Advances in Intelligent Systems and Computing 1205

Jay Kalra
Nancy J. Lightner *Editors*

Advances in Human Factors and Ergonomics in Healthcare and Medical Devices

Proceedings of the AHFE 2020 Virtual Conference on Human Factors and Ergonomics in Healthcare and Medical Devices, July 16–20, 2020, USA

Springer

Advances in Intelligent Systems and Computing

Volume 1205

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ISSN 2194-5357 ISSN 2194-5365 (electronic)
Advances in Intelligent Systems and Computing
ISBN 978-3-030-50837-1 ISBN 978-3-030-50838-8 (eBook)
https://doi.org/10.1007/978-3-030-50838-8

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Advances in Human Factors and Ergonomics 2020

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11th International Conference on Applied Human Factors and Ergonomics and the Affiliated Conferences

Proceedings of the AHFE 2020 Virtual Conference on Human Factors and Ergonomics in Healthcare and Medical Devices, and the International Conference on Human Factors in Aging and Special Needs, July 16–20, 2020, USA

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Preface

This book is concerned with human factors and ergonomics in healthcare and medical devices. The utility of this area of research is to aid the design of systems and devices for effective and safe healthcare delivery. New approaches are demonstrated for improving healthcare devices such as portable ultrasound systems. Research findings for improved work design, effective communications and systems support are also included. Healthcare informatics for the public and usability for patient users are considered separately but built on results from usability studies for medical personnel.

Quality and safety are emphasized, and medical error is considered for risk factors and information transfer in error reduction. Physical, cognitive and organizational aspects are considered in a more integrated manner so as to facilitate a systems approach to implementation. New approaches to patient handling ergonomics, emergency and operating rooms, healthcare, medical device design, human factors and ergonomics measurement and model validation are included. Recent research on special populations, collaboration and teams, as well as learning and training, allows practitioners to gain a great deal of knowledge overall from this book.

Explicitly, the book is organized into eight sections that contain the following subject areas:

Section 1 Patient Safety
Section 2 High-Reliability Organization Development
Section 3 Diagnosis Techniques
Section 4 Prosthetics
Section 5 Advances in Medical Devices and Techniques
Section 6 Healthcare Software Applications
Section 7 Safety, Integration and Interaction for Older Adults and Children
Section 8 Cognition Framework

Each of the chapters of the book was either reviewed by the members of Scientific Advisory and Editorial Board or germinated by them. Our sincere thanks and appreciation go to the Board Members listed below for their contribution to the high scientific standard maintained in developing this book.

This book would be of special value internationally to those researchers and practitioners involved in various aspects of healthcare delivery.

July 2020

Jay Kalra
Nancy J. Lightner

Contents

Patient Safety

Systematic Prevention and Treatment of Undernourishment: A Case of Collaboration Needs Across Healthcare Levels

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Abstract. This paper presents findings from a case study addressing practices in preventing and treating undernourishment at the intersection of primary and secondary care in Norway. (Primary care is the first level of healthcare that a patient usually encounters e.g. general practitioner or community nursing service). Secondary care services are usually based at hospitals and are handling more serious health conditions, patients are usually referred to them via primary care (however emergency care is also part of the secondary care level.) Two types of data were collected: nursing report summaries provided to and from the hospital upon hospitalization and discharge of patients; and semi-structured interviews with nurses in two hospital wards and home-based nursing services. The results point to weaknesses in the nutritional care process when disrupted by moving the patient between levels in the healthcare system: Nutritional information is often missing in the documentation that is transferred, and the information that is provided may be ambiguous to the recipient because of differences in language and little knowledge of each other's practices. This suggests that greater emphasis should be placed on developing boundary spanning collaboration abilities between community care services and hospital in order to facilitate continuity in nutritional care.

Keywords: Undernourishment · Healthcare levels · Collaboration · Human and organizational factors

1 Introduction

In Norwegian healthcare, attention to prevention and treatment of undernourishment as a major patient safety issue has increased for the past two decades. It has been estimated that one third of patients in Norwegian hospitals is either at risk of malnutrition or are malnourished [1], while a study found that 46% of patients receiving community nursing services (home-based) in two of the largest municipalities were either undernourished or at risk of such [2]. In Norway, the increased focus on undernourishment has been visible in the form of national guidelines for its prevention and treatment [3], its inclusion as one of the focus areas of the national patient safety program since 2017, and, finally, its inclusion as a quality indicator in nursing and care services from 2018.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 3–10, 2020.
https://doi.org/10.1007/978-3-030-50838-8_1

There are various factors that can influence a patient's nutritional status, including medical, cognitive, and psychosocial factors, and often in combination [3, 4]. There exist several studies of practices in providing nutritional care, as well as on factors that may influence these practices such as knowledge and attitudes amongst personnel, and systemic barriers such as rigid food services and lack of routines [5–8]. Most studies on nutritional care practices seem to focus on one healthcare context, for example home-based services or hospital ward(s). However, preventing and treating undernourishment is a process that implies following up a patient over a longer time period [9]. Consequently, the process may also span across different levels of the Norwegian healthcare system (e.g. primary and secondary), especially for elderly patients. In this paper, we present findings from a case study addressing practices for preventing and treating undernourishment at the intersection of primary and secondary care in Norway.

2 Method

This case study was performed during 2018–2019 in Norway with participation from community nursing services (home-based) in two municipalities and two wards at the local hospital. The main research objective was to derive knowledge on information transfer between community nursing services and the hospital to support their collaboration in providing nutritional care.

The project collected two types of data: First, we obtained nursing report summaries that the nursing service sent to the hospital upon hospitalization of patients ($N = 9$), and vice versa upon discharge of patients ($N = 9$). The reports were anonymized before being shared with the researchers. The nursing reports were analyzed with respect to structure and content to identify how information regarding patients′ nutritional status and any nutritional care provided to the patient is described. Second, we performed semi-structured interviews with nurses in two hospital wards ($N = 6$) and community nursing services ($N = 8$). The nursing report summaries were used to partly inform the interviews. The interviewees were provided examples of the hospitalization and discharge documentation and asked if these were representative for the reports they typically sent and received. Topics covered in the interviews were information needs, information typically received and sent, and ways of communicating. Transcripts from the interviews was subject to thematic open coding (i.e. not applying pre-defined analytical categories). Four main themes emerged: i) missing information, ii) differences in language, iii) individual interpretation, and iv) continuity of care. These are further elaborated on in 3.2. All quotations used are translated.

2.1 Limitations

The hospitalization and discharge documentation were not instructed to refer to any specific ward at the hospital, nor any specific nutritional issues. The request was for the latest nursing reports provided upon transfer of patients to and from the nursing services. The documentation should therefore be representative for the general information exchange between the hospital and the nursing services in this case study. The findings are, however, not necessarily representative for community nursing services and hospitals in other parts of Norway.

There are also limitations associated with the sample of interviewees at the hospital. Both hospital wards had participated in a pilot project on systematic nutritional care internally at the hospital. It is possible that as a result of this pilot project, the interviewees have a different perspective compared to nurses with less experience in prevention and treatment of undernourishment. However, given our research objective, it was beneficial to obtain insights from nurses with experience in working systematically with prevention and treatment of undernourishment. Furthermore, systematic nutritional care is expected to be introduced as best practice in Norwegian healthcare generally.

3 Results

3.1 Findings from Nursing Reports

In Norway, the electronic patient journals are used to generate and receive communication messages between different healthcare services, transmitted via an encrypted network. Several types of messages exist, hospitalization and discharge reports being amongst them. These reports follow a standardized template.

Upon hospitalization of a patient, the community nursing services send information about the reason for hospitalization as well as a nursing report summarizing important information about the patient to the hospital. The nursing report includes assessment scores of the patient's level of normal functioning, adhering to a standardized classification system for all municipality care services in Norway (IPLOS). Other information includes known diagnoses, medication, services received and contact information. The community nursing services may also provide additional information in a free text field. Of the nine hospitalization nursing reports we received, there was no provision of specific nutritional information. Further, there was no information on whether the services had performed a nutritional risk assessment of the patient.

The hospital's discharge report mainly consists of medical information, a free text field in which the hospital is to provide a summary of relevant patient information following pre-specified categories of which one is "nutrition/fluid", a specified free text field for risk assessments, control appointment and contact information. The information provided under "nutrition/fluid" varied greatly from simply describing the type of food the patient eats, their functional ability to eat themselves, or the amount of food intake during their stay. Only one of the nine discharge reports provided information that the hospital had performed a nutritional assessment of the patient. This report mentions factors that influence the patient's intake (e.g. difficulty swallowing), that the patient needs to be motivated for eating, and the type of food that s/he has eaten under "nutrition/fluid".

3.2 Findings from Interviews

Four main themes were identified in the interview data. We understand these themes to be linked together, as illustrated in Fig. 1.

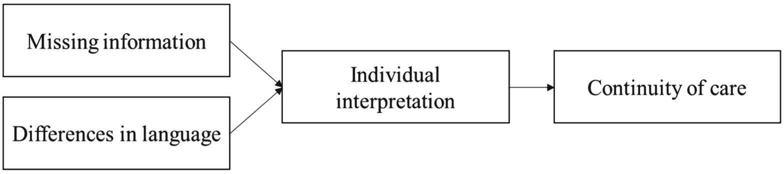

Fig. 1. Illustration of relationships between the main themes emerging from the interviews

The nurses both in the community nursing services and the hospital expressed that they generally experience to receive little concrete information related to nutrition from the other, unless it is part of the reason for hospitalization of a patient:

> *"Little information about nutrition. It might not be mentioned. Allergies, normal diet or small portions – [small portions] must be examined in more detail whether it is normal or if that is something we need to follow up on."*
>
> *(nurse, community nursing service)*

The above quote also points to how the (lack of) information regarding patient's nutrition status in the discharge report is subject to interpretation by the nurses in the home-based services. For example, if there was no specific mention of nutrition status, a nurse commented that she interpreted that as the patient having been hospitalized for something else and that nutrition have not been assessed by the hospital. The nurses in the two hospital wards explained that they a have routine for transferring the nutritional care plan that they establish for patients at risk of undernourishment. However, this information is attached in the epicrisis that is sent to the patient's general practitioner, and not necessarily to the community nursing service.

Furthermore, certain language used in the written documentation that is transferred may also give rise to differences in interpretation by the recipient. For example, the term "normal diet" which was used in some of the discharge reports was interpreted differently by nurses in the community nursing services: One nurse commented that it referred to absence of problems related to nutrition; another that it referred to no changes in patient's eating situation; whereas a third nurse commented that it indicates that there are no special restrictions related to religion or medical causes, but that it does not inform of the patient's nutritional status. The issue of language was further underscored by the nurses at the hospital. They explained that they need information that contributes to their understanding of the patient, including historical information and how s/he usually functions. The hospital nurses emphasized that the IPLOS-scores indicating the patient's level of overall functioning was of little use to them:

> *"Typically, we receive the IPLOS-scores that can mean different things to different people. […] What we need is historical information on the patient. IPLOS tells if [patient] eats themselves,*

but then you must know what the numbers mean. We don't check that. It's a system that we don't really know."

(nurse, hospital)

Nurses both at the hospital and in the community nursing services saw benefits in providing each other with information directly useful for their nutritional follow-up of patients: the risk assessment would be of benefit as historical information and allow the receiving end to compare with their own assessment and to see the patient's needs for nutritional follow-up over time; if the patient has recently been assessed they can further build on that assessment rather than start from scratch; and they can better prepare for receiving the patient (e.g. ordering any needed nutritional supplements or special products). The overall theme of benefits that the nurses describe can be understood as ensuring continuity in care as one of the nurses explains:

"It is important to know why [patient] needs nutritional care – what have they done at the hospital that means that he/she needs nutritional follow up from us. Then we can continue the work that the hospital started. It is about not starting over again, also for the patient, not having to go through it all again."

(Nurse, community nursing service)

The interviews provide further support to our finding from the analysis of nursing reports that nutritional information is often missing in the documentation that is transferred between healthcare levels in our study. Furthermore, the little information that is provided may be ambiguous to the recipient. This inadequacy in information transfer may result in insufficient nutritional care in a timely manner, hence posing a risk to patient safety. However, the community nursing services and the hospital were both in the process of implementing systematic prevention and treatment of malnutrition. It seems reasonable to assume that when greater systematism is established, the information flow between the healthcare levels will also be improved. This was indirectly indicated through the interviews with nurses at the hospital who had participated in the hospital pilot project on systematic nutritional care. These nurses followed routines for nutritional risk assessment of every patient they received, and also had routines for which nutritional information to transfer upon patient discharge. This information was extensive, in stark contrast to the nine discharge reports that we had received (from unspecified wards at the hospital).

4 Discussion

The results from our case study demonstrate that there are important shortcomings in terms of continuity in nutritional care upon transfer of patients across healthcare levels. Communication failures such as those identified in this study can be understood as a problem of neglecting coordination in healthcare [10]. Preventing and treating malnutrition amongst patients is a care process that follows the patient over time. Therefore, it may involve different care teams such as in our case with community nursing service teams and hospital wards, essentially referring to collaboration both within and between teams [11]. In Norwegian healthcare, community nursing services and hospitals each have their own distinct goals, each control their own resources and have limited need for coordination on a daily basis as each of their specific tasks are independent from each other. Yet, they share a superordinate goal to ensure the health and wellbeing of a patient through their treatment and care. The literature on multi-team systems point to cross-organizational coordination to be especially challenging and the need for creating a shared understanding between the teams [12]. Our case study support that there are specific challenges associated with coordination of care across levels in the Norwegian healthcare system in that these teams do not share a common language (e.g. the community nursing services use IPLOS-scores to indicate overall functioning of the patient while this classification is unfamiliar to the hospital nurses) and they lack an understanding of each other's activities and information needs in providing nutritional care.

[13] list three main categories of determinants for collaboration in healthcare: opportunity (time, space, tools and procedures), ability (interprofessional collaborative skills, patient-centered care skills, shared language), and willingness (safety, collegiality, role valuing). The teams in our case study were physically, geographically and organizationally distributed. Hence, the teams' primary workspaces did not promote interactions with members of the other team (in other healthcare level). However, the written communication via the electronic patient journal was pre-structured for transferring important information, thereby serving as an opportunity for effective collaboration in nutritional care. This was especially true for the hospitals discharge reports. However, the largest potential for improvement seem to be with the teams' abilities to collaborate across organizational boundaries. [14] draw upon studies of collaboration in distributed teams in the petroleum industry and emphasize that institutional language and culture may impact on the quality of the interaction. The findings from our case study suggest that technical or institutional language may indeed hamper effective collaboration across healthcare levels when this language is unfamiliar to the recipient. Interestingly, the greatest cause of transferring important patient information using a specific institutional language (i.e. IPLOS-scores) seem to be that the electronic patient journal automatically includes this in the report, thereby serving as a misguided coordination mechanism. Besides the IPLOS-scores, the information (not) provided caused the nurses who received the information to apply their own interpretation to the reports. Lack of knowledge of each other's activities and routines for following up a patient's nutrition status further contributed to vagueness of the information. This need for interpretation seemed to arise mainly due to a lack of standardized language and report contents agreed upon by both the community nursing services and the hospital.

Research on multiteam systems has shown that incorporating between-team elements as part of team training can improve team and multiteam performance, and that attending to the multiteam structure and work design is important for managing the needed coordination in such systems [15]. Ensuring familiarity with other teams' work in preventing and treating undernourishment across healthcare levels and establishing a shared language and structure for the nursing reports may contribute to improve their coordination in nutritional care. For example, secondment arrangements between community nursing services and hospitals may facilitate increased awareness of each other's practices. Although the healthcare services are following standardized templates for their nursing reports, they are likely to benefit from further detailing the use of these through a shared language and specifying information that should always be included such as whether a nutritional risk assessment has been performed, what the results are and actions taken based on this assessment.

5 Conclusion

In this paper we have presented findings from a case study addressing collaboration practices for preventing and treating undernourishment at the intersection of primary and secondary care in Norway. To our knowledge, there currently exist few studies that explore nutritional care spanning across healthcare levels, although such knowledge is important for ensuring the continuity of the care process.

The results from our case study point to weaknesses in the nutritional care process when disrupted by moving the patient between levels in the healthcare system. This transfer creates high demands for coordination between the teams and may be especially challenging because the teams belong to different organizations. We find that information of importance for understanding a patient's nutritional status is often not shared and the (lack of) information is open to individual interpretation by the recipient. There are two main reasons for this. The first being that they do not use the same language, and, second, that they have little knowledge of each other's practices. These weaknesses may result in insufficient nutritional care in a timely manner, hence posing a risk to patient safety. The results indicate that greater emphasis should be placed on establishing coordination mechanisms between the healthcare levels to ensure appropriate continuity of care.

Acknowledgements. This research was funded by the County Governor of Oslo and Akershus.

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Disclosure of Medical Error: A Necessary Step in Healthcare Improvement

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Abstract. Medical error has become a major issue around the globe. When errors occur, healthcare practitioners are faced with the ethical dilemma of if, and to whom to disclose the errors. This dilemma of disclosure is faced by healthcare providers across all disciplines, countries, and generations and has far-reaching implications on the progress of healthcare quality. Medical error disclosure is a necessary step to foster a culture of transparency, strengthen partnerships, and improve the quality of healthcare. Although the principle of medical error disclosure is widely acknowledged and endorsed by providers and patients, disclosure is far from common practice. We reviewed Canadian and global disclosure policies and discuss what steps should be taken to remedy the status quo. We suggest the implementation of a uniform policy centered on addressing errors in an ethical and non-punitive manner while respecting the patient's right to an honest disclosure be a standard of care.

Keywords: Medical error · Disclosure · Medical ethics · Quality care · Patient safety

1 Introduction

Despite best intentions and competencies, health care remains a human endeavor in which mistakes will inevitably be made. While every attempt must be made to minimize the rate of errors, their occurrence is an unpleasant reality that must be acknowledged if it is to be properly mitigated. Medical error has been defined as a problem that arises during patient management [1]. The two broad categories of medical error are errors in performance and errors in planning [2–4]. In errors of performance, the correct medical treatment for a patient does not go as planned or is left incomplete. In errors of planning, the wrong medical treatment has been chosen for the patient, or the correct treatment has been chosen for the wrong reason. Medical errors are a major concern because they have the potential to cause Adverse Events (AEs). Adverse events are defined as injuries to a patient that are the result of medical

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 11–16, 2020.
https://doi.org/10.1007/978-3-030-50838-8_2

treatment, not due to any underlying disease [2–5]. Avoidable AEs represent a failure of the healthcare system to fulfill its cardinal purpose of ensuring the safety of its patients.

The Institute of Medicine's (IOM) report "To Err is Human" described medical errors as a public health risk [6]. The report stresses that preventable medical errors are common in medical practice, resulting in the deaths of 98,000 people in United States hospitals annually and costing the nation $17–29 billion in health care, lost income, and other injury-related expenses [7]. Self-reported survey data has shown that 95% of physicians have witnessed a medical error, and 61% of health care professionals believe errors are a routine part of medical practice [8]. Because medical errors have a large impact on patient care, it is important to consider the ethical issues regarding disclosure that arise when health care providers make or witness errors. Recognition of the staggering impact of medical error and a focus on preventable harm has helped bring attention to errors and error disclosure, a trend that has accelerated with the more recent emphasis on health care quality. However, there remains a dichotomy between medical errors occurring and disclosure of those errors to patients and their families. While the healthcare industry has taken actions to minimize adverse events experienced by patients, the issue of honest disclosure has yet to be addressed.

When an error occurs, a common dilemma facing physicians is whether to disclose the error to the patient. Research findings reveal that patients are keen to know about any error that caused them harm. The patient's bill of rights demands to have full disclosure of an error. Several studies report that patients prefer disclosure and that this would enhance their trust in their physicians' honesty and would reassure them that they are receiving complete information about their overall care [9–11]. Furthermore, patients believed that humans are not perfect, they might make mistakes, and "human nature" might lead health care workers to hide errors from patients [12]. We examined the ethical dilemma facing physicians in regard to disclosing errors and the benefits that open and honest disclosure will bring to the healthcare industry. We reviewed Canadian disclosure policies, in addition to disclosure policies enacted by other nations, and discuss what steps should be taken to remedy the status quo.

2 Medical Error and Adverse Event

The rate of adverse events in hospital patients from studies worldwide has varied from 3.7% in New York to 11% in the United Kingdom and 16.6% in Australia [13–15]. In Canada, the rate varies between 5% and 7.5% [16, 17] and the "Health Care in Canada 2004" report states that about 5.2 million Canadians have experienced a preventable adverse event either in themselves or in a family member [18]. The wide variation in reported adverse event rates is due in part to differences in study methods and patient selection. We have previously proposed a 'no-fault' model whereby disclosure of adverse events to patients is integral to accreditation [19]. The United States Joint Commission on Accreditation of Healthcare Organizations (JCAHO) recommends that the doctor should conduct the disclosure, though on occasion some other member of the team will be more suitable [20].

3 Medical Error Disclosure Scene Worldwide

The majority of provincial regulatory bodies in Canada have adopted some form of disclosure policy [21]. However, these Canadian provincial initiatives remain isolated because of their non-obligatory nature and the absence of federal or provincial laws on disclosure [22]. In Australia, disclosure policy integrates the disclosure process with risk management analysis towards investigating the critical events [23]. In New Zealand, in any adverse event, patients are rehabilitated and compensated through a no-fault state-funded compensation scheme [24]. This disclosure model supports health care providers and strengthens the policy of honest disclosure. The United States JCAHO mandated an open disclosure of any critical event during care to the patient or their families [20]. By following an open disclosure policy, patient's autonomy can be preserved, and malpractice claims can be effectively reduced [25]. Healthcare providers should reflect on the patient's expectations concerning disclosure and the factors that hinder disclosure so that the gap between theory and practice can be bridged.

4 Disclosure Barriers

Although disclosure of medical errors is, in principle, the correct course of action [4, 5, 26, 27] many well-documented barriers prevent this from happening [27]. These include fear of legal repercussions from patients or their families and fear of loss of reputation among colleagues. Uncertainty about who is responsible for errors involving multiple caregivers or systemic factors can delay or prevent disclosure. In cases where errors are minor or go unnoticed, there are concerns that disclosure could cause unnecessary psychological stress or strain the relationship with the patient, ultimately resulting in more harm than benefit. Overcoming these barriers will require a fundamental change in the perception and handling of medical errors. Some centers have introduced policies where disclosure of medical error is part of the standard of care where physicians will face professional and legal consequences if they fail to disclose. Others have implemented "no-fault" or "no-blame" models for error disclosure, where the institution shoulders the blame, rather than the individual caregivers [4, 5, 26].

5 Disclosing Error – Professional and Ethical Responsibility

There is universal agreement in western medical culture that errors resulting in serious harm must be disclosed to the patient [28]. Physician organizations, such as the American Medical Association, Canadian Medical Associated (CMA), and the Canadian Medical Protective Association (CMPA) emphasize the need for physicians to inform patients about medical errors so that patients can understand the error and participate in informed decision making about subsequent management of their health care [29]. Opinion 8.12 of the Code of Medical Ethics of the American Medical Association states that "physicians should at all times deal honestly and openly with patients" [30].

6 Principles of Beneficence, Non-maleficence, Autonomy, and Justice

Four overarching ethical principles currently guide modern medicine. The principle of beneficence in medical practice refers to avoiding and preventing errors by doing what is in the best interest of the patient [31]. The principle of non-maleficence emphasizes that one should not cause harm to oneself and others [32, 33]. When patients come to a health care system to seek care, they place a great deal of trust in the system and health care providers. They expect competency and believe that physician will provide the best treatment in accordance with the principles of beneficence and non-maleficence. Autonomy is defined as the ability of an individual to make an informed, un-coerced and rational decision [32, 33]. The principle of justice is described as the moral obligation to act on the basis of fair adjudication between competing claims. According to the principles of autonomy and justice, it is the patient's right to be provided with complete information regarding treatment and any adverse events that may have occurred. In light of these principles, disclosure of error to patient and management is justified as the only defendable course of action.

7 Conclusion

As preventable medical errors and adverse events become a topic of growing concern and cost, appropriate processes must be executed. Sharing knowledge and learning about the difficult topic of medical error and how to approach it is necessary to encourage honest disclosure with patients. The disclosure of a medical error is an ethical dilemma that requires deliberative thinking and reflection by the health care providers. It is suggested that disclosure of medical error should be encouraged keeping in view the principles of medical ethics including beneficence, non-maleficence, patient autonomy, and justice. It is important that healthcare providers are aware of the legislation that is enforced in the jurisdiction under which they practice in order to make disclosure an easier and less daunting process. Improving the process of healthcare is not a mandate for physicians alone. It is a collective effort of healthcare institutions, policymakers, providers, and patients working toward the common goal. Only through such collaboration can medical error disclosure become a common, achievable, and informative practice in healthcare improvement.

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The Gap Between Japanese Medical Professionals and Foreign Patients

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Abstract. The purpose of this study is to clarify the situations in which foreign patients and Japanese medical professionals face difficulties in the Japanese medical system. The authors also aim to find out the causes of difficulties from the viewpoints of foreign patients and Japanese medical professionals. Through our literature review, four major situations were extracted, namely, at receptions, at examination rooms, during treatment decision-making, and at inpatient units. In these situations, a total of eight difficulties were found: among them, seven were caused by gaps in perceptions between foreign patients and Japanese medical professionals. Foreign patients perceive that Japanese medical professionals perceive them in a certain way. At the same time, Japanese medical professionals perceive that each foreign patient possesses a unique cultural background. These create gaps and confusion. It is necessary to find strategies to solve this issue.

Keywords: Foreign patients · Medical professionals · Gap

1 Introduction

Currently, foreign residents from more than 197 countries are living in Japan [1]. An increase in the number of tourists is anticipated for the 2020 Olympics. 79.7% of outpatient wards/clinics treated foreign patients, and 58.5% of hospital wards had foreign patient admissions in 2015. Both of these medial institutions experienced difficulty in communication with foreign patients at a rate of 65.3% [2]. According to a survey for foreign residents by The Agency of Cultural Affairs in 2001, “experiences in trouble in hospitals” ranked as the worst occasion where they could not speak Japanese well enough and encountered troubles [3]. In Japanese medical facilities, foreign patients and Japanese medical professionals are both experiencing difficulties in communication.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 17–22, 2020.
https://doi.org/10.1007/978-3-030-50838-8_3

2 Objective

The purpose of this study is to clarify the gap between experiences of foreign patients and those of Japanese medical professionals in the same medical situations when foreign patients go to Japanese hospitals or clinics.

3 Methods

The authors conducted a literature search and identified relevant articles [4–10]. The documents concerning difficulties and problems when foreign patients consult Japanese medical facilities were targeted for analysis. We used the texts of these articles to extract major themes/situations using content analysis. Pertinent codes in the articles were extracted as data. Eight situations were identified, and the viewpoints of the foreign patients and the Japanese medical professionals were compared, hereafter referred to as "the gap". Difficult situations are illustrated for each of the eight situations: difficulties at a reception desk, medical examination, treatment, inpatient stay, and payment procedures.

4 Results and Discussion

4.1 Four Major Scenes

Four major scenes were identified. (see Appendix Table 1) At the reception desk, there were <the scene in which foreign patients did not understand the Japanese registration procedure> and <the scene in which foreign patients did not understand medical information>. Foreign patients did not know the registration procedure and experienced difficulties because supplemental documents, guidance, and flyers were all in Japanese. Japanese medical professionals experienced difficulties because of the inability to explain and interact with foreign patients in foreign languages.

1. There were <situations where there was a mistake in clinical judgment because the information was insufficient> and <situations in which the patient could not fully understand the explanation of a doctor due to difficulty in communication>. Doctors were unable to gather the necessary information from patients due to a lack of knowledge of the patient's cultural and religious backgrounds and thus was unable to render a complete medical evaluation.
2. There were <situations in which a patient could not agree with the course of treatment due to the differences with the way of thinking of his/her own country or due to a difference in customs>. The foreign patients did not receive enough explanation and felt uneasy about what was done or it was not told to the patient. When his/her body was moved or touched without permission and without receiving a prior explanation, the patient wanted the medical professional to stop. In addition, the patient felt it was difficult to refuse treatment. On the other hand, medical professionals felt that they could not convey the name of the patients' diseases and patients' conditions. Because the knowledge about diseases varies from country to country and standard treatments differ, there was a situation that a patient refused the way Japanese medical professionals treated a disease.

3. There were <situations in which medical professionals insist on doing things in a Japanese way because patients could not thoroughly explain the reason for the restrictions they have on their daily lives> and <situations in which patients did not understand the unwritten Japanese rules and reasons for them>. According to patients, each individual's cultural background was not considered. In addition, there was a situation in which patients did not understand the existence of the unwritten Japanese rules and the reasons for them, and patients were surprised at "implicit consent" which is an unfamiliar concept to them. The medical professionals felt their guidance was rejected even if they considered the patients' cultural factors. Furthermore, medical professionals felt hospital rules were broken for religious reasons.
4. At the time of the payment and registration process, there were <situations in which a registration procedure was complicated, and both patients and medical professionals were inexperienced, and the process was time-consuming>.

