or measure the effect of the ergonomic evaluation. An important difficulty in using these indicators is to select a proper subset regarding the correlations between indicators. However, the selection procedure of indicators is usually based on expert

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experience. Selecting indicators requires transparent and well-defined procedures to ensure the relevance and validity of ergonomic assessments [3].

Framework types frequently used to select indicator sets include the Driving forces-Pressures-State-Impact-Response (DPSIR) and the Social-Economic-Environment (SEE) [4]. DPSIR is a causal chain framework. The SEE framework is often used to describe foundational considerations for sustainability in business.

Ergonomics and sustainability have congruent aims. Sustainability can help ergonomics by indicating processes in an economic, ecological, and social way [5]. On the one hand, sustainability is also often considered in human-centered product design [6]. Work systems can be stated as sociotechnical systems because of their human-centric structure [7]. On the other hand, life cycle thinking is a valuable tool for integrated assessments of the environmental, social, and economic outcomes of human activities [8]. Furthermore, life cycle assessment (LCA) is now described as an indicator system [9]. LCA frameworks focus both on certainty and uncertainty analysis for the selection of indicators by modeling the midpoint and endpoint impact categories vs. indicators.

Hence, we established an ergonomic indicator evaluation system based on the life cycle assessment framework. With the help of the ergonomic indicator evaluation system presented here, we can easily obtain the scores of these indicators for ergonomic evaluations. Based on the scores of these indicators, the representative ergonomic indicators can be selected. At the end of the manuscript, we used the framework to select the ergonomic indicators for a train dispatching command system.

2 Ergonomic Indicator Evaluation System Based on a Life Cycle Assessment Framework

This paper constructed an ergonomic indicator evaluation system based on a life cycle evaluation framework (Fig. 1), which explains the relationship between ergonomic indicators and ergonomic evaluation goals. We first take the evaluation goals as endpoint impact categories and use the indicator list as the starting point. It is difficult to directly score the indicators with ergonomic evaluation goals; thus, midpoint impact categories are established between the indicators and evaluation goals.

To construct an ergonomic indicator evaluation system, the evaluation goal should be determined first. Six ergonomic indicators are proposed by considering humans, the work design, and the workplace design within the ergonomic dimensions of sustainability, which are ‘Loss’, ‘Investment’, ‘Conditions’, ‘Contribution’, ‘Self-Development’ and ‘Satisfaction’ [5]. Performance and safety are the main evaluation goals in human-machine interaction assessments, and comfort is also the main research point in an ergonomic analysis [10]. Accordingly, we take the endpoint impact categories Safe and Health, Comfort, and Performance.

Because indicators are measurable, their measurement results will have a corresponding impact on the ergonomic evaluations. Similar to the unit process in an LCA, we can establish a quantitative model to represent the relationship between indicators and midpoint impact categories. The impact process from the indicator list to the midpoint impact category is deterministic.

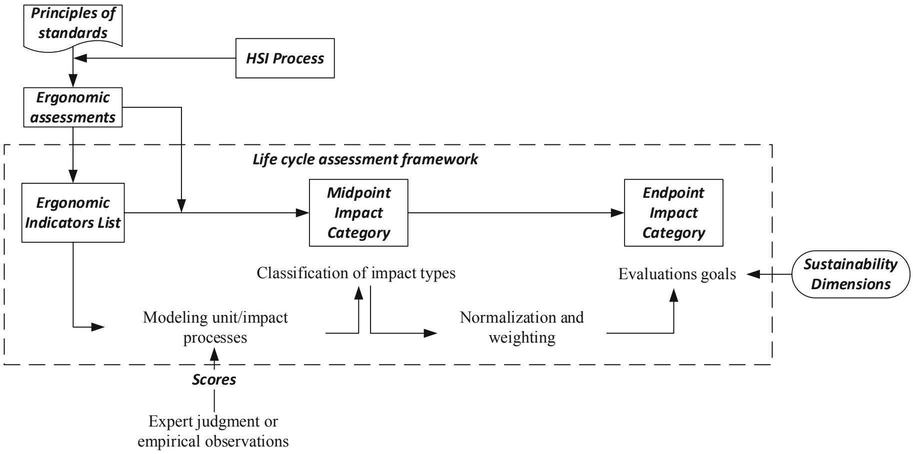

Fig. 1. Ergonomic indicator evaluation system based on a life cycle assessment framework.