4.2 Gaps Between Foreign Patients and Japanese Medical Professionals

1. In a reception desk situation, the necessary information was not given or was vague because of the language barriers. Medical professionals were aware but left patients as is, leaving the patients to feel isolated.
2. During a medical examination and explanation situation, medical professionals had difficulty due to the inability to gather necessary information and thus had a wrong clinical judgment. Patients felt that they made an effort to help medical professionals understand themselves and their symptoms. However, this led to medical professionals feeling that "patients are appealing their rights too much".
3. During treatments, medical professionals attempted to offer treatments. However, foreign patients did not feel that their opinions were not heard because of the knowledge of the disease in the patients' own countries, the differences in how to treat a disease, and the differences in customs. Medical professionals felt inadequate in providing holistic care.
4. In an inpatient stay situation, medical professionals believed that foreign patients do not follow a hospital rule because of differences in customs or religious reasons. On the other hand, foreign patients felt that the medical professional did not consider each person's cultural backgrounds and was also puzzled by the concept of "implicit consent".

It is necessary for medical professionals to realize that both foreign patients and medical professionals at host countries are expected to experience different difficulties.

5 Conclusion

Foreign patients want medical professionals to pay attention to their needs but feel that there are barriers to medical professionals' end. On the other hand, medical professionals want to provide care and comfort to patients but feel inadequate due to the language barrier. Each gap occurred due to lack of communication, specifically having low verbal communication skills, lack of self-awareness about their weaknesses, and inaccurate cultural preconceptions.

Acknowledgments. This work was supported by JSPS KAKENHI Grant JP19K10813.

Appendix

Table 1. The four major scenes where to face difficulties of foreign patients and Japanese medical professionals at a Japanese hospital

Japanese medical professionals	Foreign patients
At a reception desk	
<Situations in which a foreign patient does not understand the registration procedure>	
• There is no support of medical interpreters • I cannot explain the procedure in foreign languages	• I do not know the flow and the steps of registering for a medical consultation in Japan
<Situations in which a foreign patient cannot understand medical information>	
• I cannot translate a document	• I cannot understand written documents in Japanese • There is too much information in Japanese
At an examination room	
<Situations where there was a mistake in clinical judgement because the information was insufficient>	
• I made a mistake with clinical judgment because I could not understand my patients or could not collect pertinent information • As both languages and medical systems are different, I cannot understand my patients' past treatment history • I cannot conduct clinical examinations because of the cultural or religious rules	• It is difficult to describe my symptoms
<Situations in which a patient cannot fully understand the explanation of a doctor due to difficulty in communication>	
• Because of the language differences, I cannot clearly communicate my patients about not eating/drinking before procedures, how long patients need to be on bedrest, details of procedures, their results, and when to come back to the clinic for a consultation • Foreign patients tend to stress their rights too much	• I feel that medical professionals have psychological barriers towards us that prevent them from fully understanding us • Medical professionals think that caring for foreign patients is cumbersome

(*continued*)

Table 1. (*continued*)

Japanese medical professionals	Foreign patients
At a treatment room	
<Situations in which a patient cannot agree with the course of treatment due to the differences with the way of thinking of his/her own country or the difference in customs>	
• I cannot say the correct disease names or explain about the diseases accurately • My patients do not agree with me about the course of the treatment that is different from the way it is done in their countries	• I was surprised because medical professionals moved my body suddenly without explaination in advance • I cannot execute my rights to refuse treatment
At an inpatient unit	
<Situations in which medical professionals insist on doing things in a Japanese way because patients cannot thoroughly explain the reason of the restrictions they have on their daily lives>	
• Because of the differences in customs, patients do not want to accept my advice on healthy living based on their disease conditions	• Medical professionals do not pay attention to cultural backgrounds of each patient
<Situations in which a patient does not understand the unwritten rules and reasons for them>	
• Patients do not follow inpatient units' rules because of religious reasons	• I cannot understand the unwritten rules and reasons for them • I am puzzled over the concept of "implicit consent". I am not used to this concept at all
At a medical payment office	
<Situations in which a procedure for medical payment was complicated: Both patients and office personnel were inexperienced>	
• I am inexperienced in assisting with the registration procedure (including medical payment procedure) for a medical consultation • The process is complex	• Burden related to medial payment (Medical cost and complicated payment system) influencse whether I seek medical care or not

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Situational Awareness of Expert Nurses on the Process of Weaning a Ventilator

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Abstract. The purpose of this study is to elucidate the situational awareness of expert nurses on the process of weaning a ventilator. Participation consent was obtained from expert nurses and novice nurses who had experience weaning a ventilator. Semi-structured interviews were conducted to elucidate what information they pay attention to, and to elucidate how to collect and to assess information on the process of weaning a ventilator. Data were analyzed qualitatively comparing the skills of the 4 experts nurses with the skills of the 4 novices nurses. Expert nurses focused on both body and mental state, while novice nurses mainly focused on the body. Expert nurses judged a patient based on a few days trend. They were careful about not only oxygenation in the lungs but also oxygenation in tissues. They were also concerned that patients knew the current situation properly.

Keywords: Situational awareness · Expert nurse · Weaning a ventilator

1 Introduction

Ventilator therapy is given to patients with severe respiratory failure. However, longer duration of a ventilator therapy increases the risk of developing serious complications such as ventilator-associated pneumonia. Assessment and care for early weaning a ventilator are very important because the early weaning a ventilator improves patients' daily activities and Quality of Life [1]. It has also the effect of reducing medical costs [2]. The ability of nurses to accurately determine changing patient conditions and to provide aid greatly affects the success of early weaning a ventilator.

There are two protocols for ventilator weaning which are recommended by the society in Japan. The two protocols are Spontaneous Awakening Trial (SAT) and Spontaneous Breathing Trial (SBT). SAT is a test to evaluate whether spontaneous arousal can be achieved by stopping or reducing sedatives. We observe the patients about 30 min to 4 h. We assess arousal by using the Richmond Agitation-Sedation

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 23–29, 2020.
https://doi.org/10.1007/978-3-030-50838-8_4

Scale. If eyes are open and easy movement with verbal instructions, and if no excitement after more than 30 min after stopping sedation, we judge that SAT is cleared. When SAT is cleared, we proceed to SBT. SBT is a test to determine if a patient can tolerate without ventilator assistance. There are 'Safety Start Criteria of SBT' (Table 1) and 'Success Criteria of SBT' (Table 2). Both of them, however, determine some of the patient's condition at one point and do not necessarily represent an integrated assessment and judgment of the nurse's actual clinical practice. Also, the information to be focused on at the time of weaning differs depending on the patient's condition, but this is not considered in the SAT or SBT protocol.

Table 1. Safety Start Criteria of SBT

Clear all 1 to 5
1. Enough oxygenation
• $SpO_2 > 90\%$ under $FiO_2 \leqq$ and PEEP $\leqq$ 8cmH_2O
2. Stable cardiovascular system
• No acute myocardial ischemia, No serious arrhythmias
• Heart Rate (HR) $\leqq$ 140 bpm
• Acceptance of small amounts of use of vasopressor
3. Enough inspiration effort
• Tidal volume > 5 ml/kg
• Minitues volume < 15L/min
• Rapid shallow breathing index (RSBI) < 105 cycles/min/L
• No respiratory acidosis
4. No abnormal breathing pattern
• No overuse respiratory assist muscles
• No seesaw breathing
5. Stability of general condition
• No fever
• No serious electrolyte abnormalities
• No serious anemia
• No serious flouid overload

Table 2. Success Criteria of SBT

Clear all 1 to 5
1. Respiratory Rate < 30times/min
2. No apparent decrease compared to before the start (ex. $SpO_2 \geqq 94\%$, $PaO_2 \geqq 70$ mmHg)
3. Heart rate (HR) < 140 bpm, and
•No new arrhythmias and no sign of myocardial ischemia
4. No excessive blood pressure increase
5. No respiratory distress symptoms as follows
• Do not overuse respiratory accessory muscles
• Seesaw breathing
• Cold sweat
• Severe dyspnea, anxiety, restlessness

Generally, inexperienced beginners cannot judge situations well. However, it is pointed out that this is because they do not have enough information obtained from experiences such as human characteristics and personal past learning [3].

Endsley shows a model for situation awareness (Fig. 1).

He says that situation awareness consists of three levels. Level 1 is perception of elements in the current situation. Level 2 is comprehension of the current situation. Level 3 is projection of future status. Situation awareness is influenced by several factors.

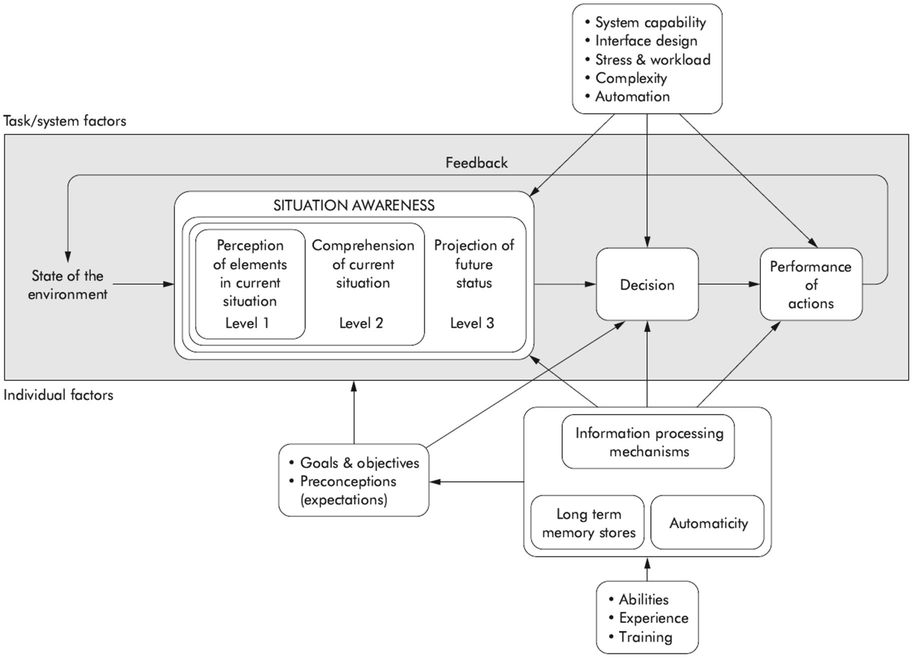

Fig. 1. Model of situation awareness by Endsley. *Human factors,* vol. 37, No. 1, p. 35, 1995.

2 Objectives

The purpose of this study is to elucidate the situational awareness of expert nurses on the process of weaning a ventilator. It is thought that clarification of the characteristics of expert nurses' situational awareness can provide suggestions for novice nurses' education.

3 Methods

Study design: Exploratory research design. Data collection: Participation consent was obtained from expert nurses and novice nurses who had experience weaning a ventilator. In this study we defined expert nurse as having at least 6 years of experience and novice nurse as having one-two years of experience. Semi-structured interviews were conducted to elucidate what information they pay attention to, and to elucidate how to collect and to assess information on the process of weaning a ventilator. Data were analyzed qualitatively comparing the skills of the experts with the skills of the novices.

Ethical Considerations: Participants were given explanations of the study objectives, their right to decline participation and that there was no penalty for not participating. Information was handled carefully to maintain anonymity. This study was conducted with the approval of the Ethics Review Board.

4 Results

Interviews were conducted with 4 expert nurses and 4 novice nurses. It shows the characteristics of nurses (Table 3).

Table 3. Participant characteristics

	Expert nurses n = 4	Novice nurses n = 4
Nurse average years of experience	22.5	1.5
ICU average years of experience	18.0	1.3
Average interview time (min)	54.8	31.3

Nurses were asked the same questions, but the interview time was longer for expert nurses.

The characteristics of situational awareness of each level is shown in Table 4.

Table 4. Characteristics of expert nurse's situational awareness.

Level		Characteristics
Level 1	Perception of elements in current situation	Focusing on both body and mental state
		Getting information for about three days instead of just one day
		Valuing not only numerical data but also information obtained from the five senses
		Focusing on information that are sensitive to change
		Varying order of information collection based on patient condition
		Understanding recovery status of underlying disease
Level 2	Comprehension of current situation	Understanding respiratory status, including its relationship to circulatory dynamics
		Making a decision with clear criteria
		Thinking about not only oxygenation in the lungs but also oxygenation in tissues
		Paying attention to pulmonary edema and arrhythmias
		Understanding patient's understanding of current situation properly
		Assessing the patient's reserve capacity
		Considering the advantages and disadvantages of extubation in a gray situation
		Making a decision based on a few days trend
Level 3	Projection of future status	Considering not only the respiratory status but also the hemodynamics and general condition after extubation
		Predicting patient status, including ethical aspects

4.1 Perception of Elements in Current Situation

Analysis revealed six characteristics at level 1. Expert nurses focused on both the body and mental state, while novice nurses mainly focused on the body. An expert nurse said ‘If a patient is nervous, it will also affect the patient’s breathing state, so I watch both the body and mental state carefully.’ Novice nurses perceived information according to SBT, but expert nurses collected information according to the patient’s situation. The ICU is full of numerical data, but expert nurses valued information obtained from their five senses on the process of weaning. An expert nurse pointed out ‘Of course, SpO_2 is important, but cold sweat, thorax movements and patient complaints are also very important.’

4.2 Comprehension of Current Situation

Experts had known patient status and not only considered respiration, but also understood respiratory status, including its association with circulation. They paid attention to arrhythmias and pulmonary edema. Experts judged patients based on a few days trend. They were care about not only oxygenation in the lungs but also oxygenation in tissues. They were careful that the patient understood the current and future situation properly.

4.3 Projection of Future Status

Extubation alters intrathoracic pressure and increases blood flow back to the heart. Experts consider not only the respiratory status but also the circulatory changes and their consequences before extubation.

Patients with heart failure become worse gradually. Extubation may be difficult with repeated hospitalization. In such a situation, expert nurses interacted with the patient while considering what the patient and the family wanted. Experts predicted patient status, including ethical aspects.

In a situation where a respirator should clearly be removed, a difference was not detected in the judgement of the expert nurses and the novice nurses. In a situation in a gray zone in which a judgment of weaning the respirator was difficult; the expert nurses and the novice nurses were different. The expert nurses were intentional in the data collection of what they saw. The expert nurses were doing assessments to connect with care while predicting in the assessment as to what was necessary to extubate.

5 Discussion

Expert nurses thought about not only oxygenation in the lungs but also oxygenation in tissues through the data of pH and HCO3-in Level 2 comprehension of the current situation, while novice nurses focused on oxygenation in the lungs. Novice nurses see the pH and HCO3-but couldn’t answer why they collected them. ‘Thinking about not only oxygenation in the lungs but also oxygenation in tissues’ and ‘Focusing on both body and mental state' indicate that expert nurses understand the patient as a whole. Thinking about the patient as a whole will lead to accurate weaning decisions.

'Making a decision based on a few days trend' means that nurses see the patient as lines, not points. Focusing on trends can makes it easier to predict ahead.

In a situation where a respirator should clearly be removed, a difference was not detected in the judgement of the expert nurses and the novice nurses. In a situation in a gray zone in which a judgment of weaning the respirator was difficult; the expert nurses and the novice nurses were different. Expert nurses consider 'the advantages and disadvantages of extubation in a gray situation' in level 2, while novice nurses ask the doctor in the same situation. This indicates that expert nurses make decisions based on hypotheses. Updating hypothesis is an essential component of the information-processing model of decision-making [4]. Updating hypothesis in difficult situations requires knowledge and experience. It is important to share knowledge and experience at conferences.

Experts valued 'not only numerical data but also information obtained from the five sense'. In particular, they valued information obtained from touch and seeing. Expert nurses collect more cues than novice nurses [5–7]. It is presumed that the amount of information expert nurses have is large because it places value on subjective data such as information obtained from the five senses.

The expert nurses were intentional in the data collection of what they saw. The expert nurses were doing assessments to connect with care while predicting in the assessment as to what was necessary to extubate. Kahneman points out that in order to perform some information processing, attentional resources according to the difficulty are necessary [8]. Expert nurses were good at situational awareness because they have so many attentional resources. These attention resources are likely to be cultivated from experience. Novice nurses need to share expert attention resources in order to be able to recognize the correct action to be taken.

6 Conclusion

The situation awareness of expert nurses on the process of weaning a ventilator was analyzed. 16 characteristics were revealed. Experts were aware of the situation of the patient's whole body instead of relying solely on protocol. It is said expert nurses sometimes practice unconsciously [9]. In the future, it is necessary to clarify the unconscious situational awareness of experts using an eye tracking camera etc.

Limitation. The number of subjects was 8, so there is a limitation to generalize. It is necessary to increase the number of subjects and further study.

Acknowledgments. We would like to thank the nurses for participating and for making this study possible. This work was supported by JSPS KAKENHI Grant JP19K22769.

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Exploring Hospital Wayfinding Systems: Design Guidelines for Wayfinding Interfaces

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Abstract. This paper is a culmination of a three-phased research project which examined the lack of usability and effectiveness of wayfinding in complex, multi-building hospitals. Researchers evaluated multiple interfaces, such as wayfinding kiosks and mobile applications, using various human factors methods. Results indicate that this problem is multi-faceted and wayfinding solutions must consider the other available aids in the environment. Incorporation of user centered design principles and requirements for the inclusion of end users in the development of wayfinding aids are needed. Beyond usability, the key learning is that wayfinding systems cannot be created in a vacuum, rather the interfaces, the placement of signage and systems, and the environment of the hospital must be considered. The wayfinding kiosk and application information should complement environmental information such as color coding, graphics, landmarks, room and elevator labeling and signage. To this end, we have included design guidelines to aid in successful wayfinding.

Keywords: Wayfinding · Hospitals · Healthcare · Human factors

1 Introduction

Medical human factors has primarily been focused on providing safer processes, tools and systems for medical professionals. While safe and effective treatment of patients is critical, the customer experience is much broader than that. Patients and visitors to hospitals can experience stress and cost the hospital money by asking medical personnel for directions and being late to or missing scheduled appointments. Therefore, this project examined the usability of wayfinding apps and touchscreen kiosks and further examined their effectiveness in context. Using real examples from current large multi-building hospitals, we hoped to highlight a need for and provide some practical solutions. We aim to bring attention to the problem of designing software solutions without examining the placement of the displays, the color coding in use, and the current labeling conventions.

This research highlights an area of the hospital patient experience that is often overlooked. In order to solve the problem, hospital administrators must first be aware that a problem exists and understand how it impacts the well-being of patients and visitors. In architecture literature, there are articles on how to use color, signage and

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 30–36, 2020.
https://doi.org/10.1007/978-3-030-50838-8_5

landmarks to improve wayfinding during building design. However, integrating technology is often done separately and not as part of the overall design. Adding an interactive touchscreen kiosk or mounted display is expensive and unfortunately these products are often designed and tested outside of the hospital. This often results in a mismatch in terminology, orientation and effectiveness of directing patients to their desired locations. Hospitals have also designed mobile apps for smartphones to assist with this problem. While wayfinding apps do solve the kiosk's obstacle of avoiding cognitive overload, they come with their own set of challenges. First, an individual must discover that this specific app exists, have a willingness to download a new app, have a smart phone to interact with the app, and the app should meet the expectation of geolocating in real-time. That is, associating locations in the environment to the user's location. None of the solutions for solving these issues are perfect on their own; however, we propose that these solutions be considered and evaluated for usability and effectiveness to create a cohesive system with the hospital environment. A well-designed environment that encompasses multiple aids that work in harmony is possible by following design guidelines and using a process of user centered design in context.

2 Background

Wayfinding can be defined as the process of understanding where you are, determining where you need to go, understanding your optimal route and recognizing when you have arrived [1]. Wayfinding aids in complex environments, such as medical-care facilities, are necessary for patients and visitors to find their destinations in a quick and efficient manner. Wayfinding in these complex environments has been shown to cause stress for newcomers, even with the assistance of aids [2]. Wayfinding aids have evolved from the use of signs and environmental cues to now include the use of technology such as interactive touchscreen displays, kiosks and apps [3]. The purpose of interactive wayfinding displays is to simplify the process of wayfinding; however, if an aid does not provide the support expected, users will likely abandon the technology [4]. Hospitals are now investing in facility-wide interactive navigation systems to complement traditional wayfinding aids. If patients and visitors do not find a system effective for their intended purpose, then there may be economic loss for the medical-care facilities who invest in an ultimately rejected technology [5].

Until recently the effectiveness of interactive wayfinding displays has predominantly been assessed through navigation and spatial tasks while the usability of the interfaces themselves has seldom been examined [3]. Wayfinding interface systems should be easy to use, effective, accessible, and intuitive. Phase one research explored both the usability and effectiveness of current wayfinding displays in order to inform best practices for future interactive display designs in complex healthcare settings. Usability evaluations and a wayfinding task based in the real-world environment allowed for the opportunity to evaluate these systems in context. Ideally, user-centered design would be incorporated in the development phases, rather than solely using retrospective judgement [5]; however, we believe evaluating current systems can help establish guidelines for future designs and fill the gap in the current literature about the design of wayfinding applications in complex environments.

This research began with an examination of the usability and effectiveness of three large hospitals' interactive, touchscreen, wayfinding interfaces [6]. Participants were recruited on site from each of these hospitals and asked to complete various tasks using the wayfinding display in their hospital. Consistent issues observed were documented and used to draw implications and develop recommendations for future designs. Results from this research indicated that basic heuristics were often overlooked, such as classifying information according to user expectations, including a universal search, minimizing unnecessary on-screen information, adhering to platform standards, presenting visual aids effectively, and orienting navigation information effectively.

In the second phase of research we explored several mobile wayfinding applications designed for large multi-building hospital complexes [7]. We decided to focus on one of these mobile smartphone applications for a heuristic analysis. In this type of evaluation, multiple researchers assess whether an interface design adheres to certain heuristics, or guidelines, that should be followed for optimal usability [8, 9]. This method provides a simplified benchmark by which to examine interface design and offers varied perspectives to identify usability issues. After prioritizing the criticality of these errors, researchers develop recommendations to be implemented in the next iteration of the design. Given that the standard set of heuristics were established by Nielsen in the nineties, it has been suggested that they may be too general to evaluate the usability of designs intended for mobile devices and therefore design-specific heuristics are recommended [10]. For this reason, we began by developing our own set of heuristics, influenced by our prior research, to evaluate this specific wayfinding application.

We found that the wayfinding application did solve some of the issues found in phase one with the touchscreen kiosk usability testing. This app presented a list of instructions after the user entered their starting and ending locations. The instructions used terminology and icons that were also available within the environment, which allowed users to confirm that they were heading in the right direction as they navigated to their destination. As the application is mobile, cognitive overload from a huge set of instructions, overlooking screens of instructions, not being accessible to wheelchair users and the interface elements not responding as expected were solved. However, this application lacked a universal search feature which is problematic because users must know how their destination is classified within the system to be successful. In addition, while the navigation elements of the application responded as expected, it did not provide real time orientation or mapping for navigation. With the advance of GPS technology, expectations have changed [11] and the ideal wayfinding application should provide real time location and direction.

This led us to search for a wayfinding application that included real time location and tracking. In phase 3, we completed a usability test that consisted of a variety of wayfinding tasks using this app on site [12]. Although the application solved many issues, it was unable to detect the user's orientation within the environment, which was frustrating to users. Brooke's (1996) System Usability Scale (SUS) was filled out by each participant [13]. The average SUS score for the system was a 72.5, which roughly translates to a "C" letter grade. While this was better than the "F" and "D" scores of the kiosks in the previous study, there is still room for improvement.

3 Results

Our overall goal was to learn from various systems and contribute guidelines for the development of future wayfinding systems to enhance their effectiveness in a real-world environment. While Nielsen's (1994) ten heuristics are well known and have been in practice for years, we found multiple instances of poor system usability that violate these rules, causing the participants frustration and/or confusion [8]. People visiting hospitals who experience the frustration of a poor interface or receive confusing or incomplete directions from a wayfinding system experience increased stress [14]. Users that experience many obstacles will abandon the technology and search for another source of information. With the amount of money invested in wayfinding systems, the importance of usability should be at the forefront of designers' minds throughout the entire process of system design [15] so that the systems can be designed to provide maximum benefit.

There is a wealth of design guidelines for effective wayfinding in public spaces. Foltz (1998) offered principles for creating "navigable" environments or enhancing an individual's ability to move from one location to another, even when the environment is unknown [16]. Individuals should have a sense of orientation within their environment, be able to successfully execute wayfinding tasks, and use common features (e.g. landmarks, signage, etc.) to assist in navigation. Correspondingly, the CRC for Construction Innovation has presented wayfinding design guidelines [17] including to provide frequent directional cues, use names and symbols, and incorporate the Principles of Universal Design. According to these guidelines, wayfinding interfaces should be simple to use and accommodate a variety of users based on their individual preferences and ability to interact with the system.

The results of our research support the value of Foltz's Design Principles in the environment. Landmarks, well-marked paths, color coded regions and signage all served as helpful environmental cues that aided in wayfinding. Individuals were more likely to accomplish their tasks and successfully reach their intended destinations when information presented through the interface corresponded with these aids in the environment. Additionally, the CRC Wayfinding Design Guidelines recommendations of designing simple and intuitive systems that are both equitable and flexible in use were also supported, especially with the mobile app in phase three of our research. All users were able to successfully navigate through the app and complete the tasks through multiple methods (e.g. multiple pathways to reach destination, universal search feature, and help icon). However, other universal design principles should be considered for all types of aids including interactive touch displays, static maps and mobile applications. Additionally, a user centered design approach should be followed, by identifying the user's end goals within the environment, implementing design principles to help accomplish those goals, and then evaluating the system in context. Iteratively testing the software interface or mobile application with end users in the environment must be a part of the process. By doing so, products stand a better chance at being optimal, effective, and efficient.

To summarize, when a wayfinding aid such as a touchscreen interface, or mobile application is added to the physical environment, design guidelines should be followed, and user testing must be done to ensure the aid is accessible, easy to use and useful. The first guideline is to *match the current environment*, understand the building's naming conventions, labeling, landmarks, zones, color codes, icons, images and signage in place to ensure consistency. Make sure the elements of the application match those in the environment. *Use landmarks* in your wayfinding directions because easily recognizable architectural elements help with orientation [16]. *Consider accessibility* in the placement of touchscreen devices and the on-screen interaction. It is always important to consider how people with varying abilities will interact with the technology, but this is even more critical in a healthcare setting. When designing interfaces, it is important to *classify information according to user expectations*, rather than using unfamiliar building or hospital terms. Conduct user testing to understand the words a patient or visitor would use to locate information. *Include a universal search* so that individuals are able to search for things specifically, rather than by category. A search function that is constrained by categories may be frustrating and difficult to use. *Use simple and relatable instructions* to the users of the system. Do not tell someone how many steps to take or how many feet to walk. People may not use the imperial system of measurement and they are not able to easily estimate distance by steps. Instead using time, such as a twenty-minute walk, may be more beneficial. *Minimize unnecessary on-screen information* by avoiding clutter so that users can focus on key pieces of information. *Adhere to platform standards.* People have expectations of how a touch screen or a mobile application works, do not make them learn a new method of interaction. *Visual aids should be presented effectively.* Avoid distracting animations and in a stationary wayfinding aid, be aware of cognitive load and avoid using multiple screens of instructions. *Orient navigation information effectively* in the environment. Users have an expectation that a map operates from their own viewpoint [17]. To adequately meet this expectation, it important that systems are designed with prior knowledge of their current location and can help a user identify their location in the environment. If a user cannot find what they are looking for while using the system, provide a way for users to *request assistance via human-human contact.* Sometimes,

Table 1. Design guidelines developed for the design of future wayfinding interfaces.

Recommended design guidelines for wayfinding interfaces
Be consistent with the physical environment, i.e. labels, icons, colors and signage
Use physical landmarks as a directional aid
Consider accessibility in the placement of touchscreen systems and on-screen interactions
Classify information and wording according to user expectations
Include a universal search feature
Use simple and relatable instructions
Minimize unnecessary on-screen information
Adhere to platform standards
Present visual aids effectively through the interface
Orient navigation information effectively from the user's viewpoint
Provide a way for users to receive help from another human
Use a systems approach

people just want to speak to another person rather than interacting with a system. *Use a systems approach* and always remember that what you are designing is part of an overall system. Conduct user testing on site to ensure that your design works well in context. By following these guidelines, wayfinding systems may help reduce the effort placed on users inside these environments and help them successfully navigate their environment. These recommended design guidelines are presented in Table 1.

4 Conclusion

The key learning from this body of research is that the wayfinding touchscreen interfaces, and mobile applications cannot be created in a vacuum. Rather the interface, the placement and the hospital environment must be considered. As wayfinding displays and applications are developed, they must be treated as part of a system. The wayfinding information should complement the environmental information such as color coding, landmarks, labeling and signage. The same design principles used to enhance wayfinding of physical spaces should extend to interface design. Design guidelines should be followed and user requirements specific to each location should be developed through an iterative process of user-centered design. Iterative research will also ensure, physical and cognitive abilities are considered, user expectations are met, and wayfinding aids are intuitive and effective. Finally, testing in context will ensure a seamless integration into a successful hospital wayfinding system.

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High-Reliability Organization Development

Design of a Fellowship Learning-by-Teaching Experience for Reflecting on *Safety* and *Change*

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Abstract. Leading change is a common topic covered in patient safety curricula. This paper describes the design of learning sessions that expand on this topic to more general concepts of *safety* and *change* across disciplines studying safety. The learning sessions were designed to be co-produced by fellows and faculty and to be thought of as an emerging phenomenon to accommodate an interprofessional class with a variety of expertise and knowledge. Cross-curricular connections were emphasized to facilitate discussion into potential interconnectedness and to identify inconsistencies. The resultant design provided the flexibility for customizing to each unique class. Future learning sessions will introduce concepts in resiliency and cognitive systems engineering while connecting to the sessions described here.

Keywords: Patient safety · Education · Human factors · Diffusion of innovation

1 Introduction

Many have thoughtfully designed and developed patient safety curricula over the past two decades [1–3]. A common module described across curricula is leading and managing change. Watts et al. (2013) describes Leading Change as one of four potential broad domains of knowledge within a Patient Safety Curriculum. Motivating Change in Organizations, as a component of this domain, has been the subject in the past for facilitating a learning experience through didactic and dialectic exercises into the theories of Diffusion of Innovations [4]. This approach provides valuable theories and a frame for inquiry into and reflecting on the nature of motivating change. We continued with this theme as the foundation for designing a live virtual learning-by-teaching experience for current post-graduate interprofessional fellows and faculty across several geographical sites.

We planned to build on the past trajectory through several approaches. One, by expanding into a more general discussion on the interrelatedness and concepts surrounding *change* and *safety,* guided by past topics. Two, by facilitating a co-produced,

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 39–46, 2020.
https://doi.org/10.1007/978-3-030-50838-8_6

cross-site, collaborative teaching experience. Three, by designing a learning session with customizability and flexibility in mind to annually accommodate a new interprofessional class with diverse knowledge and experience. Four, by fostering an environment for formulating thoughts on applying concepts covered in this educational experience to individual fellowship projects. Five, by emphasizing cross-curricular connections between concepts and theories, for example, those within the study of human factors and the diffusion of innovations.

2 Approach to Design

Moving from a specific scope of the concept of leading change to a broader scope of reflecting on concepts in safety and change introduces challenges. Change is discoursed about in many disciplines, is contextually complex, and may have a variety of meanings within varied contexts. A few examples of the wide-ranging study of change include the concept of impermanence in philosophy, calculus as a mathematical approach to inquiry into change, technological change and the diffusion of innovations, and the study of systems capacity to adapt to change in resiliency engineering and complexity science.

Our plan was to manage the potential to overwhelm by drawing on and facilitating the sharing of knowledge and experiences of a post-graduate trained interprofessional collective. In other words, deferring to expertise across the group. This strategy provides several advantages in instructing groups with extremely varied backgrounds in terms of both academics and experiences. It supported intrinsically motivating activities such as self-disclosure of lived experiences [5], provided a glimpse into existing group knowledge, and identified gaps in collective knowledge for subsequent assembly and discussion. It allowed us to meet the learners at their current state of knowledge and encourage growth through their consideration of concepts and ideas that map to their present understanding. Through this strategy, we hoped to decrease the chance of individual disengagement on either side of the spectrum of knowledge and experience in any given discipline or domain. An additional reason for broadening the discussion was to promote the opportunity to address the downsides of innovation and potential risks introduced through changes to medical products and process designs [6].

An iterative approach was used to design the learning experience. In other words, the content, context, and approach to the learning experience was viewed as an emerging phenomenon, unfolding over time, dependent on interaction, knowledge, and experience of the collective. This work builds on previous learning experiences in the curriculum. For example, previous sessions requested that fellows collaborate with others at their site to design a simulation experience to share. To broaden this strategy and to increase capacity for engagement, we designed the sessions to facilitate cross-site collaboration. Planning and learning experience stages were not formulated in isolation; in other words, the two stages were intermeshed and longitudinal in nature. In alignment with basic principles of human-centered design, the learning sessions were co-produced through participant engagement early on and in each stage. Drawing on collective expertise and facilitating co-production throughout design and delivery permits customization on the fly, tailoring the learning experience to the unique characteristics of a given interprofessional group, and provides insight into knowledge gaps. Once knowledge gaps are identified, facilitators can work towards integrating missing concepts into subsequent sessions.

Playing on historic sessions in this subject area, theories into the diffusion of innovations were utilized to initially frame the activity. We identified a comprehensive paper for fellows to read prior to the learning session, a review article describing the diffusion of innovations in the context of health care [7]. Fellows were asked to provide thoughts on the article a week prior to the planned session. Initially, we planned to assign each cross-site collaborative a distinct section of the article as their topic for preparing a learning-by-teaching session. While formulating and discussing amongst potential participants, we became concerned with the capacity to meet learning needs. We switched gears and instead asked collaboratives to develop a 10–20 min didactic including an activity, conversation, or story on a topic of interest that incorporated some concept related to *change* and *safety* for presentation to the larger group.

Prework to the learning exercises included several group email communications and individual telephone calls to assess the current distributed knowledge of the group, to gather input about proposed changes or customization, and to clarify. Groups were asked to discuss and incorporate a concept or story of *change* and *safety* regarding a topic of interest or fellowship project. In line with theories of adult learning, we

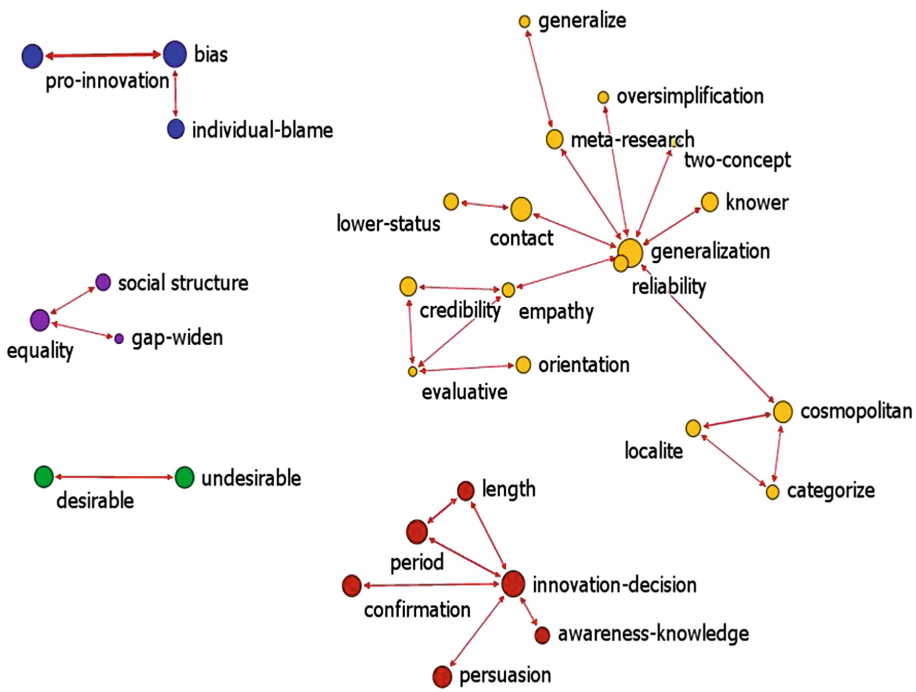

Fig. 1. Word co-occurrence network for exploring distinct linguistic features present in two references discussing the diffusion of innovations [7, 8]. This network visualization was created using PolyAnalyst™ (Version 6.5.2030; Megaputer Intelligence).

instructed each group to share learning objectives prior to fellow-led sessions. Fellows were asked to describe examples of these concepts in the real world and their application to fellowship projects.

We called groups that voiced concern with the activity to discuss and clarify instructions, informing them that the intention was for a relaxed and creative experience. We even proposed that one group consider taking on a playful resistance to this activity as an opening for a discussion on resistance to change. These group and individual conversations provided useful information for preparing the subsequent faculty-led segments. Through this approach we could identify concepts from the study of diffusion of innovations that were not covered within the provided paper or by the fellow-led learning segments.

In preparation for the sessions, we performed a linguistics analysis of the paper [7] and two editions *of Diffusion of Innovations* [4, 8], using mixed computational (Fig. 1) and manual approaches. This review was performed for two reasons. One, to identify topics not specifically addressed in the paper to consider for inclusion in the faculty-led component of the learning experience. Two, to identify concepts in *Diffusion of Innovations* that could provide examples for making cross-curriculum connections with concepts in *Human Factors*.

3 Resultant Design

The resultant learning experience included two 60-min virtual sessions broken into 20-min increments. A 20-min faculty-led introductory segment initiated the sessions, followed by four 20-min fellow-led segments, and ending in a faculty-led closing and debriefing. We relied on the paper [7] to provide baseline knowledge into diffusion concepts.

The faculty-led introductory component included a brief discussion on general concepts in diffusion of innovations such as *relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability*. Concepts missing from the provided paper were identified through the comparative linguistic analysis of the paper and two book editions. *Empathy*, *equality/equity*, and *trust* were some of the concepts missing from the paper that were integrated into the faculty-led introductory component.

The inclusion of *Leading Change* as a topic in existing safety curricula and author observations suggest that patient safety leaders are generally in favor of change if an innovation is assumed to improve safe operations. Although there are many recipes for designing and facilitating change, even with best efforts, design and implementation can be suboptimal at times and may introduce risk. There is a parallel between the importance of understanding “work as done” instead of “work as imagined” [9] and the conceptualization versus the realization of implementing change.

We viewed *empathy* or the lack thereof as a central component in framing and designing change, in terms of the influence and levels of authority and imposition and tradeoffs with autonomy and engagement in co-production. Change agents are historically, and possibly deliberately, bad at prospectively thinking about and identifying the undesirable consequences of change and the introduction or shifting of uncertainty. Change agents must effectively empathize to accurately evaluate community needs [4].

This process often manifests as the agents becoming more of a part of the community of interest and thus experiencing the complexity and socio-cultural characteristics firsthand. To this end, we introduced a short surprise activity in hopes of stimulating an emotional experience and time for reflection on the concept of *empathy*.

Patient safety professionals are developed with the intent and expectation to lead change. Because of this, we considered imposing a change on potential future change agents (fellows). After much deliberation and anxiety over the use of trickery, we decided to proceed. Just prior to what the learners believed was the start of the fellow-led portion of the session, we falsely imposed change on the groups by asking them to exchange their presentations, so that each group would lead a different group's prepared learning experience. We directed the first group to take five minutes to prepare to lead the new presentation. After 30 s, we asked groups to take a minute to reflect on and write about how they felt about this request. Prior to sharing, we announced that this proposed exchange was a hoax and fellows were then asked to share their reflections. The experience provoked a strong emotional response. The following discussion highlighted the intersection of change and *empathy*, *trust*, and *equality*.

After a 20-min faculty-led segment, fellow-led segments commenced. The four fellow-led segments covered multiple clinical areas and included insights into motivating change in support of safety initiatives. Undesirable consequences of change were a common theme in the fellow-led discussions.

Because several fellow-led segments focused on consequences by providing insightful examples, the final faculty-led segment was customized to address topics not yet covered. Before moving on, we shared our thoughts on the importance of deeper inquiry into the consequences of innovation. Rogers (2003) asks the question, "Why have there been so few studies of consequences?" and provides several responses, one being, "Consequences are difficult to measure" [4]. Although often superficially mentioned, undesirable consequences tend to receive limited attention when thinking about our own innovations.

A simple reason for this may be that it is easier to measure what we know or expect from the implementation of change than what we do not know or expect. Possibly this does not sit well with us to dabble in and be drawn into considering the potential negatives of our cherished innovation. This glossing over may be a protective measure to save us from what is often referred to as *analysis paralysis*. Often curiosity is satisfied if the innovation provides the expected results (or not) but we are overwhelmed by thinking about and attempting to predict undesirable changes. The influence of change as a function of time is also an important consideration. Impacts that may be measured with time in mind is a phenomenon described as a performance or implementation dip, and it is difficult to comprehend alternative paths never realized or pushed to extinction. Fellows might benefit from explicitly focused discussions into theories of undesirable consequences of innovation and practical manifestations. Will promoting a safe learning environment that embraces sharing personal stories of the undesirable consequences of innovation foster a critical examination of our limitations for challenging assumptions? Moving towards understanding this challenging subject could motivate additional interest into disciplines such as human-centered design and systems engineering and their approaches that systematically challenge assumptions while seeking to understand potential consequences. Gradual discussion may support the growth of shared awareness into the importance of integrating the expertise of these disciplines early on and throughout processes promoting change. In addition, this discussion draws attention to potential research opportunities in designing and developing strategies for studying and understanding the consequences and costs of innovations.

The faculty-led closing discussion highlighted several concepts not yet covered by fellow-led segments or the supplied paper, emphasizing cross-curricular connections between theories in diffusion of innovations and human factors. Pro-innovation bias was introduced and discussed as a strong belief held by a change agent that society should adopt an innovation quickly and without re-invention. This bias also places limits on diffusion research. The concept of *re-invention* was introduced as the extent to which an innovation is developed or modified by the end user. An increase in an innovation's flexibility increases the degree of re-invention, increasing the rate of adoption. Flexibility is an important consideration to keep in mind when designing usable and error-tolerant systems. It is important to consider the tradeoffs between flexibility and standardization which are often at odds. We discussed the development of dependence on innovations, consequences of dependence, and the necessity for designing with redundancy in mind to facilitate system resiliency. Connections were examined between the *empty vessel fallacy* associated with change agents when conceptualizing *indigenous knowledge systems* in "assuming that potential adopters are blank slates" [4] and the concept of *negative transfer* discussed in human factors in which users bring their previous experiences and understanding when interacting with innovations. Negative transfer may impact the safe use of innovations. Lastly, we led a discussion on *positive variation* or *positive deviance*, the idea that communities already often contain path-ways for and persons who practice locally feasible and sustainable solutions [10].

4 Discussion

In summary, we describe one story of the design and presentation of a virtual learning experience as part of a patient safety curriculum that aims to satisfy the intellectual curiosity of a class of diverse postgraduate interprofessional learners. In addition, planning for and collaborating on teaching requires fellows to construct explanations of chosen concepts [11] and to practice collaborative lesson development. Our strategy for encouraging engagement among a diverse group changing from year to year was through exploring the design of a flexible process for real time adaptation. Embracing co-production and expecting a self-organizing emerging experience were necessary.

Although these learning experiences were designed with our best efforts, there were several costs and challenges to this approach. Co-production and flexible design required extra planning and work for both fellows and faculty. Viewing this experience as an emerging process increases uncertainty and possibly anxiety, which certainly was experienced by faculty in this case. Turning from a traditional approach of relying primarily on faculty expertise and didactic learning to a collective model may bring into question faculty credibility.

Future design and development of this activity will seek to incorporate additional disciplines and cross-curricular connections. Central to resiliency engineering, cognitive system engineering, and the study of complex systems is seeking to understand constant system adaption to change and uncertainty [12, 13]. Theories and concepts discussed in these sessions were connected to a new learning session in the curriculum on current thoughts in safety science and will be connected to sessions on cognition. The cognition sessions will expand on *cognitive biases* as a primary lens for understanding safe operations in health care to naturalistic decision making, cognitive system engineering, and joint cognitive systems [14]. Finally, we ask the reader for assistance in thinking about the future design and direction of these learning experiences.

Acknowledgments. We would like to thank everybody at the Veterans Health Administration National Center for Patient Safety, patient safety fellows and fellowship faculty for their commitment to patient safety. Also, we thank B.V. Watts for providing the academic framework and leading past learning activities towards a collective understanding of these concepts. There were no relevant financial relationships or any source of support in the forms of grants, equipment, or drugs. The authors declare no conflict of interest. The opinions expressed in this article are those of the authors and do not necessarily represent those of the Department of Veterans Affairs.

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A Human Factors Framework and Heuristics for Diffusion of Innovations

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Abstract. Change management and diffusion of innovation have been studied and described extensively in the sociology and anthropology literature. Greenhalgh and colleagues (2004) provide an insightful conceptual model for the implementation of innovations. During a recent teaching experience, we encountered limitations on the model's practical utility due to the complexity. At the same time, we noted clear parallels to the field of human factors. This paper diffuses the model into a human factors framework that aids in the understanding of change management and diffusion of innovation. In addition, we provide heuristics for evaluating innovations. These may be used prior to implementation to evaluate the innovation for suitability and risk and modify it if necessary, prepare the system for change, and plan the deployment of the innovation for the greatest chance of success.

Keywords: Diffusion of innovations · Change management · Human factors framework · Heuristic evaluation

1 Introduction

Workers in health care are continually seeking improvements and systems changes to increase efficiency, reduce patient harm, and improve patient outcomes. Potential health care improvements may be identified through scientific studies, literature review, or local process improvement projects. In all cases, identification of a new tool, technology, or way to perform work is only the first step in the process. Disseminating this knowledge throughout a health care system and effecting meaningful change is a journey that can be difficult and long. In the worst-case scenario, a change that could otherwise benefit many may be rejected before it is ever implemented. The process of sharing and adopting new methods or technologies has been studied extensively and is often referred to as *diffusion of innovations*. Helping a system adapt to the resultant changes is generally described as *change management*.

Change management and diffusion of innovations have been studied and described extensively in engineering, sociology, and anthropology literature [e.g., 1–3]. Change

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 47–53, 2020.
https://doi.org/10.1007/978-3-030-50838-8_7

management emphasizes the consideration of implications for system complexity, because change can become problematic when what was intended to be a limited change to one system propagates some change to other connected systems. Formal and informal processes can be used to handle change and potentially mitigate harm from unintended consequences.

Rogers's theory on diffusion of innovations [2] incorporates work of many scholars [4], so we use it in this paper as the basis for our understanding of diffusion of innovations. Rogers described four elements whose characteristics together form the theory of diffusion of innovations: the innovation, the communication, time, and the social system. Like Rogers did in his writings, here we will use diffusion to refer to the planned as well as the spontaneous spread of new ideas.

While Rogers's theory focuses primarily on adoption of innovations by individuals, other authors have examined how ideas and innovations spread within organizations. Greenhalgh and colleagues summarized the findings of a systematic literature review to provide a comprehensive, evidence-based framework for diffusion of innovations in service organizations [3]. Some of the key components of this model are shown in Fig. 1.

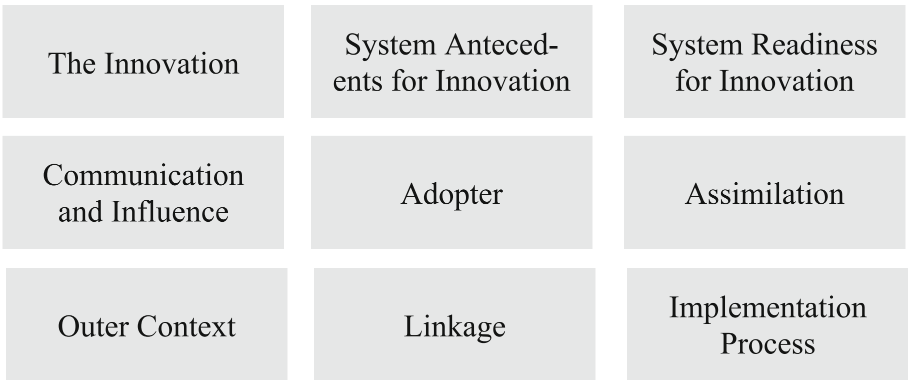

Fig. 1. Some components of a conceptual model for considering diffusion of innovations in service organizations, adapted from Greenhalgh et al. [3]

Greenhalgh later demonstrated the utility of this model by using it to draw lessons from the introduction of a large-scale health care information technology project [5]. While the paper by Greenhalgh and colleagues [3] provides an insightful and thorough conceptual model for describing implementation of innovations, it appears to be intended more for researchers and may be overly complex for most people who are new to the field. In this paper, we show how a human factors framework can aid understanding and use of diffusion of innovations models and support change management.

2 Human Factors Framework for Diffusion of Innovations

A human factors framework generally places factors into categories of user, task, tool, and environment. It emphasizes the importance of understanding the context of use in order to design to maximize human performance and minimize error. A well-known human factors framework that has been utilized in health care is the Systems Engineering Initiative for Patient Safety (SEIPS) model [6]. The work system component of the SEIPS model includes "Organization," which is sometimes considered part of the Environment in other human factors frameworks (Fig. 2).

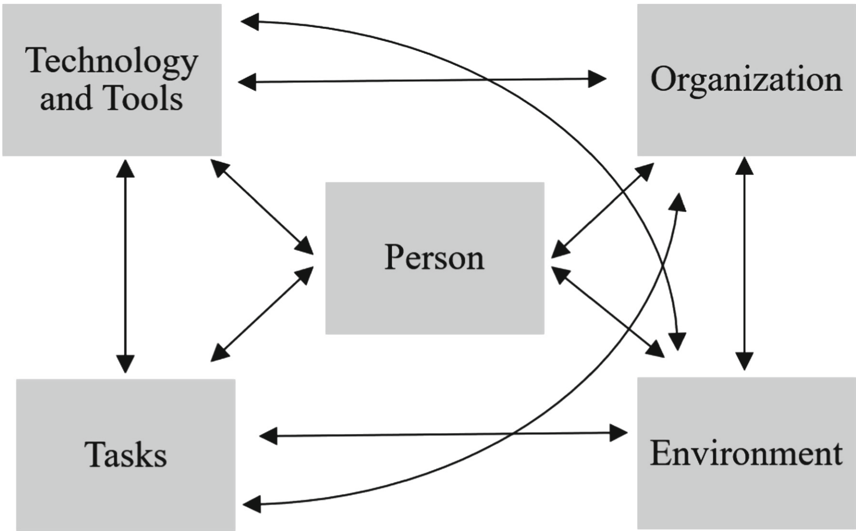

Fig. 2. Work system component of the SEIPS model, adapted from Carayon et al. [6]

The arrows in the diagram above are important, because they imply interaction between the various components of the model. A characteristic of one component may only be relevant in how it relates to a characteristic of a different component. For example, an environment with dimmed lights will make a task that requires visual acuity more difficult but will have limited effect on an auditory task. In addition, people may make changes in one area to overcome challenges introduced by the characteristics of another area. In the case of the low-light visual task, someone might introduce a flashlight (new tool) or switch from reading from a paper to reading from a monitor (changed tool) to make the task easier.

In general, viewing a workspace through the lens of a human factors framework encourages one to consider the contexts in which an innovation will be used. This can lead to thoughtful redesign of aspects of the innovation as well as an implementation strategy that will promote adoption and minimize unintended consequences of the implementation.

To understand Rogers's Diffusion of Innovations Theory [2] and the conceptual model of Diffusion in Service Organizations by Greenhalgh et al. [3] in human factors terms, it is helpful to think of the adopter as the user. The innovation may be considered to be changes in the tool and/or the task. The various components of the system, such as system antecedents for innovation, system readiness for innovation, and the outer context, may be understood as aspects of the environment and organization.

This is not a direct mapping, and there is added complexity. For example, the user/adopter is also part of a community of users, who form part of the organization but are also influenced by other parts of the organization, in addition to the environment, tasks, and technology/tools.

3 Heuristics for Diffusion of Innovations

The term heuristics, as used here, refers to general guidelines or "rules of thumb" that allow people to make decisions quickly. Usability heuristics, such as those proposed by Nielsen [7] or Zhang [8], provide a list of usability principles or best practices against which one can evaluate an interface or design. Similarly, we propose here a set of heuristics for evaluating system readiness for change related to the adoption of a particular innovation (Table 1).

Table 1. Heuristics for diffusion of innovations

Element	Heuristic
Tool/Task	The innovation was developed with end user participation (co-production)
	The innovation has a large relative advantage and low relative risk
	The innovation is compatible with workflow and task requirements
	The innovation has low complexity
	The innovation is divisible for the purpose of gaining personal experience
	Use of the innovation is highly visible to others
	The innovation can be adapted/modified/configured to fit local user needs (reinvention)
	The innovation includes documentation and access to help/support services
User	There is a significant number of potential adopters who have demonstrated a propensity to try out and use innovations
	Potential adopters are motivated and able to use the innovation
	Local opinion leaders have been identified and involved
	Champions have been located
	There are boundary spanners who can link the organization to the outside world with respect to the innovation
Organization	The system has the needed capacity for adoption (slack resources)
	A semiautonomous multidisciplinary project team has been established
	There is a formal dissemination program that accounts for adopters' needs and perspectives, tailors strategies to subgroups, uses appropriate messaging, and includes evaluation and monitoring of defined goals and milestones
	The innovation will be communicated to the potential adopter by someone who is similar in terms of beliefs, status, and education
Environment	The innovation is compatible with the environment in which it will be used
	The environment promotes trialability of the innovation

The heuristics we propose for considering proceeding with the planned diffusion of an innovation focus on aspects of the system, the innovation, and the implementation that can be changed. They also includes characteristics of the expected adopters that may be modified. The literature has identified additional important factors, but including those that cannot be controlled will detract from areas where changes can improve the innovation and adoption.

Similar to how Greenhalgh and colleagues noted that their Model of Diffusion in Service Organizations is intended as a memory aid and should not be viewed as a prescriptive formula [3], these heuristics should not be used to predict whether adoption will occur. Rather, they are intended to help one thoughtfully examine an innovation within a particular context and determine whether the innovation is likely to be a good fit and how it and components of the organization might be modified to promote fit and adoption. Review of the heuristics during the problem review, brainstorming, and design phases will be especially valuable, because they will encourage innovators to employ evidence-based evaluation and design strategies, such as having end users lead the innovation development.

4 Case Study of a Crash Cart Improvement Project

Recently, a team at the Ann Arbor VA Medical Center, led by the patient safety manager and a physician, conducted a project in which the group redesigned the crash carts that are used in codes. They assembled a multidisciplinary team with representation from key areas such as pharmacy, emergency medicine, nursing, logistics, and respiratory therapy, as well as hospital leadership.

An initial assessment of the current state revealed that the contents and configuration of crash carts within the facility varied in ways that were identified as problematic. When the code team responded to a code in the facility, they would use the closest crash cart, which might have different medications and supplies in different parts of the cart than the last code they had responded to.

After defining the problem, the team worked to determine the goal state, including which medications, tools, and supplies should be part of the crash cart; which items should not be included; and how the equipment should be grouped and arranged. They assembled pilot carts, which were taken to various hospital departments for additional evaluation and iterative redesign as well as training. Dissemination of the change is ongoing, and the team is concurrently planning for sustainment.

Some key heuristics that were followed during the early stages of this project were that the innovation was developed with significant end user involvement, was carefully designed to be compatible with workflow and task requirements as well as the environment in which it would be used, and had a large relative advantage and low relative risk. The patient safety manager established a semiautonomous multidisciplinary project team that was chosen to include staff who could serve as champions during innovation dissemination.

There were some heuristics that were more difficult to follow or that did not apply in this situation. For example, the environment does not promote trialability—it was only practical for the code team to use one cart—but evaluation and use of the cart in a simulated setting allowed users to practice. In addition, the crash carts could not be adapted to fit individual user needs, because a key characteristic of the new carts was uniformity throughout the facility. However, the carts were designed to meet local user needs within the facility rather than for standardization throughout the nationwide VA health care system.

5 Discussion

Everett Rogers wrote about applying diffusion of innovations ideas to the promotion of human factors [9]. Here we considered the inverse, proposing a human factors model for concepts important to understanding diffusion of innovations. This model integrates and builds on existing models of diffusion of innovations and human factors frameworks to aid in understanding what factors influence diffusion of innovations and how these relate to the interaction between workers and the work environment. It encourages innovators to use human factors principles to evaluate an innovation and its fit for the user, task, and environment.

Using human factors terminology and models to explain diffusion of innovations will help those with human factors and systems engineering backgrounds understand how innovations spread. It may facilitate the teaching of this content to health care and patient safety learners by utilizing terminology they may have heard in other contexts. In addition, it may encourage learners to begin to think in a systems-oriented way by demonstrating how diffusion of innovations theory fits with models of systems used in health care human factors.

Conversely, blending models of human factors and diffusion of innovations may encourage potential innovators to consider users and context of use during the design phase. It should help those who work on diffusion of innovations to engage in systems thinking and to be able to explain using human factors language why adoption is not occurring as expected or why the innovation may not be not appropriate for the context of use. Researchers who have applied complexity theory to studying the implementation of health care interventions noted the importance of elements such as sensitivity to initial conditions and awareness of interactions between participants and the work context [10], and use of human factors models may aid in evaluation of these elements.

The use of heuristics to evaluate the fit of an innovation to the context of use, including the users, tasks, organization, and environment, will help innovators systematically consider potential barriers to adoption. Engaging in this thought process is valuable because it encourages innovators to make changes that in addition to increasing the chances of adoption will also improve the utility of the innovation.

Evaluating an innovation through a human factors framework can reveal whether the design is the right fit for the system. Rather than simply focusing on how best to diffuse an innovation, leaders should consider whether this innovation will work well for the context of use, how other aspects of the system will be affected, and if there might be unintended consequences with the change. A human factors framework for diffusion of innovations can help health care innovators and leaders ask the right questions to improve system performance and patient safety.

Acknowledgments. We would like to thank everybody at the Veterans Health Administration National Center for Patient Safety for their commitment to patient safety. Special thanks to Cindy Paterson, PhD, MSA, BSN, at the Ann Arbor VA for her work on the crash cart redesign project and sharing the story. There were no relevant financial relationships or any source of support in the forms of grants, equipment, or drugs. The authors declare no conflict of interest. The opinions expressed in this article are those of the authors and do not necessarily represent those of the Department of Veterans Affairs.

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Systems Engineering for Healing Healthcare: The Journey from Compliance to Resilience

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Abstract. As healthcare strives to improve its reliability, we seek to inform healthcare systems with perspectives beyond prescription and compliance. This paper describes states of Readiness for gauging preparedness at different structural levels to facilitate strategic planning toward continuous improvement. Healthcare systems of all sizes and complexities can utilize the concept of Readiness to prioritize preparation required to anticipate change and adapt to variability associated with delivery of safe and effective healthcare by building on approaches experienced by the author in designing, training for, and conducting complex Space operations.