We can establish the midpoint impact categories by identifying the difference in the measured method of indicators. Since the unit/impact process from ergonomic indicators to the midpoint impact category is sometimes difficult to measure directly, expert judgments were used, or a statistical evaluation of empirical observations was performed. We can score the corresponding indicators for a specific midpoint impact category.The relationship between the midpoint category and the evaluation goals is relatively uncertain and can be adjusted by weights. Normalization expresses the relative magnitudes of the scores, and weighting expresses their relative significance in accordance with the goal of the evaluation. We summarized the impact types of the midpoint impact category on the evaluation goals, which provided a basis for setting the weights.

The principle of ergonomic standards provides an effective basis for determining the ergonomic assessment at each phase of the system. The life cycle of the system in the Human Factors Integration process is divided into 6 phases: concept, assessment, demonstration, manufacture, in-service, and disposal [11].To apply a whole life perspective on ergonomic indicator selection of the complex human-machine system, we divided the ergonomic assessment content into standards according to the research phase of human-system integration. Based on the corresponding ergonomic assessment, we extracted ergonomic indicators for all phases of the life cycle of the systems.

Based on the ranking of the standardized scores of indicators, the representative ergonomic indicators of each phase can be selected.

3 Application: Train Dispatching Command System

We used the framework to conduct the selection of ergonomics indicators for a train dispatching command system.

The train dispatching command system is a typical control center. Based on the ergonomic principles of the control center in ISO 11064, we compiled the assessment content of each stage, the evaluation goals and the detailed evaluation steps of each phase. Combined with the HSI design process, we summarize the ergonomic assessment steps that need to be performed at each phase in Table 1.

Table 1. Ergonomic assessment goals at various phases of the life cycle of the control center.

Phase	Ergonomic assessment goals
1. Concept	1. Clarify goals and the background requirements
	2. Define the system performance (function analysis and description)
	3. Allocate functions to humans and/or machines
	4. Define the task requirements
	5. Design the job and work organization
	6. Verify and validate the obtained results
	7. Design the conceptual framework of the current center
	8. Review and approve the conceptual design
2. Assessment	9. Add details to the design
3. Demonstration	10. Verify and validate the detailed design proposal
	11. Collect operational experiences
4. Manufacture	12. Coordinate the development of the workforce, training and support
5. In-service	13. Support operations and monitor the cost effectiveness
6. Disposal	14. Assess hazards

The extraction of ergonomic indicators should be based on the content and goals of the ergonomic assessment. For example, ISO 11064-1 states that ergonomic analysis should first define goals and system requirements, including performance, function, and project requirements, and the standard also specifies the content of each requirement. According to this principle, indicators corresponding to these evaluation goals can be proposed, such as demand efficiency indicators and performance indicators. We extracted approximately 110 ergonomic indicators related to the control center design (Table 2).

Table 2. Ergonomic indicators at various phases of the life cycle of the control center.

Phase	Ergonomic indicators			
Concept	Demand efficiency indicators	Performance requirements indicators	Operational safety indicators	…
Assessment	Task indicators	Visual requirements indicators	Environmental constraints indicators	…

(*continued*)

Table 2. (*continued*)

Phase	Ergonomic indicators			
Demonstration	Iterative design indicators	Scheme verification indicators	Process integration indicators	…
Manufacture	Equipment procurement indicators	Logistics support indicators	Operator training indicators	…
In-service	Operation audit indicators	Operation experiment indicators	Monitoring and maintenance indicators	…
Disposal	Health indicators	Safety indicators	Risk analysis indicators	…