Keywords: High reliability · Readiness · Resilience · Systems engineering

1 Introduction

Current healthcare systems are increasingly complex and multifaceted, with intricate equipment, software programs, and processes that require specialized employee training to operate safely and effectively. Clinicians must be ready to handle ongoing changes and improvements within the system. In an ever-changing environment, how do we ensure that healthcare professionals are equipped for the range of challenges and changes that they will undoubtedly experience during their careers? What has been learned about preparing healthcare professionals to be ready for change?

This paper proposes structuring levels of healthcare operational readiness in the form of Readiness Levels, similar to the stages articulated in the Capability and Maturity Model described by Curtis [1] and drawing on lessons from the National Aeronautics and Space Administration (NASA) [2, 3]. Instead of preparing crewmembers and mission controllers, we consider readiness of healthcare "operators", meaning any clinical, facility management, or leadership personnel. Readiness levels provide guidance for confirming preparedness for performance under different conditions. Each level builds on those below, and there is feedback between the levels.

Using these readiness levels, we explore how to capture and document the effect of change. This is accomplished by inquiry into understanding actual work processes and subsequently updating tools, checklists, and SOPs. A strong and sustained focus on culture is essential to the successful pursuit of increased readiness. If members of an organization feel incapable of influencing their work environment, they will not be motivated to look for what needs to change in order to continue to realize mission

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 54–61, 2020.
https://doi.org/10.1007/978-3-030-50838-8_8

success. In this context, it is important to explore “work as done” versus “work as imagined” [4, 5]. If the problem space is not well-understood, it will be difficult to increase the level of readiness.

The structure described in this paper is intended to help healthcare organizations identify their current readiness levels for employees, for units, for service lines, and for their facility. By understanding this and the relationships between the levels, organizations will be able to grow and achieve higher readiness levels. This, in turn, will hopefully further promote the delivery of safe and effective care to patients, just as it has promoted the safe operations of crewed spacecraft.

2 What Can Healthcare Learn from Other Industries?

For the past twenty years most patient safety approaches have been based on an epidemiological accident model that asks the question of what could go wrong [5, 6]. We recognize that accident investigation may always be a necessary part of patient safety, but when it is the predominant component it encourages barrier-like solutions, which may increase system complexity and brittleness. The traditional approaches to patient safety tend to be prescriptive, with a focus on compliance with thorough investigative processes. In practice, however, patient safety teams with time constraints for closing out an issue often make assumptions regarding “work as imagined” rather than assessing “work as done” during incident investigation and policy development [5, 6]. In addition, the investigation process is often used only on events involving near or actual patient harm. As a result, the investigation activities can demoralize those at the sharp end in the patient care system and may introduce uncertainty and undesirable consequences, thus impeding adoption of solutions that lead to actual system improvement.

Some more recent approaches to patient safety focus on building resilience and identifying what goes right [e.g., 5, 7]. Sharing what one team has observed may help others identify possible improvements to their systems. The goal of both approaches is to learn, from failures and successes. Sharing this knowledge may help the larger community avoid negative outcomes, but it must be done thoughtfully to avoid inadvertently introducing or shifting vulnerabilities and increasing the risk of patient harm.

Applying these ideas may align with the search for improvement in reliability; characteristics of High Reliability Organizations (HRO) include preoccupation with failure, reluctance to simplify interpretations, sensitivity to operations, commitment to resilience, and deference to expertise [8]. The goal is Organizational Learning, not a metric such as number of RCAs. How ready is leadership or the employee to achieve a goal?

Other industries and agencies, such as NASA, have been utilizing principles associated with high-reliability theory (HRT) for years. Lessons learned while a Human Factors Engineer leading training and mission design for Space Shuttle operations and Space Station construction at NASA’s Johnson Space Center may be applicable to healthcare operations. A key part of the NASA culture was addressing the idea of appearances versus actions. New team members (e.g., astronauts, mission controllers, leaders) were asked, “Do you want to have this job or DO this job?” Defining and measuring success were important.

In NASA Mission Operations, there was a recognized need for system performance insight. The team was continually querying current state, defining impacts of change on other parts of the system, and identifying what could be done to improve the probability of mission success. For example, consider the use of a robotic arm. The device is part of a system; if the crew cannot see the motion at the end of the arm, they may be unable to continue with a deployment task. An electrical fault in a critical camera would require a change in task, and that scenario would most likely have been considered and practiced prior to Mission launch. The NASA Mission Control Center amassed hundreds if not thousands of use-cases with a range of crew operators, in a range of environments, doing a range of simultaneous tasks in order to gain understanding of the remaining options to improve the likelihood of mission success in any given situation.

Crew Training at NASA was designed to identify the data and feedback crew and controllers would need in order to confirm the critical aspects of mission tasks in all conditions and to practice under all imagined malfunctions. The team goal was to train the entire organization to continually perceive, evaluate, and act to achieve mission success. Simulations of operator tasks as well as top management decisions were designed to define what signals the crew and controllers use and need, to define and most reliably achieve “nominal operations,” as well as what things might mask their ability to perceive those signals. These scenarios were practiced in simulated settings so that each crew member, console operator, mission manager, and member of leadership could understand the possible range of conditions that might occur when it was time to actually perform the mission task. The simulations identified what information was needed to allow all involved to continuously evaluate the current operational state and select actions to support mission success. Table 1 shows how some observations of how NASA culture aligns with HRT.

Can healthcare as an industry learn how to anticipate and prepare for change by using strategies from recognized HROs in other industries? NASA’s concept of defining and managing to a performance envelope and deliberately identifying options for mission success through simulation under many different conditions offers a pathway toward increased resilience to achieve success in reaching patient safety goals. If there is a product shortage, how can healthcare operations consider the current state of use, document potential causes, predict the effect on patient care of no—or limited—product availability, and prioritize use or acquire additional product? Instead of hoping it never happens, why not regularly practice what you would do if it did happen and consider the impact on all care areas?

This methodology was recently piloted with respiratory therapists considering ventilator set-up and configuration, in support of the Association for the Advancement of Medical Instrumentation (AAMI) National Coalition to Promote the Safe Use of Complex Healthcare Technology. End-users of ventilators summarized what they would need to know, what they would need to check, and what could be done to increase the safe and effective use of that technology. In other words, what did the operators want the designers and developers of the technology to change? Because the audience was the ventilator industry, which has a vested interest in product

Table 1. Observed attributes of NASA culture that align with HRT.

Component
OWN THE MISSION. Every single person is part of the success or failure
Do not make the mistake of thinking only "bad" employees make mistakes
Consider human factors principles, including what influences human performance and how we can help the person be successful every time. If something CAN go wrong, it WILL go wrong eventually. Learn from the experience *anyone* has
If I SEE something, it's my duty to SAY something
Welcome and celebrate identifications of system vulnerabilities. Champion actions to improve the chances of accomplishing your mission. Establish a standard way to communicate what you see, what you are concerned about, and what you think should be done. Foster an organizational culture that values justice where operators are not punished for being human
Learn about expected variation of outputs; never just assume there is only one pathway for achieving mission goals
What happens when I do THIS? Practice any scenario where you want to be prepared to succeed. Utilize simulation at different fidelity levels. Develop a shared mental model to identify when you're in the resilience zone and identify what "off nominal" might look like as well as what corrective actions are available
Build on existing knowledge
What have others encountered? Identify what can be learned from past experiences. For example, talk to the crew that worked on the Lunar surface as you draft mission requirements for Martian surface operations

improvement, all eventual device operators and patients may benefit from this increased understanding of what would enhance the user's capability to perceive, evaluate, and act toward a successful outcome. The experience demonstrated that industry partners welcome this opportunity to gather input for next generation enhancements in their design and development cycle.

3 Organizational Readiness Levels

The goal for this work is to translate ideas from NASA, resiliency engineering, HRT, and the Capability and Maturity Model for software, into organizational "readiness levels." These should aid healthcare employees, teams, and leaders to confirm their current operational readiness as well as identify what is needed to be better prepared, especially for system change as when introducing a new service-line or electronic health record in a hospital.

From novice to expert, the proposed Readiness levels are: 1) demonstration/ familiarity, 2) establishing standard operating procedures (SOPs), 3) sharing lessons learned, 4) structuring teams in anticipation of change, 5) practicing organizational analysis of the impact of change, and 6) simulation of extreme situations to confirm ability to detect and alter plans to successfully achieve mission objectives (Table 2).

Table 2. Readiness levels for healthcare.

Readiness level	Description
RL1	**Train and learn to DO as trained - pass the test (at that moment)**
	Can you do your job the way they taught you (until something has changed and this no longer works)
RL2	**Can you identify steps of the checklist, confirm you did what was expected**
	Update checklists as we learn more to prepare team to anticipate operational “boundaries”
RL3	**Can you work as part of a team: what is our shared vision for success, discuss differences we see/know**
	Team accountability and ownership—what went well? What was learned? What should we practice?
RL4	**Can you organize and implement Proactive exposure and practice: what could go WRONG, what could CHANGE, what would we do?**
	System resilience—are we ready for off-nominal situations?
RL5	**Can you articulate and recognize system limits of use—identify operational zones and ensure we stay in a world we understand**
	Acknowledge the situation is or is NOT one we’re ready for; team engagement for identifying different approach to achieve objectives
RL6	**Can you articulate and organize Enterprise practice/simulation to confirm available system performance**
	Actively discuss and practice “what IF” scenarios, no matter how unlikely they seem, for your community

To move toward goal state, we can begin by understanding how people interact with systems, capturing the global experience and learning all the ways humans need feedback to know current status. This was the exercise used for setting up ventilators—what are all they things you wish you could confirm as part of selection and set-up? We can understand the range of experience, including what has gone wrong for any individual and how and why. We can understand what can change in the task, with the range of human performers, the range of environments, the range of tasks, and then signal when the system is reaching its limits of use. This might occur if the person is too tired or distracted, the environment is too loud or dark, or the task is being done concurrent with other tasks rather than in isolation. If we are unable to identify an “off nominal” situation, as defined by our current readiness level, we will not be prepared to shift to a planned and understood secondary or tertiary option to ensure mission success.

4 Applying Readiness Levels to Individuals on a Team

Recently the first author (TB) assumed supervisory duties for a new group of employees and utilized the concept of readiness levels to capture the work they were performing on projects. Employees welcomed this approach for assessing readiness and defining what would help them be more effective. As an example, for something as basic as facilitating a recurring national teleconference, helping an employee outline where they were in "readiness" allowed them to feel confidence that, should they for any reason become unavailable, the mission/task could still be accomplished (Table 3).

Table 3. Sample readiness levels for use with individual employees.

Readiness level	Description
RL1	**Describe the goal of a meeting**
	What will attendees hope to accomplish?
RL2	**Create a checklist outlining the roles for the various participants**
	What will the moderator do, how can participants contribute, who will explain the need to mute lines and not place the call on hold, etc.
RL3	**Define team success, meet with team to confirm shared expectations**
	Create Metrics (e.g., no technical interruptions or complaints)
RL4	**Determine what competencies may be occasionally required**
	What permissions to give for site access, how to engage the operator to address technical difficulties, how to share the screen, etc. What questions does the employee have, what gaps exist to handle "off-nominal" situations? Let's create SOPs for those we find, and capture Q&A as we find them
RL5	**Identify business rules for "wave off" - end the call and reschedule**
	Discuss and identify limitations for hosting the call, guidelines for addressing possible situations such as an irritated or aggressive participant
RL6	**Simulate and practice**
	Define challenging scenarios and try them: How would you deal with a meeting leader who isn't hearing the participants? How would you help a participant whose comm system is degraded so as to be unintelligible?

Note that the readiness levels here are customized both for the level of operator (individual) and for the specific task and context of use. Similarly, readiness levels may be adapted to fit different users or groups of users in different work environments. The unifying factor is the idea of growth in preparedness to achieve the goal.

5 Discussion

The implementation of this kind of readiness assessment inspires a sense of growth, rather than promoting a binary determination of "trained" or "not trained." It teaches the importance of anticipating dynamics, with demonstration of how the usual approach might need to change with situational variability. By referring back to the goal and confirming the usual steps, roles, and competencies are still valid, the individual, team, or organization has a reference point against which to measure preparedness for change and for the unexpected. Designing systems that foster the proactive preparation towards increased resilience will invite active attention to any slight variance, for example, a new team member or a different procedure room. The individual, team, or leadership will engage in preparatory discussion, asking what else might need to change and how we can confirm we are ready to be successful given the new factors.

This structure has been tested at a very preliminary level in domains such as individual employee project readiness; team readiness for perceiving, evaluating, and developing action plans in a simulation setting; and clinical device readiness for successful use among clinical users. The identification of readiness can easily be illustrated as a fractal pattern, as has been described previously when discussing components of healthcare as complex adaptive systems [9]. The individual, the team, the facility, the industry choose to proactively work together to identify, communicate, and annunciate system limits as well as find and move toward best practices for the goal of safe and effective patient care, helping healthcare systems to become reliability-seeking organizations [3]. Just as the transportation industry identifies and guides drivers toward lane management—using rumble strips on the road as well as in-vehicle systems that warn the driver of lane departure—our healthcare systems can glean knowledge from different users regarding how best to provide the important feedback that we are “in our lane.” This approach may next be expanded to include medical residents to assess readiness to work collaboratively with all team members in each rotation to confirm goals, plans, roles, and practice procedures to confirm they are prepared to address the variety of situations they may encounter.

By sharing these stories of operations at NASA and initial applications in healthcare settings, we hope to integrate the engineering approach described here into the current activity directed toward improving reliability and resiliency in healthcare. This approach can be applied at levels ranging from the individual to the unit to the facility to the organization. It focuses on all components of the healthcare team, and includes professionals throughout the range of healthcare workers, which is critical for success.

Acknowledgments. We would like to thank everybody at the Veterans Health Administration National Center for Patient Safety for their commitment to patient safety. There were no relevant financial relationships or any source of support in the forms of grants, equipment, or drugs. The authors declare no conflict of interest. The opinions expressed in this article are those of the authors and do not necessarily represent those of the Department of Veterans Affairs.

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Virtual Reality (VR) in Nursing Education: Jordan Case Study

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Abstract. There are many considerations of how Virtual Reality simulation will applied in nursing education in one of the third world countries, despite the advancing of technology in some of these countries. This case study offers an insight into the methods, the practicalities of how virtual reality study will perform, and lessons learned through research team perspectives.

Keywords: Virtual Reality · Human factors · Nursing education · Human computer interaction

1 Project Overview and Context

Virtual reality (VR) simulation is a computerized and non-traditional teaching strategy that simulates real-life processes [1] that could be applied in education in allied health schools like medical, dental, nursing, and paramedical. Students can attain knowledge of the human body and practices in a virtual environment [2, 3]. In addition, it allows the students to participate in teamwork learning, collaboration, clinical judgment, and as nursing science, in the accomplishment and application of clinical skills [1]. This computer-based technology provides opportunities to students to assess critically patients' situations, demonstrate skills, and experience emotions in a controlled environment and without any risks to patients [4, 5]. It allows the students to exceed the abilities of using a manikin, to reduce the variance of clinical placements [5] and to acquire and train on many skills [6], in addition to real-life nursing practices.

The idea of this project comes from our experiences with students in pediatric and community health nursing clinical courses in clinical settings. Despite the preparation for students in the university labs, we faced problems during the application of some procedures especially those related to children's vaccination and conducting home visits. These problems related to the irritability and anxiousness of the students during the preparation and application of these procedures. All these conditions encouraged us to adopt the idea of VR simulation as a teaching method that will be use and applied in developed countries. The VR simulation provides opportunities for nursing students to enhance their competencies in knowledge and skills, and to experience feelings in a controlled and safe environment.

J. Kalra and N. J. Lightner (Eds.): AHFE 2021, AISC 1205, pp. 62–67, 2020.
https://doi.org/10.1007/978-3-030-50838-8_9

In addition, there are many international studies regarding VR simulation applied in clinical and educational areas. Most of these studies focused on assessing knowledge and skills among university students using VR simulation and others focused on the effect of VR as a therapeutic intervention on patients. Hence, we thought that we must investigate the effect of this new technology in relation to developing countries especially third world countries.

Unfortunately, although expanding the technology in the developing countries, there is a lack of studies about the VR and its effects among university nursing students, which made assessing this technology a high priority. We accept that this study will add to the body of knowledge and support the research-based evidence in relation to the importance of VR in nursing education especially in Jordan.

Thus, the main purpose of our study is to evaluate the effect of VR as a teaching strategy on the nursing student's physiological measures (blood pressure and heart rate), student's reactions, their competencies and satisfaction through VR learning. Furthermore, the study has the following hypotheses:

H1: The nursing students who will engage in VR teaching will have changes in physiological measures (blood pressure and pulse rate) and reactions than those who will not engage.

H2: The nursing students who will engage in VR teaching will have better competencies and satisfaction than those who will not engage.

1.1 Research Design

Keep in mind that this study is to evaluate the effect of an intervention, which is VR, thus an experimental control group design will be the best method to be use. This design is effective to make inferences between a cause (VR simulation) and effect (physiological measures, reactions, competencies, and satisfaction) variables.

1.2 Sampling

The sample will be the students from pediatric and community health nursing clinical courses enrolled in the Al-Zaytoonah University of Jordan. The sample size was calculated using the G*power program (3.0.10) with ANOVA repeated measures and an alpha of 0.05, a power of 0.85, and a relative effect size of 0.25 [7], and this means a sample of 84 participants who will be randomly divided into two groups (control and intervention) would be needed. For avoiding drop out of the sample, the sample size will be increased to 100 participants (50 participants in each group).

1.3 Study Instruments

The following tools will used to collect data:

- Physiological measures: These measures will be evaluated using sensors during the time series period.
- Observation methods: These methods will be conducted using special cameras to record students' reactions; such as motor responses during VR experiences.

- Competencies: It will be evaluated for both groups (control and intervention), where each student in the intervention group will be evaluated for the procedures before and after administering VR simulation and during the usual course. On the contrary, the control group who will attend the usual course will be evaluated as usual. The evaluation process will be through using the clinical procedures checklist for each course.
- Students' Satisfaction: The User Satisfaction Evaluation Questionnaire (USEQ) developed by Gil-Gómez et al. [8] will be used to assess the students' satisfaction. This questionnaire is adopted from Short Evaluation Questionnaire (SEQ) that is composed of 14 questions to evaluate satisfaction, acceptance, and security of use in VR [9]. The USEQ has six questions rated on a five-point Likert Scale ranging from 1 (not at all) to 5 (very much). The total score of the tool ranges from 6 (poor satisfaction) to 30 (excellent satisfaction). This instrument is valid and reliable; Cronbach's alpha for the scale has acceptable reliable results (0.716).

1.4 Data Collection Procedure

The researchers will divide the students into two groups (control and intervention). The control group will attend the usual course and the intervention group will attend the usual course and VR simulation sessions for two months. The VR system created even by a realistic 3D image, or by an artificial environment that presented through a mix of interactive hardware and software. The students will be involved in a real-time 3D simulation by using a connected system, which consists of head-mounted displays (HMD), headphones, hand controllers and computers with VR software.

Assessment on frequent times before, during, and after VR simulation sessions will be conducted for both groups. This assessment will include monitoring physiological measures (heart rate and blood pressure) using special devices attached to the participants and connected to mobiles, which record these measures. Then, the intervention group will be exposed to VR simulation sessions. Examples of these experiences are medication administration, growth parameters, and conducting home visits. The duration of each session is 20–30 min two times weekly. In addition, students' reactions will be observed and recorded through special cameras before, during, and after VR simulation sessions. These visual observations will be monitored and analyzed by the researchers for the research purpose. In addition, a follow up will be at frequent periods to monitor the physiological measures for both groups. Moreover, the competencies will be evaluated by asking students in both groups to perform clinical procedures (intervention group before and after VR simulation and control groups as usual course), the students will be evaluated using the procedures checklist for each course. Satisfaction will be assessed for both groups at the end of the intervention.

2 Research Practicalities

The research team encountered many expected and unexpected challenges that effect on the research project represented by:

2.1 Financial Issue

Concerning this project, we entered a big journey during purchasing equipment, we surprised that the costs of this equipment were higher than what expected in the budget due to a highly unexpected increase in the salaries and taxes in Jordan, which forced us to request increasing in the project budget. Fortunately, we have extra money from the scientific research fund in our university that helped us to continue our project.

2.2 Preparing Lab, Equipment's, and Experiences

To start our study we built a new lab specialized for virtual reality experience. The experimental lab provided with three head-mounted display (HMD) set, HTC vive, and HI5 gloves for capturing full hand and finger action for more accuracy during the interaction, such as handling the syringe.

The lab provided with three large display screens to share the content for the other students and instructor, and three high-performance computers to run the experiences with a high and fast process. To make our case study more realistic and similar to reality, a designer team developer built special experiences for our case study according to courses out-comes using a unity 3D engine.

We go through systematically building the experiences considering patient, environment, self, equipment, and steps of the procedures. At the beginning of our study, we faced some challenges and difficulties to find a VR simulation experience that suite the nursing education materials, therefore we decided to build our experiences, which still under process. Further, another challenge related to the cost of building and designing these experiences, which was expensive and need lots of time and effort, in addition to experts for making it more real and durable to use especially for educational purposes that need accuracy.

2.3 Practical Lessons Learned

Many practical lessons learned from this experience, involving:

Planning. Successful planning begins with a shared understanding of the importance of the research study, especially when conducting the first project using new technology like VR simulation in nursing education in Jordan. Further when the preparation for such experience was difficult. Hence, we as a research team developed a timeframe schedule for each step in the research process, as well as the tasks and responsibilities that will be distributed according to the competencies and interests of the research members. Planning began from preparing a VR laboratory, selecting equipment, and designing experiences that should be included in the teaching materials. In addition, follow up with the experiences' designers for the VR experiences and equipment installation was performed.

Collaboration. As researchers, one of the significant lessons we learned during performing our study is collaboration. For example, we asked the researcher who has distinctive competencies and proficiencies in designing the VR lab and equipment to contact the companies for selecting the equipment and the other one who has good experiences in clinical procedures to design the VR experiences that related to after mentioned courses. This kind of collaboration allows the researchers to form a productive team with a cooperative and mutual respect. We worked as a cross-functional team, where each one has requested to accomplish the predetermined task according to competencies within the arranged time.

For effective collaboration, we explained the roles, duties, and schedule for each researcher using the skills of communication and active listening to the interests and attention of each other. Additionally, the delegation made for some tasks after the research team discussion to attain the study goals and perform the research project. Appreciation of the work of each team member, acceptance of our mistakes, and showing respect were effective in preserving the effective collaboration and successful teamwork.

Communication. Communication is necessary for facilitating and accomplishing any work during the research study. It was effectively demonstrated between the team members from the beginning and before taking any step such as selecting and purchasing the VR lab equipment, developing the nursing VR experiences, and others. Open communication between the research teamwork was a benefit for completing each step of the study.

3 Conclusion

We can conclude that conducting any research project requires choosing the design that reflects the topic and objectives. In this study, an experimental design was used, which has many benefits. In addition, choosing the appropriate measures for evaluating the study variables is a significant step before conducting the study.

Through good planning, collaboration, and effective communication among the research team members, they can successfully perform their study. These keys can break any challenges that face the team.

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Demonstrating Wellbeing and Healthcare HCI Through Multidisciplinary Innovation and Experiential Prototyping

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Abstract. Multidisciplinary design research is a development trend of scientific research and design innovation. Through multi-angle and multi-dimensional design innovation, multidisciplinary teams help various fields solve complex design problems. This study demonstrates three cases that focus on the healthcare field. The age of the target user groups ranges from a five-year-old child to a seventy-year-old man. We explore different users' needs, materialize design innovation through multidisciplinary collaboration. Three wellbeing and healthcare auxiliary demonstrations are designed and developed for busy white-collars, children who are afraid of visiting doctors, and the elderly who take long-term medication, which includes a smart wearable device, children's diagnosis companion toy, and smart pillbox. These prototypes meet users' health needs in different contexts through informal user testing sessions. Furthermore, they encourage a healthy lifestyle and show humanistic care to target users.

Keywords: Multidisciplinary · Design innovation · Wellbeing and healthcare · HCI design · User experience

1 Introduction

Design innovation is a driver that promotes innovation by eliciting core user value and identifying critical areas of technology and product development through design [1]. In the healthcare field, Ben [2] found that by providing personalized and universal service interaction design for users, it improves people's positive experience in the hospital. With increasing awareness of wellbeing and health, users have also put forward higher requirements for medical products and services. The application of design innovation in the field of wellbeing and healthcare services significantly improve the capacity and level of healthcare services and enhance user experience.

The use of open-source hardware in medical healthcare is an innovative form of design innovation. Open-source hardware proactively retrieves data and learns, reacts, and interacts in a human-like intelligence [3], which has high applicability to wellbeing and healthcare application scenarios. It also expands a variety of possible scenarios. Moreover, Dickerson [4] applied open-source hardware in the wellbeing and healthcare field. He created a home real-time depression monitoring system that potentially detects

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 68–74, 2020.
https://doi.org/10.1007/978-3-030-50838-8_10

early signs of depression onset and tracks the progress of managing depression. Shi [5] proposed a modern health detection technology, which based on the remote health monitoring system of the Internet of Things (IoT). It collects human physiological parameters through the front-end technology and uses the Internet and mobile communication transmission technology to transmit data to remote medical monitoring through GSM. The use of open-source hardware in the areas of wellbeing and healthcare management and information services have enriched design innovation in this field. In different medical scenarios, there will be demand for personalized medical services, which combine with open-source hardware for more in-depth research and innovation.

Piotr [6] found that the unique approach adopted by multidisciplinary teams differs from the more common forms of collaborative design and is more innovative. Multidisciplinary refers to teams that include members from different departments in an organization, members from other organizations, or members from different disciplines. The multidisciplinary design has been increasingly strengthened [7]. Facing complex design problems, a designer or a team of the same discipline cannot effectively solve it, which means that teams from different fields must work together to propose a series of solutions to problems. Due to the diversity of information available to team members, multidisciplinary teams propose more creative ideas than individuals or the same background teams [8]. This feature of multidisciplinary effectively promotes wellbeing and healthcare design innovation.

The combination of multi-disciplines, human-computer interaction, and open-source hardware technology promotes design innovation in the wellbeing and healthcare field. This research studies and analyzes the health problems of three different groups of target user groups and defines users' pain points in different scenarios, carries out design innovations and designs wellbeing and healthcare products that meet the needs of them. These products built on open-source hardware, adopt different interaction methods, pay attention to different challenges of users in different contexts, work with multidisciplinary teams to carry out design innovation. Moreover, use intelligent medical equipment to assist and serve intelligent medical health management to improve people's health.

2 Related Work

Design innovation is an efficient way to learn to use design methods and processes [9]. More and more design innovations focus on the multidisciplinary element. In the Stanford Design Innovation Course ME310, Leifer [10] organized students to study in the form of multidisciplinary teams and found that multidisciplinary teams take multiple perspectives on any given challenge and generate more breakthrough discoveries and innovative ideas. Piotr affirmed the unique role of multidisciplinary in design collaboration. He found that introducing multidisciplinary team-teaching methods in a human-computer interactive course inspires students and teachers to use their various professional knowledge to deal with design problems and generate creative interactions to drive design innovation. Many studies have found that multidisciplinary design innovation plays a significant role in the field of health care. Qaosar [11] proposed that multidisciplinary teams put forward more perspectives through discussions, share technologic, and innovative ideas, which helps design better health monitoring and drug treatment features. Eskofier [12] emphasized the multidisciplinary interaction of the design team bridges the gap between research and time. It promotes more creative features, designs, and services in the health care and wellbeing field. The National Institute on Aging and the National Science Foundation [13–16] call on multidisciplinary teams to develop innovative technologies to address health issues such as elderly health issues and chronic diseases. Studies by Fritz [10] and Dermody [17] show that when designing senior and elder care products for home health care equipment and assistive devices, combining professional experts and a multidisciplinary team will design products more efficiently. Professionals understand principles of smart home and artificial intelligence knowledge building for home. Moreover, they will introduce knowledge to others. Prototyping is an essential phase of the design process because it is the most effective way to transform ideas into tangible products [18–20]. Elverum [21] proposed that prototype design is an essential link in the development of most new products. Meanwhile, prototyping is a valuable tool that explores the direction of product design, iterates existing solutions, and unifies the design team's opinions through experiential prototypes. In design innovation, many low-fidelity prototypes combine with open-source hardware, especially in the wellbeing and healthcare field. Miotto [22] developed a smart mirror that monitors and predicts disease. Moreover, it records and evaluates body position and movement to identify posture and movement problems and provides feedback for corrective actions. Castillo [23] proposed the monitoring of emotional conditions for the elderly. A series of sensors detect the elderly's face, gestures, expressions, and behaviors, and to assist the relevant physiological data to judge the elderly's emotions comprehensively. It also combines with music, color, and light to adjust the elderly's emotions to lead them to be positive and pleasant.

3 Settings

The course on experiential prototyping is committed to cultivate both innovative research and entrepreneurial talents. This course closely collaborates with both national and international innovation companies. It focuses on user, context, emotion, interaction, technology, and human factors, through practicing innovation design thinking. It promotes user experience research and explores how psychology, design, technology, and business could integrate together. The Co-making the Future China-US Young Maker Competition is an activity supporting the China-US high-level consultation on people-to-people social and cultural exchange. In the past spring semester, the research team mentored and worked with 50 student makers who worked in teams of 5 on design briefs concerning health and fitness, community development, education, energy, and transportation by combining innovative design and cutting-edge technologies. A total of 3 iterations of concept and prototype development were made. The first iteration focused on exploring conceptual possibilities and building initial prototypes. The second iteration aimed to nut-crack the hardest technological problems and further develop the concept to a mature level. The third iteration involved users and integrated user comments to finalize the prototypes.