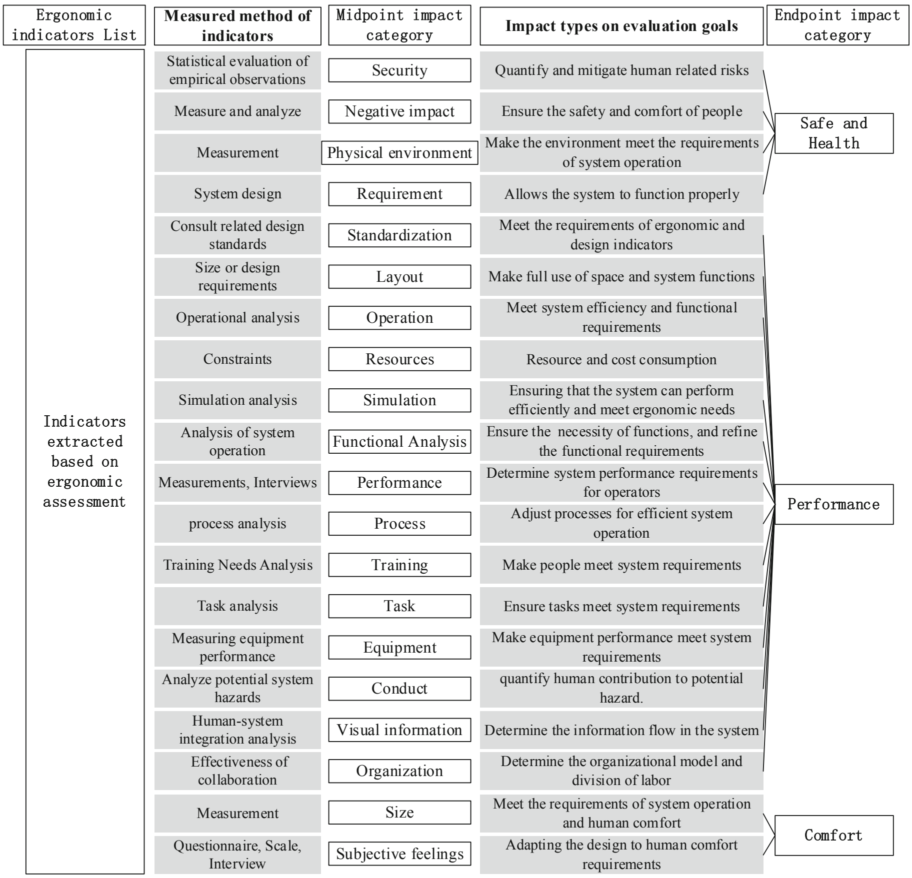

Fig. 2. Ergonomic evaluation system of the control center.

3.1 Ergonomic Evaluation System of the Control Center

By summarizing, we construct 20 midpoint impact categories (Fig. 2). For example, the safety requirement indicators, operation safety indicators, and emergency exit indicators required during the concept phase are all security indicators. They can be judged by a statistical evaluation of the empirical observations. The midpoint category of security protection will affect the endpoints (Health and Safety) in the form of quantifying and mitigating human-related risks. The ergonomic indicator evaluation system proposed in this paper mainly explains the reasons for the construction of midpoint impact categories and does not analyze the quantitative models of each midpoint category in detail.

3.2 Ergonomic Indicator Selection of the Train Dispatching Command System

We invited experts to score midpoint impact categories on indicators. All the midpoints are assigned an equal weight. Experts assigns a score on a 10-point scale, with 1 being extremely unimportant and 10 being particularly important.

According to the results of the experts' evaluations, we calculated the cumulative score of the mean scores of the indicator at each phase in the midpoint category (Fig. 3).

The demand for ergonomic indicators for the systems is mainly concentrated in the concept and evaluation phases. The indicators in the midpoint category of Operation and Simulation contribute the most to the evaluation goals.

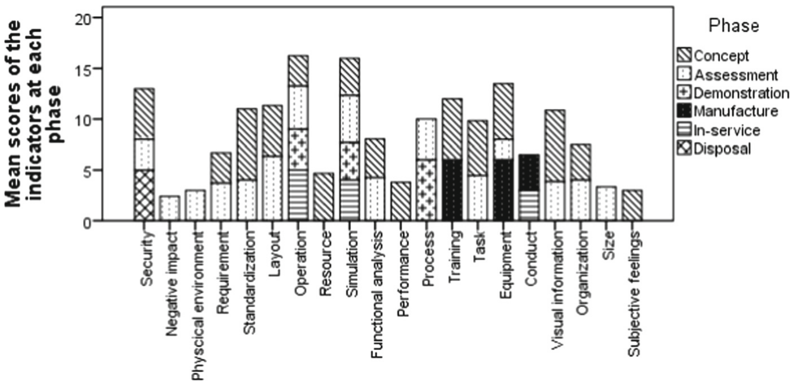

Fig. 3. The scores of the midpoint impact categories at each phase.

4 Discussion

This study proposes a structural framework to present the relations between the ergonomic indicators and the evaluation goals, which ensures the validity of the selected indicators. The selection of ergonomic indicators also provides effective support for the whole life cycle of the ergonomic evaluation of complex human-machine systems.

This method still depends on the experts' scoring process for the indicator. The scoring process is relatively subjective, which is significantly related to the experience of the experts [12]. Ergonomic assessment indicators are extracted less often at the manufacturing, use, and disposal phases. The main reason is that there are fewer human factor analysis principles in the later phases of the life cycle in the standard, and HSI puts the main ergonomic activities in the early phase of the life cycle. Relevant literature can be used to complement an ergonomic analysis or ergonomic assessment activities in the manufacturing, use and disposal phases.

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Research on the Parameters of Human - Machine Interaction of Command and Control System Operator Based on Fitts Law

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Abstract. Fitts proposed the Fitts Law, a human motion behavior prediction model based on information theory, which established the functional relationship between motion time, motion amplitude and target area width, and became one of the few quantitative models in the field of human-computer interaction. However, the parameters related to devices of a and b need to be tested in combination with specific population and devices. Based on the hardware equipment such as mouse and eye tracker, this paper carried out the experimental design and implementation of interactive motion data collection for command and control system operators, and collected data of 20 people in total. The analysis of experimental data shows that the average value of 20 person-times is: a = 160.7, b = 227. The above research not only improves Fitts Law in the field of command and control system, but also provides a quantitative model targeted at specific groups for later cognitive and behavioral modeling of operators and human-machine interface design.

Keywords: Fitts Law · Command and control system · Cognitive behavior modeling · Human-machine interaction · Human-machine interface

1 Introduction

Complex cognitive operational behaviors can be decomposed into four basic cognitive behaviors: eye movement behavior, visual perception, cognitive behavior and motor behavior [1, 2]. The motion behavior can be modeled by Fitts Law [3]. Fitts proposed Fitts Law, a human motion behavior prediction model, based on information theory. Fitts' Law established a functional relationship between motion time, motion amplitude and target area width, which has been widely applied as one of the few quantifiable human-computer interaction models [3]. For placement tasks with a motion amplitude of A and a width of the target region of W, Fitts' Law gives the prediction formula of the mean motion time T as follows:

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$$T = a + b\log_2(A/W) \quad (1)$$

Where, A represents the range of movement, W represents the width of the target, and MT represents the movement time. a and b are parameters related to equipment and users, which need to be tested in combination with specific population and equipment.

The modeling of specific device interaction behavior of command and control system operators is of great significance for cognitive behavior modeling and human-computer interaction interface design, but Fitts Law research achievements in the field of command and control system operator is less. It is urgent to carry out the experimental design and implementation of interactive movement data collection for command and control system operators based on mouse and eye tracker, providing data support for the human-computer interaction design of command and control system and the cognitive behavior modeling of operators. Therefore, this experiment measured the parameter a and b of Fitts Law formula for mouse interaction behavior of command and control system operators.

2 Experiment Equipment

Experimental equipment includes: PC, monitor, simulation software, mouse, keyboard and eye movement measurement equipment. The eye movement measuring equipment is the Tobii Pro Spectrum 600 eye movement instrument. It is a screen eye tracker with a sample rate of 600 Hz that allows for a wide range of head compensation with high precision and accuracy without the need for any bondage devices [4]. The display resolution of the interface was 1920 × 1080, the screen size was 30 × 53 cm, and the distance from the screen was 0.65 m.