4 HOLA HOOP

According to the research of the National Institutes of Health [14], post-80s and post-90s are struggling both working pressure and life pressure. Commonly, they are busy with work results in sub-health. Young people have health-conscious but lack healthy behaviors as well as initiative and self-management awareness, and they do not have enough motivation to encourage them to exercise regularly. Time and space limit traditional sports, and these sports cannot meet the needs of young people who want to maximize the use of fragmented time for exercise. HOLA HOOP is a smart wearable device designed for white-collar office workers who are often sedentary and have insufficient physical activity based on IoT technology. It breaks space constraints and achieves fragmented sports needs for young sedentary users, thereby improving sub-health status. Sensors connected to open-source hardware obtain data of user actions, the control code to achieve interaction. The shell is a detachable clasp structure for product modularization. The hardware configuration includes the MPU6050 six-axis sensor with built-in three-axis acceleration and three-axis angular velocity device. By combining with the Kalman filter, HOLA HOOP analyzes Euler Angle and quaternions. Arduino and IO expansion board accepts a six-axis signal from the sensor, and the signal is parsed, four relay control switches are closed. Relay switch closure controls the vibration of the motor. When receiving the MCU signal after coming from low level to high level, normally open switch into a normally closed switch, to form pathways with battery, motor vibration, form the whole workflow.

A usage scenario is as follows: Jiang is a programmer working at an Internet company and often works overtime, so he has no sufficient time to exercise. Jiang's body appeared sub-healthy status gradually. Jiang tried to exercise with various kinds of independent fitness in his free time, but he could not control the exercise time either find friends to exercise together. So, he gave up exercising alone. Until one day, a new programmer colleague recommended him HOLA HOOP. In a weekend, Jiang downloads the HOLA HOOP mobile application, adjusts, and wears HOLA HOOP, according to his figure. Following the instructions of the app, he chooses a song he likes and starts the 'rhythmic' fitness mode to play somatosensory interactive games. During the game, Jiang feels a real hula hoop feedback according to different vibration on it. After completing a game, Jiang finds that he could upload custom rhythm and be able to share it with social media and invite others to challenge him, which makes him feel passionate. Jiang launches a challenge to play a somatosensory game with his friends. After the game, he is pleasantly surprised that HOLA HOOP could collect his body and movement data through the game, generating a personalized training plan intelligently to help him improve his health status. Jiang and his programmer friends have begun to use HOLA HOOP for sports.

5 Meng Meng

Meng Meng is an interactive toy for children accompany diagnosis and treatment, which assists during the process of children's medical treatment. The shape of the bear gives the users a great feeling, which increases the sense of security and shortens the distance between them. Wearing a nurse hat shows the warm spirit of selfless dedication. The color design uses white and pink, and white represents the angel in white, pure and selfless, pink gives the child a warm feeling, makes the child relaxed, and is willing to collaborate with the waiting diagnosis. This study focuses on children between the ages of 5 and 8 who go to the hospital. Because of the fear of doctors, making they have a strange feeling about the hospital environment. Because of the psychological factors of anxiety and fear, children prefer crying and making noises before going to the hospital, which seriously affects the efficiency of doctors and hospital order. It is efficient that establishing a good trust relationship between children and doctors when checking physical status, and it achieve smooth communication and information synchronization between parents and doctors.

A usage scenario is as follows: Huahua is a five-year-old child. One day, she is sick. Her mother wants to take her to the hospital. Because she has an impression of fear when she went to the hospital last time, she is crying all the time. When they arrive at the hospital lobby, her mother rents a Meng Meng robot. The robot is lovely, which makes her curious and feel safe. After Mother turns on the robot following the user's Guide, the robot introduces itself to everyone and tells Huahua a story which brings her into the story scenario and reduces her fear and discomfort in the hospital. Following the voice command in the story scenario. She puts her head on the robot's head to take temperature measurement to detect heartbeat rate and blood oxygen saturation. After the physical examination, Meng Meng encourages Huahua to enhances self-confidence and reduces the fear of the hospital. At the same time, the detection data are sent to the terminal of doctors and parents for information synchronization. Finally, Huahua comes to the clinic. The doctor encourages her behavior and begins to diagnose. After the treatment, she feels better and overcomes fear of the hospital.

6 Magic Cube

There are a large number of the elderly in China who need to take medical treatment, especially using prescription medications for a long time because of their chronic diseases, and the diverse types of medications. In 2015, the World Health Organization (WHO) statistics showed that one-seventh older adults worldwide died of unreasonable medication. With the increase of age, the elderly often need to take medications, even multiple medications. They prefer to go to the pharmacy to buy medicines and take medicines based on their own experience rather than consult a doctor for a diagnosis. Magic Cube is a smart composable medicine bottle with a smart voice assistant. It contains four parts: 1) communication module, 2) receiver, 3) mobile application, 4) actuator. Medication behavior data is recorded and then transit to the smartphone and to the cloud through wireless technology to live an intelligent life.

A usage scenario is as follows: Lily, who retired at the age of 55, lives alone and suffers from hypertension and diabetes. She needs to take medicine every day to stabilize her condition. At 11am, Magic Cube sends out a voice reminder to Lily, 'Hey, Lily! It's time to take medicine!' At that time the phone is ringing. Lily prefers answering the phone, so she pats the Magic Cube and receives a voice response 'Magic Cube will remind you after ten minutes.' After a while, the device sends a voice reminder again, 'Hey, Lily! It is time to take medicine!'. With the help, Lily takes medicine regularly, fixedly and quantitatively every day, and chronic diseases such as hypertension and hyperglycemia are effectively controlled.

7 Conclusion and Future Perspectives

The multidisciplinary team researches the performance of existing similar products on the market, understands the needs of target users and other stakeholders and users' daily interaction behaviors. Collecting behavior and analyzing interview data to find new design possibilities. The teams use open-source hardware to implement the features of the concept system and test in the real environment several times and iterate the prototype continuously to create useful and easy-to-use products. In the future, multidisciplinary design innovation will be combined with cutting-edge technology and applied to more fields. In the course collaboration, students from different disciplines formed a multidisciplinary team and participated in Dolby, Google, and LEGO projects. Teams combined cutting-edge technologies such as AR and VR to make design innovations in e-sports, smart wearables, and factory experiences. Multidisciplinary design innovation will implement a human-centered user experience design method at the interpersonal level to help users solve real problems. It will also be applied to institutions that have high social responsibilities and have different stakeholders, such as government agencies, important transportation hubs, museums, etc. to help improve government office efficiency, transportation hub travel experience, museum user experience, and other social issues.

Acknowledgments. We would like to thank our teaching team, students, and the Fulbright Research Scholar Grant (ID: PS00284539).

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Diagnosis Techniques

The Value of the Medical Autopsy as a Quality Improvement Tool in Modern Diagnostic Medicine

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Abstract. The quality of healthcare is an emerging concern worldwide. In any health care process, adverse events resulting from errors are inevitable. The role of the medical autopsy is evolving yet it remains a cornerstone in the progress of healthcare quality and diagnostic medicine. Although the autopsy has been instrumental in understanding disease processes for the past 3000 years, there has been a concerning decrease in autopsy rates. This trend is influenced by barriers pertaining to resources, consent, and medicolegal hesitations. Reversing the trend in falling autopsy rates will require recognition of the role of the medical autopsy as an essential feedback mechanism in healthcare quality improvement. The autopsy has shaped the current state of medicine and with appropriate implementation, support, and collaboration will continue to guide the path forward.

Keywords: Autopsy · Quality improvement · Diagnostic accuracy · Post-mortem imaging · Medical education · Pathology

1 Introduction

The autopsy has been used as a diagnostic tool for more than 3000 years [1]. Today, autopsies continue to play an essential role in understanding disease and improving the diagnostic process. The medical autopsy is widely regarded as the gold standard in identifying pathologies and identifying cause of death. By providing a gold standard of cause of death to compare clinical diagnoses to [2], autopsies have allowed for the measurement of medical error as well as the monitoring of changes over time [3]. However, the rate of autopsies continues to decline, from approximately 60% in the 1960s to less than 10% in the past decade [4]. For example, some institutions have recently experienced as much as a 30% decrease in autopsy rates within a 5-year period [5]. This established quality assurance tool will bring to light diagnostic discrepancies

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 77–82, 2020.
https://doi.org/10.1007/978-3-030-50838-8_11

and will play an important role in contributing to new clinical knowledge, medical education, and quality assurance programs [6].

2 Barriers and Challenges

Barriers exist to conducting medical autopsies. The cost of an autopsy has been found to range between $1250–$2500 USD per autopsy [7, 8]. It has been found that approximately 10% of administrators felt that autopsy is unimportant important [9]. There is often a reluctance on the part of the relatives to request and consent to medical autopsies [10]. Barriers that have contributed to the decline in autopsy rates include limited financial resources, medicolegal hesitations, and workforce shortages [9] as well as lack of minimum autopsy rate requirements for hospital accreditation, and limited exposure to autopsies for medical trainees [4].

There are numerous requirements to make autopsy a valid quality monitor. These include sufficiently high autopsy rates, and thorough autopsy procedures [11]. The gradual decrease of medical autopsy rates in North America and across the globe has been described as a tremendous missed opportunity to gain understanding into how to reduce deaths attributable to medical errors [12]. Reversing the trend in falling autopsy rates will require recognition of the role of autopsy in quality improvement, support from governing bodies, and provision of information to families and the communities.

3 Imaging Techniques

In the present landscape of healthcare, imaging studies cannot yet reliably replace the medical autopsy [13] but may be an appropriate adjunct in certain circumstances. However, concerns have been raised regarding over-reliance and blind trust in imaging techniques as well as the premature movement to implement these modalities as a substitute for autopsies [5, 14]. Post-mortem computerized tomography (CT) scans have certain advantages over autopsies in recognizing fractures and free gas. Post mortem magnetic resonance imaging (MRI) and CT scans have been found to be more advantageous in detecting pneumomediastinum, pneumopericardium and pericardial effusions than traditional autopsies [15]. Post-mortem CT scans have also found to be a supplement to forensic autopsies cases of lethal lesions in craniofacial trauma or gunshots as well as skeletal lesion [16] but perform poorly in detecting organ damage [14]. Autopsy remain superior in the detection of diaphragm injuries, heart lesions and hemomediastinum [15]. A meta-analysis of 118 articles concluded that post-mortem CT and MRI studies have not yet reached consistently high enough performance quality standards to provide a meaningful supplement to the clinical autopsy [17].

The decision to use autopsy or imaging modalities should take into consideration if the death was of natural causes, if autopsy is appropriate in the given circumstances of the case, and if the finding will be used in a meaningful way. It is also important to consider if the cause of death is of acceptable standard and certainty to inform health-care planning [18]. Despite advancements in CT and MRI imaging, these modalities cannot yet provide the level of detail or quality required to serve as an alternative for the medical autopsy. There is approximately a 30% discrepancy rate between imaging and the gold standard autopsy [19]. When used appropriately, autopsies can provide insights into the accuracy and limitations of imaging modalities [20] and together these tools can guide the improvement of healthcare quality.

4 Education

Low rates of autopsy create a potential for selection bias and overconfidence in diagnostic accuracy. Autopsies tend to be ordered for clinically challenging cases [21] and cases of diagnostic uncertainty [3]. However, findings by Cameron *et al.* suggest that clinician certainty in the diagnosis and clinical judgement of the need for autopsy and had little influence on the rate of discrepancies [10]. More specifically, among cases where the clinician felt certain of the diagnosis the discrepancy rate was 12%, compared to the rate of 15% for all levels of certainty. Among cases where the clinician would normally have ordered an autopsy the discrepancy rate was 15% whereas among cases, compared to 14% among cases for which an autopsy would not have been [10]. In this way autopsies serve as an essential quality measurement and feedback tool that allows for the calibration of diagnostic processes [22].

The medical autopsy guides improvements in new diagnostic technology [12] and is an important tool in education and research [6]. It remains an important quality management tool that allows us to better understand the challenges in interpreting clinical signs and investigations [20]. The widespread decline in autopsy rates suggests a ubiquitous underestimation of the value of the medical autopsy as a feedback mechanism and educational tool to reducing diagnostic error [10]. The underutilization of a gold standard of diagnosis represents missed opportunities to reflect as a medical profession and to measure changes in medical error over time.

5 Contribution to Quality Improvement

The medical autopsy has four key contributions to quality improvement. These include education, advancing understanding of disease¸ improving safety through detecting infectious diseases and allowing for comparisons between clinical and autopsy diagnoses [9] ¸ and providing closure for both physicians and bereaved relatives [5]. From an epidemiological perspective, post-mortem examinations provide more accurate disease mortality data and can detect emerging and infectious diseases. Post-mortem examinations continue to play an important role in major role in detecting missed infectious diseases and provide insights into the sensitivity and specificity of clinical means of detecting diseases such as TB, endocarditis, bronchopneumonia [23].

Autopsy reports continue to serve as an invaluable source of data for the assessment of the current state of diagnostic medicine. Comparisons between clinical diagnoses and autopsy findings allow us to measure rates of medical error and identify areas in which healthcare can be improved. For example, our preliminary results show that across a 5-year period (2006–2011), the autopsy rate in the Saskatoon Health Region was 6.0% [4]. There was an overall discordance rate of 15% between clinical and autopsy diagnoses and in 10.2% of cases, knowledge of the diagnosis pre-mortem would have changed treatment to prolong disease or cure disease. These findings are well aligned with previous findings on medical error. Meta analyses have shown that between 45% and 76.5% of autopsies reveal at least one unexpected finding by Roulson *et al.* [24] and that in approximately 40% of cases the unexpected finding contributed to the death of the patient [25].

Lower autopsy rates are associated with higher rates of diagnostic errors. More specifically, for every 10% increase in autopsy rates was associated with a 12.4% decrease in major medical errors [3]. It has been suggested that if autopsies were performed on all deceased patients, then the missed major diagnoses rate would be as little as 4% [12]. This illustrates the important educational value of autopsy examinations in progressing medical diagnostics [21].

6 Communication and Collaboration

Collaboration is an essential component of the appropriate utilization of autopsies as a quality improvement tool. The appropriate implementation of autopsies relies on effective communication and knowledge dissemination of post-mortem findings. However, a lack of communication and information exchange between clinicians and pathologists has been found to be prevalent in healthcare today [5, 6]. The median rate of autopsy requests which have a specific question was 72.7% [26]. In almost 50% of cases, clinicians were never informed of the results of the autopsy [6]. Strengthening consultation between clinicians and pathologist before and after the procedure will ensure that clinical context is provided and that lessons learned from the autopsy contribute to the improvement in quality of healthcare.

Lower autopsy rates have subsequently been associated with higher rates of diagnostic errors. This area of work contributes to the field of diagnostic medicine by enhancing accuracy, knowledge of disease [21, 24] and providing more accurate epidemiological mortality data [27]. The medical autopsy is a necessary quality assurance tool in clinical and pathology practice [5, 28]. Through education, communication, collaboration and health advocacy the value of the medical autopsy can be recognized and properly utilized to advance our understanding of the practice of medicine as it has done for the past 3000 years.

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Modeling and Simulation of the Human Rye and Its Correlation Between Increased Intraocular Pressure and the Thickness of the Cornea

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Abstract. This work consists in the mathematical analysis, to establish a correlation between the increase of the intraocular pressure and the central thickness of the cornea, our database was acquired from both sick and healthy patients of the "Santa Lucia" clinic from the city of Quito, which complied with some rules of inclusion and exclusion that are presented later, this database was segmented based on false positives and false negatives, this was done to handle our data in a reduced way. After applying different types of interpolation, we obtained an equation that relates both to the intraocular pressure and the central thickness of the cornea, then analyzed the behavior of the equation against different types of data, both sick people and healthy people. The results obtained were encouraging, since with the identification of glaucoma at an early stage, the number of people who can lose their sight permanently will be reduced.

Keywords: Intraocular pressure · Central thickness of the cornea · Human eye modeling · Mathematical correlation

1 Introduction

Glaucoma affects 65 million people in the world. It is called primary open angle glaucoma (POAG) to the optic neuropathy that occurs in the absence of ocular or systemic disorders that cause increase in resistance to aqueous flow or damage to the optic nerve, usually associated with intraocular pressure (IOP) high [1, 2].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 83–90, 2020.
https://doi.org/10.1007/978-3-030-50838-8_12

The thick or thin corneas induce an estimate of erroneous pressure reading, so, the measurement of the PIO seeks to obtain a value as close to a true value, for which, the use of the Goldmann Tonometer applanation is most effective [1, 3].

According to the Organization of American States, the three countries with a higher rate of disability in America are Peru with 18.5%, the US with 15%, and Ecuador with 12.8% [4]. Despite the fact that there is the prevention of various disabilities, there is a limited number of investigations, there are silent diseases such as Glaucoma, where only investigating treatments for this do not move forward and stabilizes.

Ecuador is a developing country; therefore, there is the availability of methods for early detection of the disease, the same as if not treated in time cause irreparable damage to the vision.

2 Methodology

2.1 Anatomy, Histology and Corneal Physiology

The functioning of the eye is due to the fact that the rays of light that we constantly receive affect, through the lens of the eye in the retina at the back of the eye; there the light rays are converted into impulses that travel through the optic nerve to the brain's cortex related to vision, creating the images we see [5].

The shape of the cornea is oval, with a horizontal diameter of about 12 mm and 11.5 mm vertical. The physical integrity of the functions of the epithelium and endothelium remain unscathed corneal property be a transparent tissue, thus fulfilling the important role refractive surgery that possesses. The anatomy of the cornea, together with the optical properties, determines its high dioptric power [6].

The corneal periphery is more flat and thick that the central area. The dioptric power total of the cornea is between 42 and 42.5 diopters, approximately 70% of the optical system of the eye [7]. The average corneal thickness in the vertex is of 550 µm, although the confidence interval with a 95% of this measure can be between 485–610 µm. This thickness increases as we move away from the apex toward the periphery, reaching the 700–800 µm in the region adjacent to the limbo [8–10].

2.2 Relationship Between Glaucoma and the Thickness of the Cornea

The central thickness of the cornea, GCC, is one of predictive factors in the possible progression of glaucoma. It is known that the GCC can affect the action of the IOP, as the thinner corneas leads to an underestimation of the values, while still controversial whether the effect of such thickness in glaucoma is due to their direct action in making erroneous measurements type tension headaches with the different tonometers [11–13].

Has ensured that the GCC varies between the different subtypes of glaucoma and among different groups of risk of glaucoma, especially in older individuals, but it remains unknown whether differences in the GCC explained in its entirety the increased tendency to suffer from glaucoma [14–16].

To determine the GCC, there are different methodologies, especially used the ultrasonic pachymetry, which consists of a biometric meter with a built-in microprocessor, based on the issuing of an ultrasound beam through a transducer that is placed in contact with the corneal surface and thus determines the corneal thickness [17, 18].

Part of this beam is reflected at the interface corneal endothelium aqueous humor and returns to the transducer. By measuring the length of time invested in this route and making it away under the speed of sound, through the corneal tissue, 1630 m/s, can get an accurate measurement of corneal thickness [19].

2.3 Inclusion-Exclusion Criteria in Patients

The study population in this work comprised 119 patients, 97 patients affected by GPAA (different cases) and 22 healthy individuals (controls) both at the systemic level as the eye. The data of patients were obtained from the Clinic "Santa Lucia" in the city of Quito, which are used for the mathematical characterization required.

The patients underwent a complete eye examination, including registration of the best corrected visual acuity, as well as the IOP was measured using TAG, TCD and tonometer. To be included in the study, healthy people must fulfill a number of criteria among which are:

- Minimum age of 18 years of age.
- Best corrected visual acuity of at least 20/25 according to the scale of Snellen's chart.
- Biomicroscopy, fundoscopy and normal perimetry, iridocorneal angle automatically open and normal.
- A value of IOP not exceeding 20 mmHg, independently of the perimeter normality, if was made.

They were used as exclusion criteria those subjects with:

- Spherical equivalent greater than 5 diopters and/or astigmatism greater than 3 diopters.
- Any opacity that could alter the corneal surface and prevent the correct visualization of the CNO.
- All subjects with some kind of pathology in a systematic manner or with alterations in the automated perimetry due to other diseases or disorders of the central nervous system.
- Any type of refractive eye surgery or in the patient that could affect the central corneal thickness

GPAA patients that are considered with glaucomatous eyes are included if:

- Have abnormal results, reproducible and consistent with glaucomatous injury.
- There is evidence of glaucomatous damage to the optic nerve head. Have open angles in the gonioscopy.
- For the control of their pathology may be under hypotensor therapy.

They were excluded from the group of participants with GPAA:

- Patients with another type of glaucoma.

- Patients with morphological alterations of the pupil

3 Development and Results

The parameters for the analysis of condition of glaucoma are an increase in intraocular pressure, opening angle and the value of the central thickness of the cornea, in such a way that the mathematical modeling correlated especially the IOP with the CCT.

The data of the IOP used, are those that exceed the 20 mmHg. However, when the value of CCT exceeds 500 μm, are also considered in the analysis, despite the fact that the value of the PIO is lower than the value indicated above. In Fig. 1, shows the relationship between the values of CCT-IOP, useful for the approach of the mathematical model.

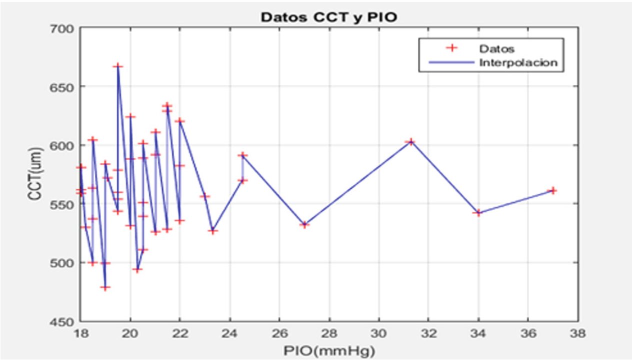


Fig. 1. Relationship between CCT-IOP.

The LaGrange interpolation presents better results of optimization in the final equation in MATLAB®, where the values of CCT correspond to f(x) and IOP correspond to f(y) Eq. (1).

For the analysis of results was performed a diagnostic test of sensitivity and specificity, in order to determine the presence or absence of a pathology that has a population in general. To perform the analysis of results are used data from 97 people who are sick and 21 healthy people, data that meet the inclusion and exclusion criteria listed above, Table 1 and Table 2.

Table 1. Polynomial interpolant response respect to the state of health.

State of health	Positive (+)	Negative (−)	Total
Glaucoma	69	28	97
Healed	18	3	21

Table 2. Sensitivity and Specificity of the equation.

Sensitivity	P (+) Sick	0.71134021
Specificity	P (−) Healed	0.14285714
False (−)	P (−) Sick	0.28865979
False (+)	P (+) Healed	0.85714286

Figure 2, shows the operating characteristic curve of the receiver, ROC, is visible that the results of the Eq. (1) are acceptable, in that it is closer to the sensitivity to the specificity, in such a way that checks that people who have glaucoma also have problems with the thickness of the cornea.

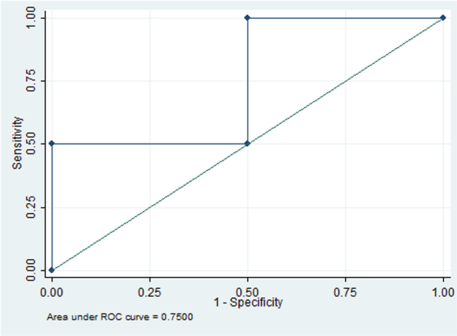


Fig. 2. Curve R.O.C.

The graphical interface is developed in Python, enter da-ta of the central thickness of the cornea (CCT), and delivers an approximate value of intraocular pressure (IOP), if the value calculated is within the parameters established medical is an indication of “Suspect of Glaucoma” (“Sospecha de Glaucoma”), in the equation will show the point of intersection; otherwise displays a value of IOP equal to zero and a message with the phrase “No Glaucoma suspect”, (“No sospecha de glaucoma”) Fig. 3.

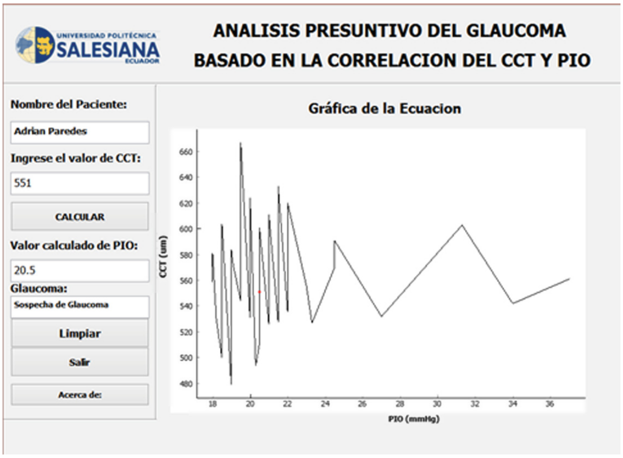
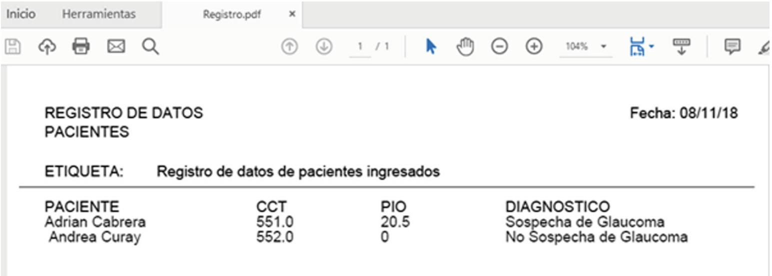


Fig. 3. Patient with suspect of glaucoma.

$$
\begin{aligned}
3.15479878264514e - 56 * x * *42 + 7.4705202727023e - 52 * x * *41 \\
&- 8.63332669883833e - 48 * x * *40 \\
&+ 6.48834545770548e - 44 * x * *39 \\
&- 3.56532589633583e - 40 * x * *38 \\
&+ 1.52692284321206e - 36 * x * *37 \\
&- 5.30536732082227e - 33 * x * *36 \\
&+ 1.53713300476697e - 29 * x * *35 \\
&- 3.78812831783496e - 26 * x * *34 \\
&+ 8.06009060349951e - 23 * x * *33 - 1.4978777338621e \\
&- 19 * x * *32 + 2.45357780848572e - 16 * x * *31 \\
&- 3.56853649757748e - 13 * x * *30 \\
&+ 4.63576695936076e - 10 * x * *29 \\
&- 5.40491421282392e - 7 * x * *28 \\
&+ 0.000567801488860989 * x * *27 - 0.539169063458936 \\
&* x * *26 + 463.957030338561 * x * *25 \\
&- 362507.792478894 * x * *24 + 257567337.194311 * x* \\
&* 23 - 166589701103.764 * x * *22 + 98141971207623.4 \\
&* x * *21 - 5.26742491803109e + 16 * x * *20 \\
&+ 2.57508280284071e + 19 * x * *19 \\
&- 1.14595605494747e + 22 * x * *18 \\
&+ 4.63744300832026e + 24 * x * *17 \\
&- 1.70402515431951e + 27 * x * *16 \\
&+ 5.67411033935181e + 29 * x * *15 \\
&- 1.70781283195647e + 32 * x * *14 \\
&+ 4.63151723485256e + 34 * x * *13 \\
&- 1.12730662159973e + 37 * x * *12 \\
&+ 2.45076676377337e + 39 * x * *11 \\
&- 4.73073640683569e + 41 * x * *10 \\
&+ 8.04901161445099e + 43 * x * *9 - 1.19612774691481e \\
&+ 46 * x * *8 + 1.53466854689676e + 48 * x * *7 \\
&- 1.67482283435245e + 50 * x * *6 + 1.52412570866962e \\
&+ 52 * x * *5 - 1.12526088366647e + 54 * x * *4 \\
&+ 6.4749774107713e + 55 * x * *3 - 2.72416109111307e \\
&+ 57 * x * *2 + 7.45342335828059e + 58 \\
&* -9.95238006506451e +
\end{aligned}
\tag{1}
$$

The software creates a PDF file with the data entered in the interface and the calculated value, in such a way to carry out an order of each patient, as shown in Fig. 4.



REGISTRO DE DATOS
PACIENTES

Fecha: 08/11/18

ETIQUETA: Registro de datos de pacientes ingresados

PACIENTE	CCT	PIO	DIAGNOSTICO
Adrian Cabrera	551.0	20.5	Sospecha de Glaucoma
Andrea Curay	552.0	0	No Sospecha de Glaucoma

Fig. 4. Results of the proposed program for the correlation between CCT-IOP for detection of glaucoma.

4 Conclusions

Glaucoma is one of the most dangerous diseases, since they are silent and do not show any kind of symptoms this can progress slowly to cause blindness in an irreversible manner, that is why, people have some type of vision difficulties should be carried out different types of evaluations to determine what the problem is and to be diagnosed, proceed to the treatment.

With this tool, is intended to give the possibility to doctors to know the thickness of the cornea, or perform a medical follow-up with respect to the thickness of the cornea, in turn if glaucoma is or is not affecting the corneal thickness.

So far, the results are good, with response in some cases equal to the real and in other cases very close. It is noted that the number of patients with diagnosis of glaucoma affects all age groups, with a higher percentage in patients 54 years and older, this is an indicator of the importance of addressing this social problem.

With the polynomial interpolant applied to the database obtained from the clinic, determines the correlation between the thickness of the cornea and the increase of intraocular pressure. The identification of glaucoma at an early stage, will reduce the number of people who may lose their sight permanently.

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Identification and Prevention of Glaucoma Through Digital Processing of Biomedical Imaging by the Relationship Between Volume of Nerve Fibers and Intraocular Pressure

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Abstract. Glaucoma is the second leading cause of blindness worldwide and the first in an irreversible way, many of the studies and investigations are concentrated in methods of control and treatment, however, there are few studies carried out in the areas of prevention and early detection of glaucoma, so, in this research presents the effect of increased intraocular pressure in the optic nerve, especially in damage caused in the layer of nerve fibers and their impact with the visual field, To do this, you work with background images of human eye, obtained from the Clinic "Santa Lucia", digital image processing to characterize parameters that determine a presumptive diagnosis of glaucoma suspect, the results are presented to specialists for a medical diagnosis.

Keywords: Intraocular pressure · Glaucoma · Retinal fiber nerve · Optical coherence tomography · Image processing

1 Introduction

Currently, the glaucoma is the leading cause of blindness in an irreversible manner and the second leading cause of blind-ness in the world, because it is a disease that has no symptoms that may warn his presence, through the tonometry, main method applied at present, it is possible to obtain the value of the intraocular pressure, whose range is

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 91–98, 2020.
https://doi.org/10.1007/978-3-030-50838-8_13

considered normal, if they are between 10 and 20 mmHg, outside of this range, it is necessary to other types of tests to determine if the patient is suspect of having glaucoma [1–3].

The increase of intraocular pressure, affects the optic nerve, which in turn affects the retinal fiber nerve layer, generating the field of vision and visual acuity, which even can take up to 5 years for the functional damage becomes a structural damage in the human eye, that is to say, it could take up to 5 years that a definitive diagnosis, that is when, the medical specialist, what it does is to develop a treatment to avoid this disease progresses and continue harming the human eye [4, 5].

After the measurement of intraocular pressure with the tonometer, it is necessary to perform a gonioscopy that determines the drainage angle of aqueous humor through the trabecular meshwork and canal of Schlemm, subsequently, an important consideration is the retinal tomography (HTR) [5], in Ecuador, these tests can only be per-formed in specialized clinics that are supplied with the necessary equipment for the detection of this disease, the same ones that have costs little accessible to the majority of the Ecudorian population.

For the detection of glaucoma, for example, proposals have been put forward on the relationship cup-disc and the rule ISNT with very good results, however, the approach to the volume of nerve fibers, it is to a certain extent innovative, determine the damage suffered and its incidence in the field and visual acuity, requires attention, especially for the development of support tools for the specialist and that, in addition, reduce time detection as well as the cost of the tests to be performed [6, 7].

2 Methodology

Once detected glaucoma, it is the task of the specialist doctor to perform a program for the control and treatment of the disease; however, the problem is in the detection and even in the classification of type of glaucoma that can have a patient, for which, innvotive methods have been developed to identify and diagnose his presence.

Through the digital processing of medical images of the human eye, you can obtain the respective areas so as to determine the relationship cup-disc, by completing the analysis with the rule ISNT and in this way, deliver a diagnosis where determines if the patient has the disease or is healthy [8, 9], similarly, the damage to the optic nerve, affects the thickness of neuroretinal ring and the retinal fiber nerve layer, RFNL, once taken into account the wear due to the increase in intraocular pressure [10].

The focus of this research focuses on the retinal nerve fiber layer, in particular, the relationship of his volume that is affected by the increase of intraocular pressure, where, beside, it is important to consider the effect on the acuity and visual field, thickness of the cornea and the relationship cup-disc in conjunction with ISNT rule.

The retina is a thin layer formed by multiple layers, located in the back of the eye which is the front of the fibrous layer, useful for analyzing the RFNL. To be an extension of the central nervous system, CNS, the same that is connected to the brain via the optic nerve and allows the viewing of images that are projected from the cornea and lens [11]. Images used for the analysis of the retina are: the image of the fundus of the eye and the image of optical coherence tomography, OCT, circular sweep.

The image of the fundus of the eye, Fig. 1a, displays the posterior area of the retina of the human eye, besides the central area that corresponds to the fovea, the macula and the lighter area which is the optical disk and the blood vessels distributed by the retina. This type of image is used for medical diagnosis by means of the methods cup-disc and ISNT rule, based on the analysis of the optical disc [12].

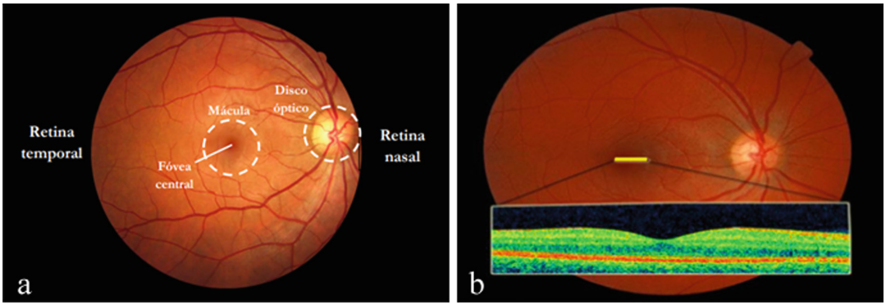

Fig. 1. a) Fundus of human eye [12], b) Composition of layers of the retina [12]

After the preliminary tests whose result is a glaucoma suspect, it is necessary to obtain the images of optical coherence Tomography, OCT, of the retina, where, there is no image characteristics of the fundus of the eye, if not observed in depth the composition of layers of the retina, Fig. 1b. That is to say, the image OCT focuses on a specific area of the retina in depth [11, 12].

Patients with glaucoma have visual field loss that occurs in different phases of the disease, this anomaly is affected to the anatomy of the retina and also to the axons of the ganglion cells on their way to the optic nerve, because the first flaw that suffers is a thinning of the nerve fibers (CFN) or also called diffuse loss [13].

The reduction of the thinning of the retinal nerve fiber layer thickness, occurs when the pattern is reduced, that is, the bottom of the eye presents a dark appearance because the light is not reflected, so it is necessary to an assessment of the blood vessels. If the analysis the nerve fiber layer cannot be appreciated, it is said to be caused by the following reasons [13]:

- The patient has an advanced decrease in nerve fibers.
- There is a turbidity of media.
- The fundus of the eye is little pigmentation.
- The “photo” is out of focus.

In the optical disk in the upper and lower poles the presence of RFNL, is more evident and voluminous, according to data standards in healthy people, the measures of the average thickness of the RFNL, is approximately 128.4 ± 15.4 μm, in the event that the person has early glaucoma, the value of the thickness decreases to 102.0 ± 25.4 μm, failing if the person already has the disease of glaucoma, this value drops to 86.5 ± 31.5 μm by standard [14]. Close to 20% of patients with glaucoma, the bundles of nerve fibers that have an aspect to silvery striations, with age become less visible, so, the lens also loses clarity. In the ischemic optic neuropathy, there is a difference in the RFNL, as the decrease of the same, can be diffuse or focal, in both cases the vision loss is inevitable [14, 15]. By the exposed, it is proposed the following methodology to determine if the patient is suspected of having glaucoma:

2.1 Images Acquisition

The images are obtained from patients after the examination of optical coherence tomography, OCT, in the clinic "Santa Lucia", these images correspond to the fundus of the eye and is distinguished the retinal nerve fiber layer as well as the layer of ganglion vessels of the retina, Fig. 2.

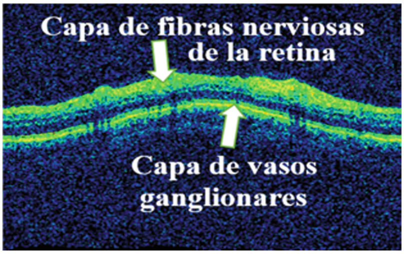

Fig. 2. Optical coherence tomography

2.2 Image Processing

Once the image obtained is suitable for processing, is carried out processes of conversion from RGB to HSV, Fig. 3a, and through morphological processes of erosion, dilation and filters, obtain the retinal nerve fiber layer, as well as the layer of ganglion vessels, Fig. 3b and Fig. 3c.

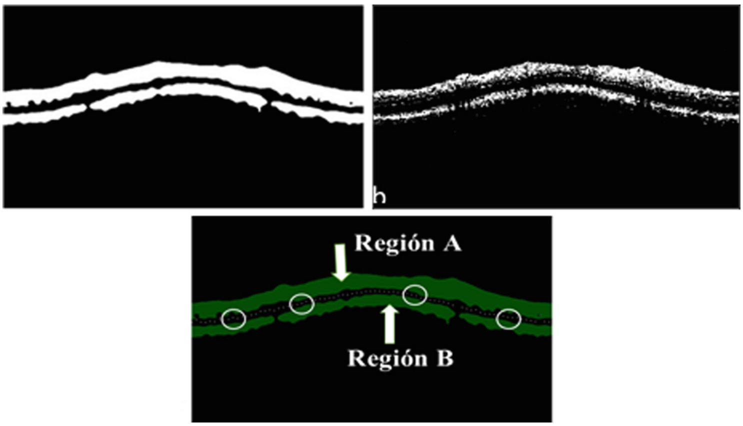

Fig. 3. a) Conversion from RGB to HSV, b) Filtered image OCT, c) Retinal fiber nerve layer, Region A and ganglion vessels layer, Region B

2.3 Analysis of the Thickness of the Nerve Fiver Layer

The best outcome for the calculation for the area of the Region, it was with the interpolation polynomial Newton in differences divided, in addition, the polynomial allows the separation of the two regions, Fig. 4.

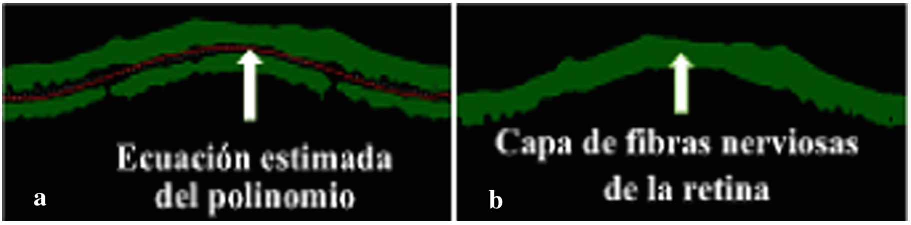

Fig. 4. a) The red line represents the interpolation polynomial Newton, b) Area of the retinal fiber nerve layer

Segmented the Region A, so that we can calculate his area, establishing benchmarks between the upper and lower limits, whose average distances we determine the size of thickness, obtaining as a result the presumptive diagnosis of the presence of glaucoma, i.e., the results can be healthy, patient with suspicion of glaucoma, with glaucoma, these results are compared with medical diagnosis as a check on the efficiency of the proposed software, Fig. 5.

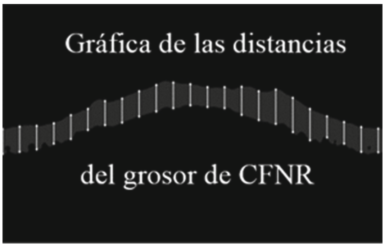

Fig. 5. Calculation of the area of the retinal fiber nerve layer

3 Development and Results

The proposed software, is used by same in the two eyes of 10 patients selected at random from a list of 78 in total, right eye (RE) and left eye (LE), each with its respective diagnosis: normal-healthy, with risk of glaucoma and diagnosed with glaucoma. Table 1.

Table 1. Database from clinic "Santa Lucía"

Patient	CFNR LE (μm)	Diagnosis "Sta Lucia" LE	CFNR RE (μm)	Diagnosis "Sta Lucia" RE	Gender	
					F	M
2	71	Suspect	52	Glaucoma		X
3	98	Normal	57	Glaucoma		X
9	84	Normal	84	Normal		X
14	64	Glaucoma	61	Glaucoma		X
15	92	Normal	92	Normal		X
33	56	Glaucoma	88	Normal	X	
34	74	Suspect	93	Normal		X
48	34	Glaucoma	53	Glaucoma		X
56	87	Normal	83	Normal		X
61	86	Normal	86	Normal	X	

With the ranges established by the images obtained by the OCT of the clinic "Santa Lucia", glaucoma is classified as follows: for the left eye (LE), patient with glaucoma between 37–68 μm, patient with suspected glaucoma between >68–75 μm and healthy patient between 76–109 μm, with total error of 2.32%, For the right eye (RE), patient with glaucoma between 52–65 μm, patient with suspected glaucoma between 67–74 μm and healthy patient between >74–109 μm, with total error of 4.11%.

The process of analysis is done individually for each eye, considering that, of 78 patients, for the left eye has a matching diagnosis in 65 eyes, while for the right eye is has a matching diagnosis in 60 eyes, this is considered as positive values, 13 and 18 patients represent the values of false negatives of left and right eye, respectively.

This procedure was applied to a total of 234 patients of the clinic, whose test results presented in Table 2 corresponding to the analysis of the left eye and in Table 3 that corresponds to the analysis of the right eye.

Table 2. Identification of Glaucoma through the method proposed in the left eye

True-positives	True-negatives	False positives	False negatives
65	150	6	13

The probability that an individual can regard it as if he was ill and that this is correct, it is known as sensitivity, while the specificity is the probability of prescribe in a precise manner that a subject is healthy, in the same way, it applies for each eye. In the Table 4 presents the results of the proposed method to determine the ratio of retinal fibers nerve as a tool of support for the specialist.

Table 3. Identification of Glaucoma through the method proposed in the right eye

True-positives	True-negatives	False positives	False negatives
60	145	11	18

Table 4. Results of identification of Glaucoma

Sensitivity LE	Specificity LE	Sensitivity RE	Specificity RE
83.33%	96.15%	76.92%	92.95%

4 Conclusions

Glaucoma is a silent disease and painless, which is why we don't have symptoms that may warn of their presence, the appropriate control could prevent the serious consequences of this disease.

The intraocular pressure measurement warns of an anomaly in the human eye, when it exceeds the average value of 20 mmHg it necessary to do other tests with more advanced methods such as the analysis of the relationship cup-disc, ISNT rule and the relationship of the volume of retinal nerve fibers, to determine if there is damage to the optic nerve.

With the identification of glaucoma at an early stage, will reduce the number of people who may lose their sight permanently. It was observed that the method of relationship of volume of nerve fibers presents a value of absolute error of 4.11%, compared with the method of cup-disc with a value of absolute error of 4.53% and ISNT rule with a value of absolute error of 14.61%, demonstrating that there is a better detection and serves as a tool of support for the prevention of glaucoma in initial stages.

With the digital processing of images of the fundus of the eye is possible innovative strategies such as support tools for the early detection and prevention of glaucoma, avoiding the patient arrives to have severe visual disability.

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Study of Corneal Biomechanics and Modeling of Young's Module in Healthy and Pathological Corneas

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Abstract. This work seeks to determine the modulus of elasticity of the cornea from corneal biomechanical parameters. Data was taken from the ophthalmological exams of 55 patients. All these patients have undergone some type of surgery or treatment. Of these patients, 70.37% are considered to have a healthy corneal structure and 24.07% have pathological corneas according to the biomechanical properties of the corneal structure. The calculation is performed and the results of the corneal elasticity module are presented for both healthy and pathological corneas before and after having over-come the disease after the surgical intervention. The tabulated results are truly important within the ophthalmological field because they serve as a tool to know the structural state of the corneal tissue of each patient. With this modeling it is intended that it is possible to diagnose eye diseases promptly and thus prevent difficulties in the patient's vision.

Keywords: Corneal biomechanics · Biomechanical parameters · Intraocular pressure · Elasticity modulus · Young's modulus

1 Introduction

Corneal biomechanics are very important because it is possible to analyze both the balance and the deformation of the cornea subjected to forces such as intraocular pressure (IOP) in the back and external forces such as atmospheric pressure [1–3].

Recent research has focused on developing techniques that allow measuring biomechanical properties without invading tissue and analyzing structural and molecular behavior in pathological and healthy corneas. The development of hand technology with ophthalmology has substantially improved the quality of life for those who have gradually lost their sense of sight. Procedures such as Lasik, Crosslinking etc. are now simple, little invasive and effective in correcting these vision errors [2, 4–6].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 99–105, 2020.
https://doi.org/10.1007/978-3-030-50838-8_14

However, there are cases when these procedures are unsuccessful, because the tissue conditions are not suitable for such procedures. It is why there is a lot of research on the biomechanics of the eye. This work focuses on studying the biomechanics together with the structural analysis of the forces exerted on the corneal tissue. It is vital to determine the Young's modulus (elasticity modulus) value that allows to know the condition under the cornea remains during the ophthalmologic review [3, 4].

Through the study of corneal biomechanics and its biomechanical parameters, support for the specialist's diagnosis can be provided based on previous examinations given that if the patient shows weakening of the lamellae in the corneal structure. Therefore, there is a decompensation of the parameters biomechanics that undergoes refractive surgery produces postoperative ectasia [7].

Consequently, the study of the biomechanics of the cornea as well as the modeling of Young's modulus, also known as the modulus of elasticity, are studied and considered crucial in the ophthalmological field. There are several works [8–11] where authors present their studies for this topic from different points of view using different methodologies.

2 Methodology

2.1 Corneal Biomechanics

Corneal biomechanics defined as science that studies the corneal tissue deformation in an equilibrium state when subjected to external action [8].

The field of corneal biomechanics is undoubtedly a wide range of possibilities for the analysis of: keratoplasties, intracorneal segments, refractive surgery, SMILE, cross-linking, among others; that demand the knowledge of the corneal structure from its architecture, the behavior of the tissue in both healthy and pathological corneas, with the aim of predicting the changes that occur in response to the treatment provided by the specialist [1, 6].

The study of corneal biomechanics is essential, especially in the area of refractive surgery, where new investigations of viscoelastic materials are carried out for the conservation of corneal tissue integrity [12].

Lesso R. et al., who performs a biomechanical analysis of the human cornea, where he uses a nonlinear behavioral material that resembles the cornea, a finite element model (FEM) has allowed him to observe the reaction of the material by varying different parameters such as the corneal radius, length, depth, thickness, etc., obtaining useful results applicable in myopia correction surgery [8].

Calderín B., et al., use FEM to determine the areas of greatest concentration of stresses that appear in the sclera due to their geometry, where scleral stiffness (Young's modulus) is also considered, concluding that this tissue manifests alterations when it occurs glaucoma due to abnormal intraocular pressure [9].

The research conducted by Shih PJ. et al., presents a biomechanical simulation of the concentration of stress and IOP in corneas undergoing refractive surgical procedures, where FEM is applied to determine the action of the corneal tissue under tension and flexion, in order to detect possible sensitive areas and other potential errors post-surgery [10, 11, 13].

2.2 Young's Module

The modeling of the corneal material involves several processes. In the first place it is necessary a simulation material that presents characteristics similar to the behavior and composition of the corneal tissue [14].

If there is not an established method to define the behavior of the human eye and its different elasticity characteristics in each part of the eyeball, researchers in the area have performed different modeling where different characteristics are considered according to their need [15, 16].

In this case it is necessary to perform the calculation of the corneal elasticity module as one of the fundamental parameters and, through bibliographic review [17, 18], several authors with different models have been reached as the basis of this work. The study presented previously [3] where different methods for calculating the modulus of elasticity of the corneal material are detailed, a database of 55 patients with different surgical procedures such as Lasik Relex SMILE[1] (S), Excimer FEMTO[2] (EF), Excimer MICROQUERATOMO[3] (EM), Ring Surgery (A), Crosslinking (C) and Glaucoma (G). The SMILE, FEMTO and MICROCHERATOMO procedures, the cornea is considered healthy before these surgical procedures. The geometry of the cornea does not present any type of anomaly and examinations are performed only before the surgical process. On the other hand, in the case of Rings and Crosslinking surgery the geometry of the cornea affects. Therefore, it presents altered factors, such as IOP and thinning in the central thickness of the cornea, causing keratoconus at different levels (acute, severe, chronic). In these cases, patients who have been undergoing surgery have a history before and after the intervention, then the database shows that there are patients who present presurgical and postsurgical values.

To obtain the force that is exerted on the surface of the cornea, the IOP is being considered, where through the equations of the tonometry principle and the Pascal principle for fluids. This tells us that fluids can be measured by means of the force exerted on the area unit in conditions where the diameter of incidence of the air jet on the cornea is between 2.5 mm to 4 mm that are considered normal [19, 20]. Then the force exerted on the cornea would be given by Eq. (1).

$$F = P * A \tag{1}$$

Where:

F is the Force applied to the cornea
P is the Pressure on the cornea IOP
A is the Air jet incidence area

The calculation of the force is necessary to obtain the value of the modulus of elasticity, since the values that are taken to solve this equation are obtained from the tests performed on the Oculus Corvis equipment.

[1] Lasik Relex SMILE: little-invasive technique used to correct diopters through the cornea [21].

[2] LASIK Technique: used to correct myopia [21].

[3] LASIK Technique: used to correct nearsightedness, farsightedness and astigmatism [21].

From the Hooke's law Eq. (2) the equation is conditioned according to the corneal geometry and considering for this case biomechanical factors such as: The IOP, the central thickness of the cornea, the diameter of elevation, CBI, the radius of anterior and posterior curvature with which the distance between the anterior and posterior aspect of the cornea is calculated, so that from this the Young's modulus can be obtained based on the Force.

$$F = -E * X \tag{2}$$

Where

F is the Force applied to the cornea
E is the modulus of elasticity
X is the function that shapes the cornea based on its geometry and biomechanical parameters.

Basing the calculations on the study carried out previously [3] and solving the function of the hand with medical specialists in the area and considering that the cornea of almost incomprehensible material is considered that the Poisson ratio has a constant value of 0.49, the Eq. (3).

$$E = 0.5P * (Ra^\wedge 2 - 0.49 * Ra)/(D * CCT) \tag{3}$$

Where:

P is the IOP
Ra is the Radius of anterior curvature
D is the difference between the anterior and posterior radius of curvature
CCT is the central thickness of the cornea.

3 Results Obtained from the Model

For the calculation of the force it is necessary to obtain the value of applied area of incidence that has resulted in 20.3575 mm^2, considering that the diameter of the air jet that is applied on the cornea is 3.6 mm, IOP and Area values are in Pa and mm^2, respectively and a value of 0.49 is considered for the Poisson ratio, (value without magnitude) indispensable for the Young's modulus calculation.

The force applied to the cornea is obtained. The values that are taken to solve this equation are extracted from the exams performed on the Oculus Corvis and Oculus Pentacam equipment, having as a result Table 1.

Table 1. Results of the *Force* applied on the corneal surface in OD and OI.

Status	Procedures	Age	Pre OD	Pre OI	Post OD	Post OI
Healthy	Excimer FEMTO	29	39,779	42,323	38,191	40,130
	Excimer MICRO	32	43,426	45,235	26,689	26,689
	SMILE	29	39,640	42,783	33,625	34,831
	Average	30	40,948	43,447	32,835	33,883
Pathological	RINGS	31	34,379	37,093	36,098	36,641
	CROSSLINKING	27	34,702	31,212	40,440	36,098
	Average	29	34,541	34,152	38,269	36,370
General average	GLAUCOMA	58	47,497	39,807	56,318	44,783
	With glaucoma	31	38,902	41,045	37,817	37,249
	Without glaucoma	31	38,676	40,951	37,155	37,125

While the values of the modulus of elasticity are presented in Table 2, these results are contrasted with others results obtained from previous studies presented by other authors-researchers of the mathematical model whose average value is 0.29 MPa, checking the validity of the model made.

Table 2. Results of the *Elasticity Module* for OD and OI.

Status	Procedures	Age	Pre OD	Pre OI	Post OD	Post OI
Healthy	Excimer FEMTO	29	0,338	0,365	0,321	0,340
	Excimer MICRO	32	0,367	0,376	0,328	0,324
	SMILE	29	0,368	0,393	0,326	0,345
	Average	30	0,358	0,378	0,325	0,336
Pathological	RINGS	31	0,279	0,293	0,272	0,203
	CROSSLINKING	27	0,299	0,315	0,397	0,309
	Average	29	0,289	0,304	0,335	0,256
General average	GLAUCOMA	58	0,592	0,47	0,76	0,556
	With glaucoma	31	0,353	0,368	0,358	0,338
	Without glaucoma	31	0,344	0,362	0,341	0,332

The results of both the applied force and Young's modulus are segmented by pathologies before and after the patient has undergone surgery. In the case of patients who have Glaucoma, they have values above 0.47 Mpa because in these cases the IOP rises markedly. However, this is not indicative to determine that the cornea is pathological as shown in the results.

4 Conclusions

Corneal biomechanics has a great impact on the research area because through this study, support can be given to the medical specialist, new ways are studied every day to improve the quality of life, so the modeling of the modulus of elasticity plays an important role in ophthalmological studies since with this parameter you can analyze the structural condition where you find the cornea.

The results obtained indicate that the proposed model is correct. After the extensive study presented, the Elasticity Module of approximately 110 corneas has been calculated. These parameters have been obtained from a database made with information extracted from 55 patients examined at the “Santa Lucia” clinic in the city of Quito, resulting in values between 0.32 MPa and 0.37 MPa in eyes with healthy corneas. While for pathological corneas, the values are between 0.25 MPa and 0.33 MPa, ranges very close to a Young Module with an average value of 0.29 MPa from work done by other researchers.

Care should be taken in the interpretation of results according to the presented pathology since in the case of glaucoma eyes it presents high values of Young’s modulus (0.47 MPa to 0.76 MPa) although its geometry is not structurally affected. However, this demonstrates that the study of both corneal biomechanics and that of the young module are of great importance in determining different pathology and the state of the pathology development that the patient presents.

5 Future Work

As a next step, we seek to create the geometric model of the cornea. The Neo-Hookean material has been selected and its characteristics are adjusted to those of the cornea of the parameters already mentioned (Young’s modulus, Poisson’s ratio, density). The shape of the material is defined by the corneal geometry obtained by tomography, resulting in a greater similarity of geometry and characteristics of a cornea to perform the simulation.

Finally, it is proposed to perform the simulation of corneal biomechanics by applying a pressure similar to that exerted by the air jet of the tonometer to obtain maps of the distribution of pressure and tension exerted on the surface of the cornea. This way they can analyze the areas of fragility in the corneal tissue.

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The Influence of Ergonomics of Human-Machine Systems on the Emergence and Development of Cognitive Function Disorders

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Abstract. The aim of the work is to obtain mathematical models for predicting and early diagnosis of cognitive disorders of operators of human-machine systems, provoked by prolonged psycho-emotional stress and chronic fatigue arising from ergonomic risk factors. The work uses technical means of monitoring the state of various components of such cognitive functions as attention, memory, thinking and energy characteristics of biologically active points “associated” with the studied cognitive functions. As a basic mathematical apparatus, the synthesis methodology of hybrid fuzzy decision rules is used. In the course of the research, mathematical models were obtained for predicting and early diagnosis of impaired attention and memory functions associated with the professional activities of operators of human-machine systems. During mathematical modeling, expert assessment and statistical tests, it was found that the confidence in the correct decision-making using the obtained mathematical models exceeds 0.85.

Keywords: Human-machine systems · Cognitive function disorders · Decision-making · Psycho-emotional stress

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 106–114, 2020.
https://doi.org/10.1007/978-3-030-50838-8_15

1 Introduction

The world is widely conducting research related to the study of the impact of ergonomics of human-machine systems on the functional state and state of human health [1–8].

It is known that miscalculations of designers in the ergonomics of human-machine systems led to the appearance and development of socially significant diseases, including the human cognitive sphere [1–6, 9–17].

Violation of cognitive functions leads to a decrease in memory, mental abilities and other cognitive functions compared with the initial level (individual norm).

Light cognitive impairment (LCI) for most people is not critical, except for a number of professions that have special requirements for attention, memory, thinking, etc. Under certain circumstances, mild cognitive impairment leads to a stage of mild cognitive impairment (MCI), which includes impairment intellectually-mnestic functions of various modality, not reaching the degree of dementia (acquired dementia).

The main risk factors for the appearance and development of cognitive impairment during human contact with technological systems are stresses, a high level of psychoemotional impairment and chronic fatigue, accompanied by intensive switching of attention, impaired memory, impaired mental activity, etc.

Thus, the technical means of man-machine systems negatively affecting the cognitive functions of a person, on the one hand, reduce the reliability and quality of their work, and on the other hand, can lead to persistent disorders of cognitive functions from the mild stage to the development of dementia.

Researchers involved in the assessment and rehabilitation of cognitive functions note that one of the urgent tasks of modern psychology, psychophysiology, neurology, engineering psychology, psychiatry and other related sciences is forecasting, timely identification, and accurate classification of cognitive function states, which will ensure adequate correction prevention and treatment of emerging disorders.

Modern psychology, psychiatry and neurology use a fairly wide variety of methods and means to solve the problems of evaluating various cognitive functions and their properties, which are technically performed both as independent devices and programs, and as part of sufficiently powerful computer complexes for cognitive rehabilitation (Creha Com, Cogni Plus, a complex for studying the features of attention and memory (CSFAM), etc.) [13, 15, 16, 18–20].