3 Experimental Subjects

The subjects were 20 command and control system operators, all male, aged between 20 and 40. The subjects showed no color weakness or color blindness.

4 Eye Movement Preparation Time Measurement Experiment

4.1 Experimental Task

Given the formula of Fitt's Law, 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. In this experiment, subjects were required to complete two tasks for the determination of a and b. Firstly, the target width W is unchanged and the target distance is changed. Secondly, the target distance A is unchanged and the target width is changed. The subjects were asked to use the mouse to complete the "click" operation on the display interface of the main experiment. The example is shown in in Fig. 1.

Fig. 1. Experiment task display interface 1

G, D are two rectangular ICONS with the size and distance set. G and D are set as rectangles because the icon in the command and control system is a rectangle. “Click” means “click the yellow rectangle icon to start the test. During the test, click two rectangle ICONS back and forth until the end dialog box pops up”.

In this experiment, the subjects need to complete three experiments of target distance A = 100, 200 and 400 pixels, and three experiments of target width W = 10, 20 and 40 pixels intersection, so as to obtain a total of 9 independent variables, namely the moving time T.

In addition, before the experiment begins, the subject needs to explain the experiment briefly. Each subject carries out the exercise of “test times is 3” for the experiment with given parameters, so that the participants become familiar with the experiment content. After issuing the experiment command, the subject completed the experiment at a comfortable speed.

4.2 Experimental Results

Through the analysis and function fitting of the experimental results, the parameters of Fitt’s Law of this interface, a and b, can be obtained.

The experimental variables are A (the distance between the current position of the device and the target position) and W (the size of the target). A is 100, 200, 400; W is 10, 20, 40. The number of subjects was 20, and each person had to do at least 9 experiments.

The experimental results are shown in Table 1, where

$$\mathrm{ID} = \log_2(\mathrm{A}/\mathrm{W}) \tag{2}$$

T is listed as the average time value of 20 people completing the task under different experimental conditions in Table 1 (Fig. 2).

Table 1. Average task completion time of 20 subjects

A (pixels)	W (pixels)	ID (bits)	T (ms)
100	10	3.46	975.35
100	20	2.58	764.25
100	40	1.81	600.25
200	10	4.39	1204.6
200	20	3.46	923.7
200	40	2.58	703.05
400	10	5.36	1359.2
400	20	4.39	1171.75
400	40	3.46	890.95
Mean value		3.50	954.79

Table 2. Experimental data of 20 subjects

Num	A&W								
	A = 100 W = 10	A = 100 W = 20	A = 100 W = 40	A = 200 W = 10	A = 200 W = 20	A = 200 W = 40	A = 400 W = 10	A = 400 W = 20	A = 400 W = 40
1	963	763	601	1189	924	703	1366	1159	878
2	974	765	610	1207	936	711	1361	1173	892
3	976	773	617	1210	927	705	1353	1171	895
4	988	765	591	1196	925	701	1359	1172	890
5	975	764	601	1205	883	720	1351	1180	887
6	977	731	621	1204	918	687	1354	1179	891
7	985	763	600	1219	926	692	1359	1175	896
8	979	781	616	1206	907	714	1360	1172	897
9	983	765	594	1221	925	688	1367	1160	890
10	975	785	598	1205	929	693	1371	1168	891
11	989	763	599	1204	915	699	1347	1175	884
12	976	754	601	1198	923	712	1361	1174	892
13	969	776	602	1206	934	724	1358	1183	881
14	962	763	597	1200	919	702	1357	1170	893
15	971	763	601	1211	935	691	1358	1165	898
16	973	775	594	1216	908	690	1350	1169	890
17	980	751	601	1190	941	702	1370	1173	901
18	975	765	571	1207	952	706	1360	1176	893
19	960	757	587	1205	933	718	1371	1171	897
20	977	763	603	1193	914	703	1351	1170	883
Mean value	975.35	764.25	600.25	1204.6	923.7	703.05	1359.2	1171.75	890.95