A significant number of known software and hardware systems and complexes for assessing the state of cognitive functions use the test subject's response to symbolic, digital, sound and mixed test tasks with a function to assess the reaction and the number of errors by which the norm and deviations from the norm of the studied psychological function or its components are judged. An analysis of the known methods and means of assessing the state of cognitive functions showed that, solving their specific problems, they are not focused on solving the problems of forecasting and early diagnosis of cognitive functions with the accuracy required for practical applications.

The level of a person's functional reserve is determined by number of different indicators such as power imbalance of meridian structures, psycho-emotional tension, intellectual and physical exhaustion, parameters of pulse and arterial pressure at the impact of the dosed intellectual and physical activities on the base of heterogeneous fuzzy models usage [63]. The evaluation of risk of cardiovascular diseases in persons at various functional states using monitoring stress indicators and developing fuzzy logic model [62]. The study shows that the used indicators don't give sufficient accuracy for practical purposes because they don't take into account the impact of ergonomics on the functional status, the health of the people status, and the used technical systems owing to the fuzzy and latent (hidden) nature of the links between them. A method of synthesis of hybrid fuzzy decision rules groups is proposed for the analysis of the data structure by specially developed algorithm exploratory analysis based on fuzzy application. Mathematical modelling and software showed that the confidence in the decisions made by the selected class of problems exceeds the level of 0.85. This allows recommending the use of the obtained results in clinical practice [17].

2 Research Methods

An analysis of the data structure used in psychodiagnostics to assess the state of cognitive functions, including prognosis and early diagnosis, showed that the problems solved in the work belong to the class of poorly formalized tasks with fuzzy defined boundaries of different states of the studied [2–4, 10, 12, 13, 17, 21–25].

The experience in solving problems with a similar data structure obtained at the Department of Biomedical Engineering of Southwestern State University (Russian Federation) showed that to solve the selected class of problems it is advisable to use the methodology for the synthesis of hybrid fuzzy decision rules (MSHFD) described in sufficient detail in the works [9, 10, 12, 13, 24, 26–44].

One of the basic elements of hybrid fuzzy decision rules is the membership function of the studied classes of states $\mu_{\ell}(Y_S)$.

In accordance with the general recommendations of MSHFD, two classes are selected in forecasting problems:

ω0- the subject for a given time T0 will not have cognitive impairment by the function being studied or its properties with identifier S, which are determined on a scale YS;

ωP - after a specified time T0, the subject will have a violation of cognitive functions (properties) defined by the identifier S (S - attention switchability, selectivity of attention, …, memory, …, mobility of thinking, …). For the tasks of early diagnosis, expert psychologists have identified four classes of conditions ω_{ℓ} – (ℓ = n (norm), ℓ = l (light cognitive impairment), ℓ = m (mild cognitive impairment), ℓ = c (initial clinical stage)).

For the applications studied in the work, the MSHFD is modified in the following sequence of actions:

1. Under the guidance of a cognitive scientist with experience in the synthesis of hybrid fuzzy decision rules, a group of experts is formed with competencies in the selected class of cognitive functions and their properties. Their training is being organized in the field of synthesis of hybrid fuzzy decision rules and reflexology. The quantitative composition of the expert group is determined by the requirements

adopted in qualimetry, and their qualitative composition is adjusted taking into account the concordance coefficient calculated on the test tasks.

2. Taking into account medical-technical and technological limitations, methods and means of clinical evaluation of the analyzed cognitive functions and their properties are selected. The informative value of indicators determining the studied cognitive functions and their properties is determined and a list of informative signs (indicators) is selected YS. Based on the recommendations of the MSHFD for the selected state classes, experts construct the corresponding membership functions using the Delphi method $\mu_\ell(Y_S)$.
3. The mechanisms of determining the belonging of the subject to the studied classes of states are determined in addition to $\mu_\ell(Y_S)$ describing the current state of the studied cognitive functions and their properties: correction normalizing functions of time $f_{es}(t)$, taking into account the time deviation YS from their nominal values for the observation period; average values $Y_{S\ell}$ for the observation period; correction factors $K_{\ell S}$ that take into account various conditions that contribute to the emergence and development of cognitive disorders.
4. Taking into account the recommendations of the MSHFD [28, 45], the obtained components are aggregated into private decision rules for assessing confidence in the subject's belonging to classes ω_ℓ:

$$UTP_{\ell S} \;=\; F_p[\mu_\ell(Y_S), \mu_\ell(Y_{SC}), f_{\ell S}(t), K_{\ell S}, T_P] \tag{1}$$

$$UTR_{\ell S} = F_R[\mu_\ell(Y_S), \mu_\ell(Y_{SC}), f_{\ell S}(t), K_{\ell S}] \tag{2}$$

where $UTP_{\ell S}$ - confidence that the subject will develop a cognitive function disorder or its properties with identifier S; $UTR_{\ell S}$ - of an early stage ℓ of a cognitive function disorder or its properties with identifier S; F_P and F_R - relevant aggregation functions; T_P - forecast time.

Expressions (1) and (2) include the components described by experts in Sect. 2.

5. The risk factors leading to the appearance and development of the studied cognitive impairment are determined. Models for assessing confidence UFR_P in the appearance and development of risk factors are synthesized (P = psychoemotional stress, fatigue, schizophrenia, stroke, …). The scales UFR_P are used to construct the functions of belonging to the class prediction of the appearance and development of the studied cognitive disorders $\mu_{\Pi S}(UFR_P)$. Aggregation (1) with $\mu_{\Pi S}(UFR_P)$ gives an updated predictive model

$$UTP^*_{\ell S} = Ag_p[UTP_{\ell S}, \mu_{\prod S}(UFR_P)], \tag{3}$$

where Ag_p - corresponding aggregation function.

6. If technical capabilities are available, private models of forecasting (indicator UB_P) and early diagnosis (indicator UB_R) of cognitive impairment by biologically active points (BAP) "associated" with the cognitive impairment under study are built. The synthesis mechanism of prognostic and diagnostic decision rules for energy imbalance of the BAT is described in [12, 18, 46–56].

Aggregation UB_P and UB_R with models (1), (2) and (3) gives refined models for forecasting and early diagnosis

$$UPB_{\ell S} = Ag_{PB}[UTP_{\ell S}, UB_P]; \tag{4}$$

or

$$UPB_{\ell S} = Ag_{PB}[UTP^*_{\ell S}, UB_P]; \tag{5}$$

$$URB_{\ell S} = Ag_{RB}[UTR_{\ell S}, UB_R]; \tag{6}$$

where $UPB_{\ell S}$ - confidence in the appearance and development of cognitive impairment in the class ω_ℓ for cognitive function (property) S, taking into account the energy imbalance of BAP; $URB_{\ell S}$ - confidence in the presence of early stages of cognitive impairment by class ω_ℓ for function (property) S; Ag_{PB}, Ag_{RB}- the corresponding aggregation functions determined in accordance with the recommendations [12, 13, 35, 39].

The energy imbalance of BAP can be used to determine the level of psychoemotional stress YP and fatigue YU [13, 18, 21–23, 52, 57–61] included in the indicator UFR_P. In addition, indicators YP and YU are recommended to be used to control the processes of cognitive rehabilitation as indicators of the patient's condition.

3 Conclusion

The obtained mathematical models make it possible to predict the appearance and development of violations of attention indicators such as concentration, volume, selectivity, switchability, distributability, and stability among operators of information-saturated human-machine systems. Expert confidence in the resulting mathematical models exceeds 0,85. In the course of statistical tests on control samples compiled for computer operators, it was shown that the confidence in the correct forecast for the most "suffering" indicator of concentration of attention for a three-year forecast period exceeds 0,85.

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Information-Analytical Systems for Assessing the Rehabilitation of the Patients with Endocrine Diseases

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Abstract. Assessing the body's reserves (rehabilitation potential) to predict the risk of developing diseases or their outcomes (rehabilitation prognosis) is very important. This provides an opportunity for an individual approach to the patient. The proposed method for assessing the basic component of the rehabilitation potential - the morpho-functional index (MFI), developed using computer modeling methods, allows you to obtain accurate (quantitative) and objective information about the state of the human body at the starting point of the examination and to monitor the course of the process in dynamics. The effectiveness of the use of the MFI indicator is confirmed by examples of its use in clinical practice.

Keywords: Assessment of adaptation reserves · Rehabilitation potential · Rehabilitation prognosis · Morpho-functional index

1 Introduction

Currently, the active development of digital healthcare requires increasing the speed of patient screening, processing, transmission and output of information. At different levels of research, innovative technologies are introduced in order to simplify contact with medical organizations for the patient.

These tools are presented in a wide aspect, from individual devices for monitoring the patient's condition, transmitting data to the medical information-analytical system, to the use of advanced information technologies in medicine ("big data" [1], "artificial intelligence" [2, 3], "Robotics" [4], "virtual reality" [5], "telemedicine", etc.)

Certainly, at the same time, the need for an individual approach to the patient in diagnosis, treatment was repeatedly stated and accepted for development [1, 2]. In this regard, new approaches are also required to assess the reserves of adaptation and make

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 115–121, 2020.
https://doi.org/10.1007/978-3-030-50838-8_16

a rehabilitation prognosis, particularly in patients with endocrine pathology to determine further tactics of patient management. There is no more individualized characteristic for the state of an organism than an assessment of its adaptive capabilities. Exactly these reserves determine the possibilities for the formation of protective and adaptive mechanisms to the environmental conditions, since they are individual for each person, both sick and healthy. They are usually characterized as rehabilitation potential – RP. The main difficulty is to correctly measure it and rely on this information when choosing a treatment or rehabilitation option.

The rehabilitation potential (RP) is the ability to restore the body after (in the process) the disease. RP includes biological (or basic), psychological and social components. The search for methods of objectifying the RP is one of the most promising areas of research.

Purpose. To develop the analytical-information system for determining RP in patients with diabetes mellitus (DM).

2 Design

Patients were hospitalized in a specialized endocrinology department of the hospital with a diagnosis of diabetes mellitus were subjected to a single-stage epidemiological study (cross-sectional observational study).

The study was conducted in the Endocrinology Department of City Clinical Hospital. A.K. Eramishantseva (Moscow) and Clinical hospital of civil aviation (Moscow) and endocrinology department of the regional clinical hospital (Izhevsk). The study has been conducted since 2010.

The compliance of the study with the norms of biomedical ethics is confirmed by the conclusion of the Ethics Committee of the Medical Institute of RUDN University (Protocol №. 8 of February 18, 2016) and the Izhevsk Medical Academy (Protocol №. 8 February 18, 2010).

3 Materials and Methods

The study comprised of 362 patients, the adaptation potential was calculated according to generally accepted methods, and then the computer simulation method was used, in particular, the image segmentation method to develop a method for assessing the basic component of RP—the morpho-functional index (MFI) [6]. The index simultaneously does not only reflect the functional state of the autonomic nervous system but also characterize myocardial hemodynamic parameters.

The high reliability of the studied parameters is due to the simultaneous 24-hr blood pressure monitoring (BPM) and the method of Holter monitoring (HM).

4 Results

At the earlier stage patient has been determined by a formula “Index of Functional Changes” (IFC):

$$\text{IFC} = 0,011\text{PR} + 0,014\text{SBP} + 0,008\text{DBP} + 0,014\text{A} + 0,009\text{BM} - 0,009\text{H} - 0,27$$

where:

PR – Pulse rate, beats/min; SBP – Systolic blood pressure mm/hg.; DBP - Diastolic blood pressure mm/hg;
A - age (number of years); BM- Body mass kg; H - Height, sm.

IFC has been twice determined. At the first time by real data (see formula) IFC 1. At the second time IFC has been determined as patients organism is at ideal condition IFC2. Delta- It is a difference between IFC1 and IFC2, morpho-functional index (MFI). Image processing algorithm - segmenting a region into a subdomain; evaluation criteria are obtained (Fig. 1). When plotting, the main set turned out to be approximately within the framework of the proposed standards, but the formula required the clarification (Fig. 2). MFI as basic component of rehabilitation potential (RP) has been assessed (patent № 2344751RU, 2009y. "The method of determining the biological component of RP of patients with diabetes" [6] and patent № 2007613898 "Software determine the level of MFI of the patient and rehabilitation prognosis").

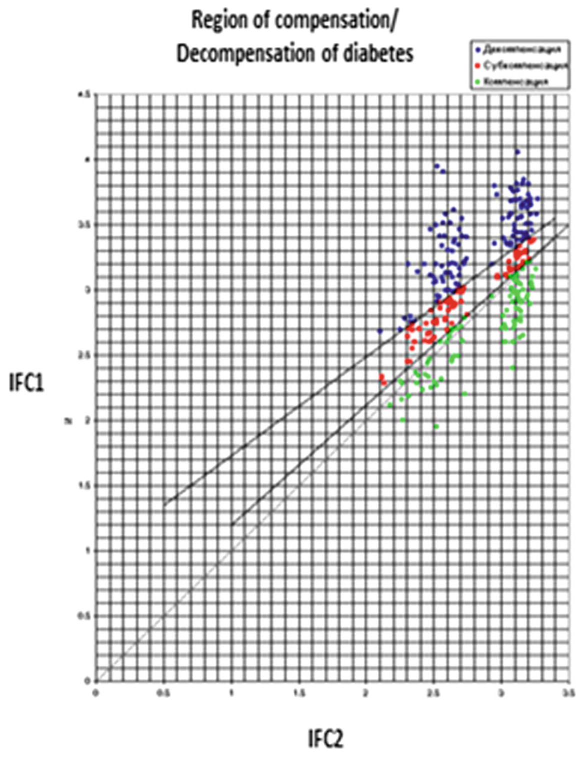

Fig. 1. Functional reserve of organism

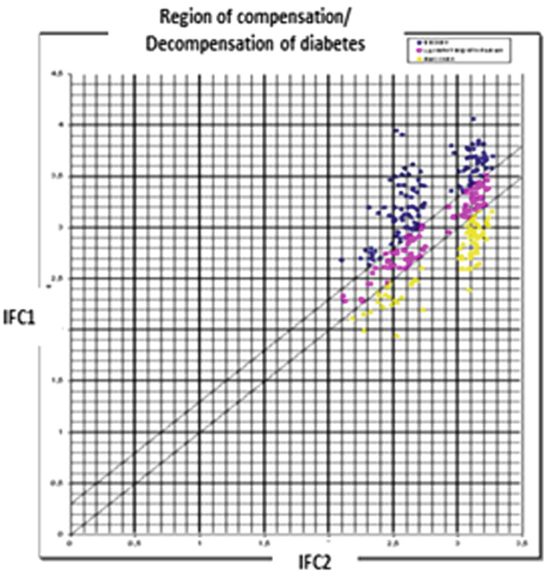

Fig. 2. Functional reserve of organism (formula required the clarification)

$$\frac{0{,}011P - 0{,}0101P^{*} + 0{,}014S - 0{,}0129S^{*} + 0{,}008D - 0{,}0074D^{*} + 0{,}0011A + 0{,}009W - 0{,}0083W - 0{,}0083W^{*} - 0{,}0007H - 0{,}302}{0{,}7343 - 0{,}00178P^{*} - 0{,}00226S^{*-}0{,}00129D^{*} - 0{,}00226A - 0{,}00145W^{*} + 0{,}00145H} \tag{1}$$

P-The heart rate is the actual average for the day (beats/min.);
*P * - the pulse rate is ideal within the limits of the age norm (beats/min.)*
SBP - the systolic blood pressure (BP) actual on the average for a day (mm of mercury);
*S * - SBP is ideal by age (mm Hg)*
DBP - the diastolic BP actual on the average for a day (mm of mercury);
*D * - DBP is ideal*
W - actual body weight (BW) at the time of examination (kg);
*W * - ideal BW(kg), which is determined by the formula*
A - the actual age;
H - growth of the patient at the time of the examination (cm).

According to formula, which has been already used, those are HR, Systolic & diastolic blood pressure, AGE, BW, height. All parameters are compared with parameters of the same patient, if he would have been in healthy (ideal) condition (deviation from the norm). MFI - an inverse value to RP. The more the deviation (size MFI) is lower RP. Comparison with clinical results of evaluating RP on an array of 139 patients with diabetes with an established disability group and assessed in a traditional way (expert assessment) with rehabilitation potential, the average correlation between these indicators (r = 0,73; p = 0,001).

Range of MFI:

- MFI $\leq$ 0 - good compensation of DM, favorable course, biological component of RP high, rehabilitation prognosis favorable;
- 0 $\leq$ MFI < 1 - satisfactory compensation of DM, biological component of RP satisfactory, rehabilitation prognosis relatively favorable;
- MFI $\geq$ 1 - unsatisfactory compensation of diabetes, multiple complications, biological component of RP low, unfavorable prognosis;

Thus, we got the indicator that we have been looking for a long time. MFI – the only criterion that is directly related to diabetes compensation and can characterize the effectiveness of ongoing rehabilitation measures even before the normalization of metabolic parameters. Thus, under the control of MFIs, adaptation indicators and compensation for diabetes were found, and it is possible to assess the effectiveness of rehabilitation in the dynamics and prospects of rehabilitation.

Advantages of the method:

- * Objectivity - a quantitative characteristic of the biological component of RP is provided, which is calculated independently of the specialist's level of training, his qualifications and commitment to a particular medical school.
- * Standardization of assessment - common criteria for any region.
- * Efficiency – saving a specialist's time (even a mid-level specialist can record and get results in a computer program).
- * Dynamic assessment – It can be used to control the quality of therapeutic management.

To facilitate the calculations, the "Software for determining the level of the functional state and compensatory capabilities of the body" was developed. (Kurnikova I. Certificate of official registration № 2007614560 от 30.10.07г.).

The computer program "Software for determining the level of the functional state and compensatory abilities of the body" was developed made the formula easy to use (Certificate of official registration No. 2007614560 from 10.30.07.)

We evaluated the effectiveness of the MFI indicator uses by using various methods, including analyzing the relationship between metabolic control indicators (HBA1c) and the basic component of the rehabilitation potential (RP). When examining patients in a state of metabolic compensation, it was found that even normal metabolic indices do not guarantee a favorable course of diabetes in 18.8% of patients with type 2 diabetes, if the adaptive capabilities of the body are exhausted. The obtained data allow us to explain those cases when a seemingly good metabolic compensation of diabetes does not slow down the rate of progression of vascular complications.

During the observation process, patients were individually offered a medical rehabilitation program, depending on the type of diabetes, stage of the disease, severity of complications and personality traits. In addition to medical events, patients were educated. The index of MFIs in patients with type 2 diabetes decreased markedly, while diabetes compensation was achieved in 67%. In the group of patients with diabetes lasting more than 15 years, the effectiveness of rehabilitation activity was low - satisfactory compensation was achieved in less than a third of patients (31%).

Poor DM compensation has always been accompanied by an increase in the level of system functioning.

The adequacy of rehabilitation activity and the attitude of patients to them were the leading factor affecting the achievement of diabetes compensation seen in not all patients. A group of patients (17 people) was emphasized who, despite a positive outlook and careful control of diabetes, had progressed complications and found that these were patients whose MFI score at the time of the initial examination was higher than 3 points. In the process of rehabilitation, their MFI decreased slightly, but did not fall below 2 points. All patients with MFI > 1.5 points were included in the group with an unfavorable clinical prognosis. Of these, the second disability group was established in 88% of patients (15 people). Calculating the MFI in the dynamics of each specific observation allows us to evaluate the clinical prognosis, effectiveness and sufficiency of rehabilitation action.

According to the research results, the correlation between the values of MFI, RP and rehabilitation prognosis (RP) was high and were r = 0.68 and r = 0.71, respectively, which allowed us to determine the clinical rehabilitation prognosis, the indicator of the prospects of medical rehabilitation measures and the restoration of the ability to work. A comparative analysis of the biological component of the rehabilitation potential (RP), the rehabilitation prognosis (RPr), and the RP and RPr indicators established in the Federal Bureau of Medical and Social Expertise [FB MSE] (the study was conducted in 2010) showed an even higher correlation of r = 0.81. A total of 79 patients were examined, 7 conclusions did not match (8.9%). Each case of mismatch was analyzed individually in the dynamics of a prospective study.

As it turned out, in more than half of the cases (4 people), the MFI indicator was more accurate:

- One patient with MFI of 0.16, a high RP and a favorable IFI RPr, and a doubtful prognosis based on the results of the FB MSE examination was rehabilitated after a year.
- Two patients with MFI > 1.5, but satisfactory RP and relatively favorable RPr changed the disability group to a more severe one within a year (MFI is the expected prospect);
- One patient with MFI of 0.11, but a low RP and an unclear MFI prognosis was determined to have a satisfactory RP and a relatively favorable RP after re-examination. Stability in these indicators was maintained during 4 years of observation and re-examination. There was also no negative dynamics in the clinical course of the disease.

5 Conclusion

Reducing the body's adaptive capacity is a new risk factor for physicians. An objective assessment of adaptive capabilities allows you to predict the development of the disease, the occurrence and progression of complications, and to make rehabilitation and labor prognosis, as well as the risk of the patient's disability. In this regard, diagnostic methods that would allow us to assess the state of the organism as whole, methods that are based on the assessment of its general, fundamental properties are of interest. In our opinion, these conditions are met by methods for assessing the body's rehabilitation capabilities. The methods we developed for assessing the functional state and compensatory capabilities of the body made it possible to bring the methods for determining rehabilitation indicators closer to widespread practical implementation. The definition of MFIs and RPs, thus, becomes a working tool in clinical and functional diagnostics, a means for monitoring the quality and adequacy of the therapy in patients with diabetes mellitus and making a labor forecast.

The patient, even with an unfavorable course of the disease and significant functional disorders, retains biological resources that provide an opportunity to compensate for the consequences of the disease. The difficulty is rather how to measure these resources and use the acquired knowledge in practice. The development of methods for assessing the compensatory abilities of the body made it possible to transfer such categories as "rehabilitation potential" from the field of scientific research to practical work. The MFI allows you to dynamically evaluate the compensation of diabetes ($r = 0.71$; $P = 0.001$), the rehabilitation potential ($r = 0.86$; $P = 0.0008$) and provides dynamic monitoring of the rehabilitation process.

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Prosthetics

High Accuracy Multi-channel Surface EMG Acquisition System for Prosthetic Devices Control

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Abstract. Most of the upper limb prosthetic devices are controlled using biological signals, mainly EMG. The main problem with these systems is that the hardware needed for treatment and acquisition of the biosignals are not clear. This paper has presented the design of an interface for acquiring real-time electromyographic signals for a prosthetic upper limb system, considering the stages of acquisition, digitalization and presentation of the information, using a high-speed and high-resolution system. The digitalization system uses a 24-bit, 256-kSPS, 8 channel ADC whose information is read with a SOC ZYNQ-7000 based system, PYNQ. Using the advantages of the PYNQ, the Programmable Logic of the device, ensures the parallel synchronous acquisition, while the Processing System handles the datacasting and the communication of the information.

Keywords: EMG · SoC · Multi-channel acquisition · Prosthetic devices · PYNQ · ZYNQ · ADC · High-resolution

1 Introduction

Upper limb amputations are a major cause of disability in the world. Approximately 25,000 people in the United States have severe upper limb loss, of this group, about 80% choose to use a prosthesis daily, 40% are transhumeral amputations [1, 2].

Despite the advances in technology, it is estimated that between 50% and 60% of people with upper-limb loss do not use any type of prosthetic devices. Although most of the available prostheses replace the lost limb and manage to do the necessary movements, those are devices with considerable weight and size, in addition to having a complexity that prevents users from easily manipulating them [3–5]. This can cause the device to fall into the so-called Uncanny Valley, which can be defined as a feeling of eeriness and non-belonging that users experiment when they see or use a humanlike device but that behaves in an unforeseen way. This effect can be reduced with an adequate design of the prosthetic device that includes the anthropometric, physiological and psychological characteristics of the users [6]. Thus, the design and subsequent control of prosthetic devices of the upper limb that allow users to have the same skill as

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 125–130, 2020.
https://doi.org/10.1007/978-3-030-50838-8_17

with a natural limb is a great challenge. The principal ways for signal acquisition and device control are performed through surface electromyography (sEMG) [7]. Currently, commands based on users' intention of movement do not always allow the correct manipulation of most advanced prostheses [8], and the limited source of biometric signals requires uncomfortable movements to activate the actions of these devices with recognition systems for the intention of movement [9].

2 Background

The loss of a limb means a great change for the affected person because the body must adapt to the fact of continuing with its activities of daily living, reducing its quality of life. To replace this deficiency, those affected persons use prosthetic devices [10]. The technology has contributed greatly to the development of prostheses and currently, there are prosthetic devices with sensors and actuators with greater functionality than the traditional ones. Among the signals used for the control of active prostheses are the biological signals, such as electromyography (EMG), electroencephalography (EEG), electrocorticography (ECoG), the EMG being the most used signal so far [10]. EMG is preferred because of the ease of use for the acquisition of muscle signals and because it is not an invasive technique. The myoelectric control uses signals that are acquired from the member's residual muscles to control the degrees of freedom (DOF) of active prosthetic devices used by amputees [11, 12].

2.1 Required Architecture

The biopotential sensing systems have power, pre-amplification stages with an instrumentation amplifier, analog filtering, rectification, analog-digital conversion and control [13, 14].

For the conversion stage, a 12-bit ADC can separate the voltage range from the input signal into 4095 intervals. This is sufficient for most kinesiological configurations. Very small signals may need further amplification to achieve a better resolution in amplitude [14]. To further improve the gain resolution and compensate for the low amplification that may occur in early stages, a 24-bit ADC is recommended [13]. The sampling rate must be at least 1000 Hz (double the EMG band) or even 1500 Hz to avoid losses in the signal [14]. [10, 11, 13] suggests that the sampling rate be 2 kHz to have a greater amount of signal information. Among the characteristics that the ADC must fulfill are: (a) simultaneous sampling of the channels to avoid errors in time and synchronization, (b) serial connection of several of these devices to avoid the error, (c) low power consumption and (d) minimum processing cost. The block diagram for the proposed system is presented in Fig. 1.

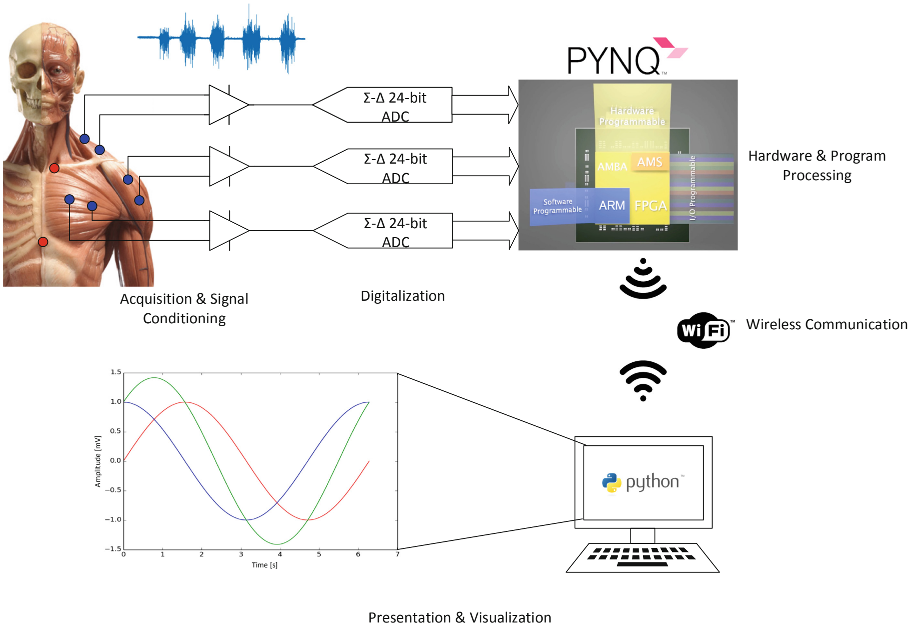

Fig. 1. Block architecture of the EMG acquisition system, shows the synchronous multichannel acquisition and digitization interface that is processed by an SoC, it manages wireless communication with a data presentation terminal.

3 Materials and Methods

3.1 Preamplifier Board

Isolation was realized using biomedical instrumentation buffers. The AD8244 was chosen for its simple source power supply and full-range operation and 3 MHz bandwidth.

This interface has an instrumentation amplifier, a body feedback circuit also called a right leg (RLD) and an anti-alias filter. The instrumentation amplifier used is the AD8237 that works with simple source, full-range gain and no zero crossing distortion [15].

For the design of the filter, the most important frequencies of the EMG signal were considered, therefore, the cut-off frequencies of the bandpass filter were set at $f_i \approx$ 20 Hz and $f_f \approx$ 500 Hz. The use of a two-pole Sallen-Key architecture for high pass and low pass filter was considered.

3.2 Analog to Digital Converter Board

The AD7768 synchronous multichannel ADC was chosen, which is the recommended ADC for precision medical electromyography. It has 8 channels, 24 bits of resolution in sigma-delta architecture (Σ-Δ), a bandwidth of 110.8 kHz per channel, or a maximum of 256kSPS [16].

3.3 The Controller Board

HDL. The ADC outputs a burst of synchronous pulses to each other, for which an HDL processing system is required to perform tasks concurrently and at the same time handle a simple user interface. For this reason, it was decided to use the DIGILENT® PYNQ-Z1 embedded system that is based on the Zynq-7000 SoC (combination between an ARM Cortex-A9 processor and an FPGA of the Artix-7 family, from Xilinx) [17]. The modules designed in HDL of this device can be integrated into an interface developed in Python, which greatly simplifies the development of projects and facilitates the scalability of applications [18].