The fitting results are shown in the Fig. 2 below:

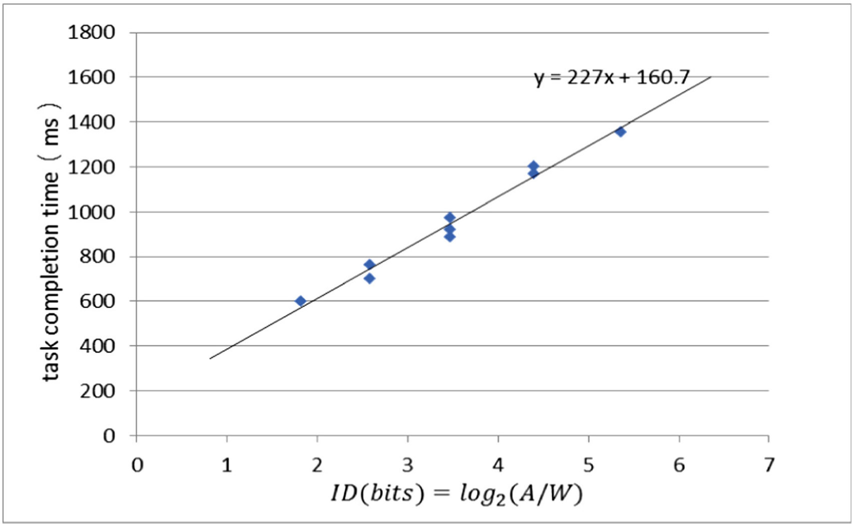

Fig. 2. Function fitting results of Fitts Law in this experiment

The fitting function is: T = 160.7 + 227 $\log_2$ (A/W), and the parameters of Fitts law a and b under the command and control system interface are a = 160.7 and b = 227 respectively.

In order to verify the degree of function fitting, error analysis of function fitting is carried out. In general, the parameters that describe the degree of fit between the fitting function and the measured data include sum of squares of error (SSE) [5], Coefficient of determination (R-square) [6], Degree-of-freedom adjusted coefficient of determination (Adjusted R-square) [7], and Root mean squared error (RMSE). The smaller the SSE, the better the model selection and fitting. The range of R-square is [0, 1]. The closer it is to 1, the stronger the explanatory ability of the variables of the fitting function to the Y-axis value is, and the better the fitting degree of the model to the data is. The closer the Adjusted R-square was to 1, the better the fitting degree was. RMSE is consistent with SSE principle, the smaller the better.

Using matlab to analyze the fitting degree of the fitting function, the results are shown in Table 3 below.

Table 3. Analysis of fitting degree of fitting function

SSE	R-square	Adjusted R-square	RMSE
1.0208e + 04	0.9797	0.9768	38.1878

As shown in Table 3, the error sum squared of the experimental fitting function is 1.0208e + 04, which is the smallest among all fitting methods (such as exponential function fitting, quadratic term fitting, etc.). The fixed coefficient (R-square) of this fitting function is 0.9797, which is close to 1. The Adjusted R-square was 0.9768, which was close to 1, so it could be seen that the fitting function had a high fitting degree. For RMSE, this fitting is 38.1878, which is within the acceptable range. Therefore, the value of the fitting function accords with the actual value,and the fitting function of this experiment has a good fitting degree.

5 The Experimental Conclusion

The complex cognitive operation behavior can be divided into four basic cognitive behaviors: eye movement behavior, visual perception, cognitive behavior and motor behavior. This paper carried out the experimental design and implementation of interactive motion data collection for command and control system operators, and measured and modeled the mouse movement behavior of 20 subjects of command and control system operators. According to the experimental measurement, the parameters of Fitts Law for the commander's mouse interaction are a = 160.7 and b = 227, and Fitts Law is described as $T = 160.7 + 227 \log_2(A/W)$ in milliseconds (ms). The research in this paper not only improves Fitts Law in the field of command and control system, but also provides a quantitative model targeted at specific groups for later cognitive behavior modeling of operators and human-machine interface design.

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Author Index

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