A 32-bit Shift Register, synchronous to an external clock signal and a data-ready pulse, was implemented, from which the 32 bits are split into 24 data bits and 8 header bits.

SO. In the ARM core of the SoC the transmission of the data acquired by the embedded system is managed, every time there is an interruption in the system, this sends the ADC acquisitions one by one through Sockets based on TCP-IP.

Visualization System. The visualization system is implemented in a terminal that runs Python with a Switch server that receives the information sent by the embedded system, and plots it dynamically, thus allowing visual verification of the signals.

4 Validation

The validation of the designed device was carried out based on the comparison of the developed system and a standard instrument. EMG signals were acquired from a male subject, 25 years old, ectomorph, BMI 18.8, brown skin (skin phototype 3) with electrodes arranged in such a way that they can acquire signals from the following muscles: Pectoralis Major, Serratus Anterior, Rectus Abdominis, Obliquus Externus Abdominis, Neck Extensors, Trapezius p. Ascendant, Latissimus Dorsi and Trapezius p. Transversus. Before the execution of the test protocol, the participant was informed of the nature of the tests, after which informed consent was signed.

The validation of the designed device was performed under visual inspection as suggested by the literature since untreated EMG signals can be considered stochastic.

The standard instrument used was the Biopac © BSL MP45. The impedance measurements of the skin indicate that there is a variation of impedances depending on the phototype of the test subject so that higher impedance values are evidenced in a subject with brown skin, one of the acquired signals is presented in Fig. 2.

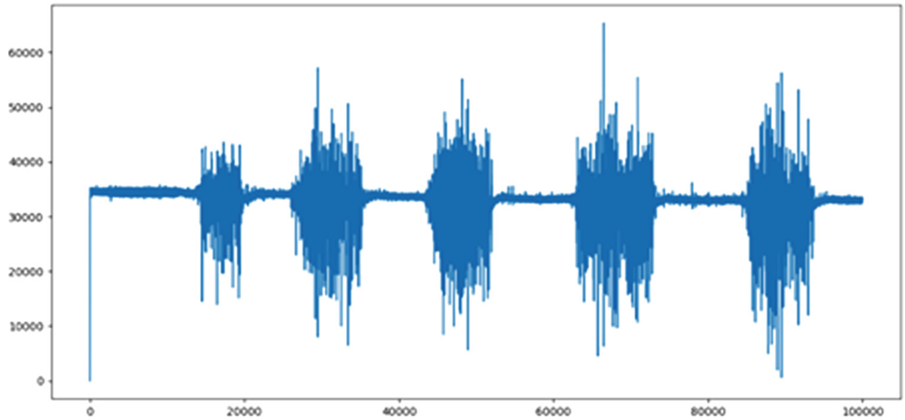

Fig. 2. Electromyographic signal acquired by one of the channels of the acquisition system.

5 Discussion and Conclusion

In the review of the state of the art on devices for acquiring surface EMG signals for prosthetic devices, the complexity that some of these systems can have by being limited to the use of microcontrollers is evident, using two or more of these to perform in separate cores the signal acquisition processes and their processing logic. These architectures will be simplified by introducing the use of SoC, where several hardware-level processes can be performed in parallel and the integrated microprocessor is automatically dedicated to data management.

The use of the embedded system PYNQ makes easier the development of projects on SoC by using a Python-based operating system, which allows applications developed on it to be socialized with a larger group of people working on the project and where the curve of knowledge necessary for the management of this system is minor compared to other specific embedded systems in the same IC ZYNQ. Because the project is based on this SoC, the scalability of the architecture is possible to develop other processes related to the research project, such as the filtering of signals at the hardware level, application of artificial intelligence architectures for the recognition of patterns, digital control modules, etc., without this having an impact on the processing capacity and the execution of the programming logic. In this way, the execution of processes and saving of resources can be configured in both hardware and programming for a multitasking device such as an arm prosthesis.

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Patronized sEMG Acquisition System Proposal Using Patient Journey Mapping for Upper Limb Prosthesis

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Abstract. Electromyographic signals are widely used in the study of control systems for prosthetic devices, but the way they are acquired hinders the replicability of the studies performed, generating a large variation between each measurement of the signals. One of the main problems in the acquisition of myoelectric signals is the location and repositioning of the surface electrodes, this is something that could be solved by analyzing the most common distributions and configurations of electrodes and rethinking the design of the acquisition systems, forms or methods for that are more comfortable for the patient. In this research, a prototype was built that has the acquisition points of standardized signals, which is easy to use and provides greater autonomy to the users of these systems. To develop this device, the design of the idea using the "Patient Journey Mapping" methodology, which allows finding interdependencies and friction points in the whole process of using the prototype of SEMG signal sensing, the solution is subsequently designed, building the prototype and the system for the tests performed on it.

Keywords: Journey mapping · sEMG · Protocol · Design · Healthcare · Prosthesis

1 Introduction

Electromyographic signals are widely used in the study of control systems for prosthetic devices, but the way they are perceived greatly hinders the replicability of the studies performed, generating a large variation between each measurement of these signs. This is mainly due to the stochastic characteristics of the EMG signal and a large amount of noise (artifacts) that can contaminate the signal.

One of the main problems in the acquisition of myoelectric signals is the location and repositioning of the electrodes, this is something that can be solved by analyzing the most common distributions and configurations of electrodes and rethinking the design of the systems, forms or methods of acquisition, to make them more comfortable for the patient. In practice, what most limits the use of EMG is the change of the electrodes, the variations of force and the involuntary activation of the muscles [1].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 131–137, 2020.
https://doi.org/10.1007/978-3-030-50838-8_18

In general, the interface of commercial prostheses is performed as in [2, 3], that is, active or passive electrodes are embedded in the prosthesis receptacle for proper acquisition, while for experimental tests, they are generally used Disposable electrodes and tests that are generally cannot be repeated as one would like to have, or not present, a suitable bioelectric signal acquisition protocol as in [4–8]. In [9] it even proposes the use of stainless steel based electrodes, leaving completely the line of recommendations of SENIAM and the state of the art.

In [2, 3] it is indicated that the user interface module makes contact with the passive EMG electrodes in the socket to make direct contact with the user's residual member. Up to eight pairs of bipolar electrodes can be connected to the user interface module. In [10] 11 SEMG sensors were used for data acquisition.

After the state of the art developed by [11] and the analysis of literature, the authors describe that the procedures for the acquisition of SEMG are very poorly reported and make clear the need for a clear signal acquisition protocol and that offer appropriate guides for the acquisition of SEMG.

1.1 Journey Maps

The journey maps are a tool for the design of services and products in the area of health, which represents the stages that a patient goes through or "points of contact" with the product, designing from their point of view. This tool allows the designer to optimize the user experience of the product, where different actors and their interdependencies are involved with the product design and use process [12, 13].

2 Idea Design

This is an idea designing technique presented by the TU Delft design manual [14].

2.1 Identification of Friction and Problems on the Investigation with Prosthetic Devices

To identify the problems, it was based on a previous study that exposes the problems existing in the research with prosthetic devices as well as proposals for its design [1].

2.2 Defining Essentials

What is the Problem? The problem is that there is no standardized system for the acquisition of electromyographic signals for use in the control of upper limb prostheses; Signal acquisition protocols are unknown or not properly documented; The patient feels uncomfortable and it is annoying to constantly replace the electrodes throughout the day and their need for third party help for the correct location of these.

Who is Involved? The patient, researchers from specialized biomedical centers, therapists and family members of the patient are involved.

When Does This Happen? It happens in the stages of testing with the patient of the prosthetic devices and, depending on the design, in the stage of using the prosthetic device.

Where Does This Happen? The user takes it with him as long as he needs to use the prosthetic device.

Why This Happens? In the stages of development of prosthetic devices, it is necessary to identify the acquisition points of the biometric signals, as well as a system that ensures the repetitiveness of the acquisitions, but usually disposable electrodes are used that should be replaced several times throughout the day and that third-party help is needed for positioning.
The tables and identification lists of relevant actors are omitted in this work.

2.3 Idea Design

The procedure for the ideation of the signal sensing system is presented in Table 1, which is similar to the work done in [15].

Table 1. Idea design using patient journey mapping.

Stages	Investigation			Production		Usage
Substages	Taking anthropometric measurements	Design of the device	Making signs	Design of Acquisition System	Validation	Using the device
Emotions	Expectation	Doubt	Anxiety	Hope	Satisfaction	Relief
The behavior of the patient	The patient must wait for their measures are taken	The patient participates in the different tests by the investigator	The patient sees how time and are developed prosthetic systems	The patient checks end systems for handling prosthetic devices	The patient uses prosthetic devices until they are of satisfaction and usefulness	The patient uses daily prosthetic device and can perform their daily activities
treating physician	Explains and teaches how to take action and where	Feedback on the anatomic functionality of the upper limb	Check that the signals being taken are appropriate and are well taken	Review and suggests suitable points for taking signals	Verify that no harm to the patient	Check the health of the patient and their status regarding the use of the prosthetic device
Investigator	Receive measures and parameterized designs	Creates the prosthetic device using the treating physician and the patient	Signal processing and control device	Create the ultimate system for making and signal processing	Performs all relevant evidence with the doctor and patient to validate the constant use of the prosthetic device	The patient receives feedback to make improvements in future work

2.4 Solution

The design of a reusable standardized system that is positioned on the following acquisition points is considered:

Taking reference points in C7, TH8, Acromion, Clavicular mid-head, sternum.

Bipolar acquisition points: Pectoralis major, anterior serratus, abdominal rectus, abdominal external obliques, neck extenders, transverse trapezius, wide dorsal, ascending trapezius;

All these points are considered to achieve different combinations that can be useful in different patients in different situations so that the patient adapts to the muscle combination that is most comfortable for him.

A compression t-shirt is chosen because it offers direct fixation on the patient's body and the muscles on which they are going to study do not move mostly when making body movements, which allows reducing noise (artifacts) by movement and electrode displacement, this system is represented in Fig. 1. In this first stage, dry electrodes will be used for acquisition, in subsequent studies, it is suggested to test with conductive and skin preparation gels.

Fig. 1. Signal acquisition t-shirt, solution idea design.

2.5 Solution Prototype

The proposed SEMG signal sensing prototype consists of round Ag/AgCl electrodes with a diameter of 10 mm, BioMed brand, model SE12, arranged with an inter-electrode separation of 20 mm in a thermal pressure compression jacket, TCA mark, arranged to cover the muscles: pectoralis major, anterior serratus, abdominal rectus, abdominal external obliques, neck extenders, transverse trapezius, wide dorsal and ascending trapezius; as well as the anatomical reference points: C7, TH8, Acromion, and sternum. For the manufacturing process of the prototype, the services of a textile designer were used. In Fig. 2. the prototype shirt is shown with the anatomical sites on which the acquisition will be made, on which the electrode cables are connected.

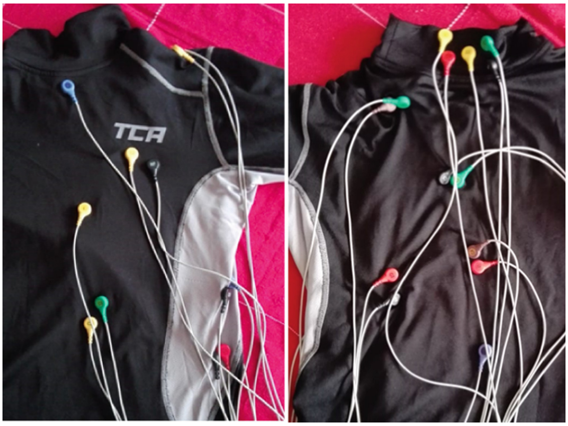

Fig. 2. Compression shirts of the patronized system, with the cables placed on the NaCl electrodes ready for the acquisition of biopotentials.

2.6 Tests

Tests performed on a young adult male, mesomorphic, white skin color, with adipose panicle distribution in moderate quantity, BMI 25.8, size 176 cm, weight 80 kg. Tests performed at rest. For the proposed system, Ag/AgCl electrodes model SE12 of the bio-medical brand were used, they are circular electrodes of 10 mm diameter, for data collection a 20 mm IED was used between the bipolar configurations and the indicated reference points; while for the traditional system Ag/AgCl electrodes were used, NORAXON brand, HEX Dual Electrodes model that are arranged with a 20 mm IED and Ag/AgCl electrodes, 3 M brand, the bioimpedance measurements are presented on Table 2.

Table 2. Comparison between skin bioimpedance with respect to the systems used.

Measuring area	Traditional system		Proposed system	
	Proskit	NI myDAQ	Proskit	NI myDAQ
Pectoralis Major	3.53k–2.3k	4.9k–4.8k	4.5k–5.6k	6.2k–5.8k
Serratus anterior	65k–48k	48k–42.9k	70k–65k	76k–52k
Abdominal Rect	3.8k–4k	4.2k–5.1k	7.5k–8k	6.3k–7.8k
External obliques	10M–9.3M	9.62M–9.72M	18M–15M	8.6M–12M
Next extensors 1	2.89k–2.9k	2.68k–3.3k	4.8k–5.2k	3.7k–4.2k
Next Extensors 2	18.2k–12.2k	18k–13.4k	20k–17.3k	15.3k–19.2k
Trapeze Transversus	7.2k–5.8k	7.13k–7.1k	9.4k–8.1k	6.4k–8.4k
Latissimus Dorsi	6.3M–5.52M	5.55M–5.5M	8.4M–6.3M	7.4M–8.3M
Trapeze Ascending	83k–66k	87.8k–67.2k	100k–97k	115k–80.3k

3 Conclusion

The proposed system, under equal conditions of skin preparation, has a higher impedance than the traditional system, since they are dry electro-two.

As for the acquisition of signals, the proposed system allows a more flexible and adaptable acquisition to the user's body, thus allowing similar and in some cases better acquisitions than the traditional system.

Serious problems of subjection were presented at the reference points of the sternum and TH8, which must be brought closer to the contact with the body manually, this can be solved using double-sided tape on the peripheries of the electrode provided in said zone. Likewise, to improve the sensing capacity of the electrodes, it is recommended for future work the use of a small layer of conductive fabric arranged between the electrode and the shirt fabric.

The use of this system is much friendlier to the patient since it gives the user autonomy since it reduces the need for third parties in the daily location of the disposable electrodes on their skin, which consumes a considerable amount of time, on average an hour and a half. This system is much more convenient to use and does not leave the glue marks that usually leave commercial electrodes for EMG or EKG.

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Uncanny Valley Effect on Upper Limb Prosthetic Devices on the Ecuadorian Context: Study Proposal

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Abstract. The main objectives of rehabilitative treatment in the amputee patient are the psychophysical recovery of the patient through protetization and, finally, their socio-labor reintegration. To be able to measure the achievements obtained with the rehabilitative treatment we need to have objective assessment measures (functional assessment scales) that will allow the use of standard terminology. The objective of this study is to review various scales of assessment of the amputee. The scales have been classified as universal (Barthel Index, Pulses Profile, Functional Independence Measure, and Edinburg scale) and specific: for members (Enneking scale and Locomotion Score in Rheumatoid Arthritis) and for amputees (Day scale and the questionnaire Prosthetic Profile of the Amputee). This study seeks to discover the design parameters and the acceptance of the population that uses prosthetic devices and their environment (family, work and health personnel) towards new technologies in terms of prostheses to discover and understand the functioning of the Uncanny Valley in the Ecuadorian environment, to avoid falling into it. The results will be adequately delimited and tabulated by intelligent computer systems.

Keywords: Uncanny valley · Anthropomorphism · Humanlikeness · Upper limb · Prosthesis · Ecuador · Sensation · Perception · Social acceptation

1 Introduction

It has been empirically evidenced that the rejection of the upper limb prosthetic devices is very high, even reaching 80%, an effect that does not occur with the lower limb prostheses [1, 2]. Some of the hypotheses raised suggest that rejection has both psychological and aesthetic factors since in itself the amputation of a member can generate unpleasant psychological consequences and especially the difficulty of accepting the new condition of your body; and that although a prosthesis helps its user to gain mobility and the ability to return to social activities, to be accepted by users they must be comfortable and functional, in addition to having a nice cosmetic [3]. On the other hand, technology gradually has a greater social inclusion, including in the area of

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 138–144, 2020.
https://doi.org/10.1007/978-3-030-50838-8_19

medicine, where there are robots for assisted surgery, rehabilitation, etc., so it is essential to know what the perception is you have the technology and know-how to make designs that are better included in society [4–6]. It seeks to discover the design parameters and the acceptance of the population of the traumatology area of a public hospital towards new technologies in terms of prostheses to discover and understand the operation of the Uncanny Valley in our environment, to avoid falling into it.

1.1 Uncanny Valley

Uncanny Valley is the effect proposed by [7] (Fig. 1 and Fig. 2), which describes a negative emotional response when it comes into contact with entities that appear almost human [8]. It tries to discover the level of familiarity and human-likeness (anthropomorphism) of various objects through the level of acceptance that observers show about them, however, there is very little research about prosthetic devices within the Uncanny Valley [3]. In one of the few studies conducted by [9], described the change in behavior from "Valley" to an "N", suggesting that it is almost impossible to recover from the feeling of strangeness generated by being a new device. This has been a hot topic in recent research, but no adequate conclusion has been reached, it may be important for research that definitions of characteristics such as anthropomorphism, human-likeness, and eeriness can be better operationalized so that there are no doubts and can be analyzed from an objective point of view [8]. To avoid problems and that the studies are better replicable in any part of the world for which Lay [8] summarized in 5 steps:

1. The stimulus must cover a wide range of human-likeness, with a minimum of five points including human and non-human extremes
2. The anthropomorphism of the stimulus shown to the patient must be quantifiable
3. Emotions that have measures must be clearly identifiable and quantifiable
4. A response to strangeness must be collected, as well as family or emotional response in order to contrast the information
5. Consider the deviations in process

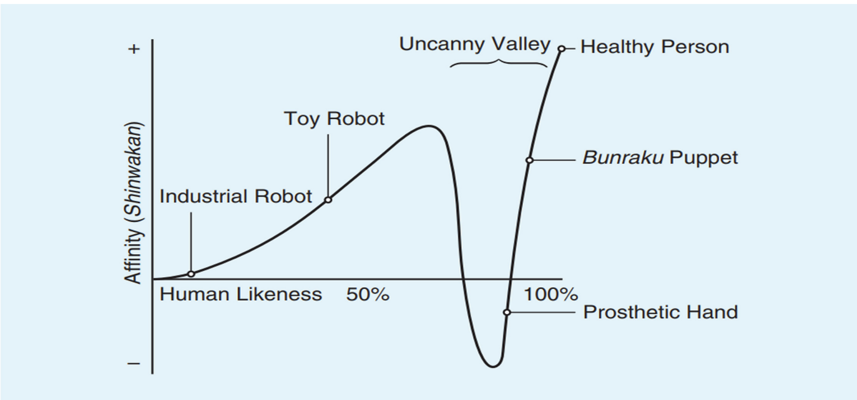

Fig. 1. It shows the graph of the Uncanny Valley effect proposed by Mori, for entities that show different degrees of human-likeness [7].

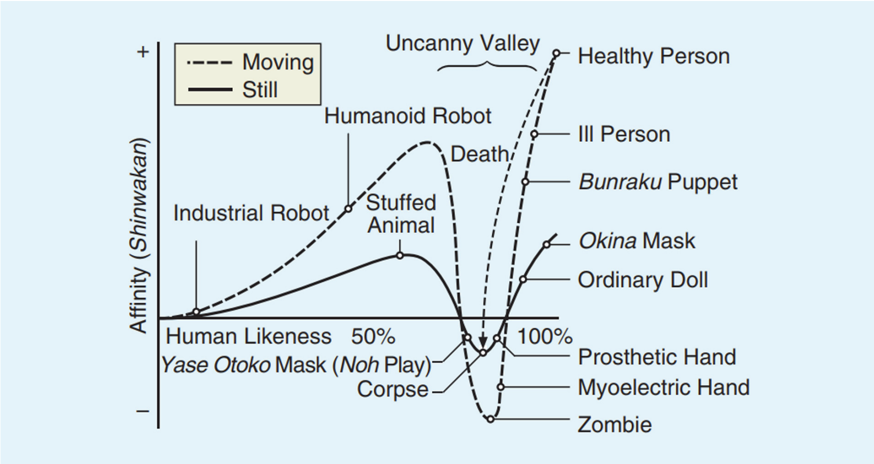

Fig. 2. The presence of movement steepens the Uncanny Valley effect, comparing human-like beings in movement and without movement [7].

[10] Confirms that it is necessary to establish methodologies for the study of the uncanny valley properly, closing the cracks that exist in the literature on this effect, although there have been studies that have evaluated the perception of robotic systems, studies on prosthetic devices remain scarce.

1.2 Anthropomorphism

Anthropomorphism refers to the attribution of the human form, human characteristics, or human behavior to a non-human entity, such as robots, computers, and animals. It is important that in order to evaluate the anthropomorphism of an entity, several points of view of experts are needed, which based on tests can reach a consensus based on the speed of movement, how much it reminds a person, and the empathy it generates [11].

1.3 Senso-Perception

Within the Gestalt movement, perception is considered as the fundamental process of mental activity and assumes that other psychological activities such as learning, memory, thinking, among others, depend on the proper functioning of the perceptual organization process. Prior to this movement, the perception was understood as the result of body processes such as sensory activity [12]. Then, using several experiments, we tried to show that perceptual activity is not a causal process since perceptual activity has the ability to go beyond the limits of objective data to add qualities [13].

1.4 Tools to Evaluate Senso-Perception

The main objectives of rehabilitative treatment in the amputee patient are the psychophysical recovery of the patient through potentization and, finally, their socio-labor reintegration. In order to measure the achievements obtained with the rehabilitative treatment, we need to have objective assessment measures (functional assessment scales) that will allow us to use the standard terminology. The objective of this study is to review various scales of assessment of the amputee. We have classified the scales into universal (Barthel Index, Pulses Profile, Functional Independence Measure, and Edin-burg scale) and specific: for members (Enneking scale and Locomotion Score in Rheumatoid Arthritis) and for amputees (Day scale and Prosthetic questionnaire Profile of the Amputee). We make a comparative chart among all according to their categories and items and describe the characteristics of some of them [14].

2 Methodological Design

2.1 General Objective of the Study

Identify the characteristics that cause rejection or acceptance in a patient who uses an active prosthetic device and the functionality they provide. In other fields of robotics, similar acceptance and perception studies have already been carried out, it is now necessary to rely on these studies to perform adequate work on the acceptance of prosthetic devices of the upper limb [15].

2.2 Specific Objectives of the Study

- Analyze the autonomy of amputee patients
- Analyze the perception of patients towards prostheses available in the market
- Analyze the feeling of patients towards prostheses available in the market
- Analyze the functionality of prostheses available in the market
- Determine the existence of the "Uncanny Valley" phenomenon and its characteristics in the Ecuadorian environment
- Find a model capable of predicting acceptance trends towards new prosthetic devices

2.3 Procedure

By applying the following forms and surveys to the subjects within the health facility, the pertinent data will be collected for this investigation:

- PPA (Prosthetic Profile of the Amputee), which values protection.
- Enneking scale, which assesses the pain and satisfaction that the patient experiences with a prosthetic device.
- Karnofsky scale, which assesses the quality of life of patients.
- Barthel scale, which assesses the independence of patients

Similarly as proposed by [16], users of prosthetic devices and control groups will be presented with images of prostheses developed in Ecuador and the most important worldwide, and the sensation presented by the simulated use of these devices that will be accompanied by a survey that will present a test capable of measuring the perception of human similarity, projected safety, and anthropomorphism of each of the prostheses available in Ecuador.

It must be stated a priori that the human-likeness of the devices will be evaluated in two different ways, first that perceived by researchers, who are more accustomed to working with these elements, and the human-likeness perceived by users of prosthetic devices. and the control group

The graphs that must be presented for the understanding of the reactions associated with the prosthetic devices are the following:

1. Human-likeness perceived by researcher vs perception
2. Human-likeness perceived researcher vs human-likeness perceived by the test subject
3. Feeling vs. perception
4. Functionality vs. perception
5. Feeling vs. functionality
6. Human-likeness perceived by the test subject vs functionality

In addition, the tables presented must compare the socio-demographic variables with human-likeness and acceptance of the devices. Crossing with socio-demographic variables is necessary since the perception of technology is something that has been learned or acquired since childhood and depends a lot on the situation in which the individual has developed [17].

With all this information, intelligent computer systems will be trained to predict or at least estimate the acceptance rate of one design or another based on socio-demographic variables similar to the work done by [18].

The data collection tools that will be taken into account to carry out this research are described below:

- For the preparation of the following investigation, an authorization will be requested from the staff of the Teaching and Research Department of a public hospital.
- Informed consent will be requested from the patient part of the validation population.
- Permission will be requested from the Salesian Polytechnic University to use its development and research spaces, as well as their consent and endorsement for this research.
- The public hospital will be asked for permission to conduct research at your institution, as well as access to patients in the area of traumatology and apply the tests described above.
- In the case of the control population, given the case that they will not work with informed consent and to protect the integrity of the participating patients, their names will not be disclosed and each one will be assigned a code numerically. After the statistical analysis, the copy of the database will be deleted.
- The information will be subject to any verification requested by the Department of Teaching and Research. After the investigation protocol is approved, the information will be collected, which will be kept with absolute confidentiality, which will be used to build an intelligent predictive classification system that offers guidelines for the design of new prosthetic devices.

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Mechatronic Design of Trans-humeral Prosthesis Based on a Goniometry and Anthropometry Study

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Abstract. This article will discuss the mechatronic design of a transhumeral prosthesis, considering and analyzing commercial prosthetic designs, also taking into account the real range of motion of a human arm, the characteristics of speed, torques, a very important parameter that is the aesthetics, the anthropometric measurements of a person, the actuators and materials to be used to obtain an accessible transhumeral prosthesis with the aforementioned parameters.

Keywords: Prosthetics · Transhumeral · Actuators · Torques · Anthropometry

1 Introduction

An amputation is an acquired condition whose result is the loss of a limb and whose cause is usually an injury, a disease or a surgical operation [1]. Usually the loss of a member causes psychological trauma to the patient; he may fear that amputation decreases acceptance by other people; the loss of a part of the body alters the image that the patient has of his body and can lower his self-esteem.

The patient will face the possibility of locomotion loss; permanent disability changes in their customs and perhaps loss of work. Any response to amputation is highly individual [2].

A transhumeral amputation is one that occurs above the elbow. In a transhumeral type prosthesis, the arm or hand should offer amputees a natural, intuitive and cognitively simple control over numerous degrees of biomimetic freedom [3].

Technological advances, such as integrated controllers, lithium-ion batteries and brushless motors, have allowed greater hardware for performance. The man-machine interface has evolved due to the use of algorithms for the processing of more sophisticated electromyography signals (EMG). However, despite these technological and scientific advances, it estimated that only 50% to 60% of people with an upper limb amputation use a prosthesis and of this group, only 40% to 60% use a prosthesis myoelectric [4, 5]. Prosthetics are crucial devices for amputees to improve the quality of their lives.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 145–151, 2020.
https://doi.org/10.1007/978-3-030-50838-8_20

2 Background

The specifications of the transhumeral prosthesis prototype should focus on meeting patient satisfaction. The design specifications were established taking into account the needs of an ordinary person, also considering prosthesis analysis and study of the human anatomy looking for a prototype that meets the minimum requirements of operation, cost and aesthetics.

2.1 Specs

The purpose of the transhumeral prosthesis prototype is to have 4 degrees of freedom that simulates the movements of flexion and extension of the elbow, flexion and extension of the wrist, rotation of the forearm in addition to abduction and adduction of the wrist, so that a extra space for the location of census and control elements.

In Fig. 1, you can see all the movements that the transhumeral prosthesis must comply.

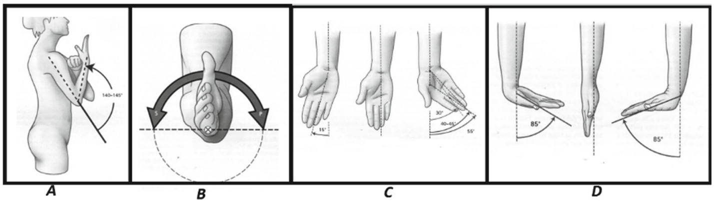

Fig. 1. Proposed movements for the transhumeral prosthesis [6]. A) Flex elbow extension. B) Forearm suppression. C) Abduction and Adduction. D) Wrist Flexo-extension.

In addition to these movements, this device will be coupled to "Maki 3.0" a right-hand prosthesis that is already developed at the Universidad Politécnica Salesiana, Cuenca-Ecuador (Fig. 2).

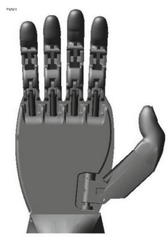

Fig. 2. Final prototype of Maki 3.0 developed at the Universidad Politécnica Salesiana [7].

"Maki 3.0" has a weight of 326 g, a height of 188.83 mm, a width of 84.13 mm and a thickness of 35.5 mm and it was established that the prosthesis could support a weight of 40 N (Maximum load supported by the actuators) [5].

3 Mechanical Design

3.1 Ranges of Motion

Elbow Flexo-Extension
The total range of motion of a healthy elbow is usually 0° (fully extended) to approximately 145° (fully flexed), although it is indicated that most ADLs can be performed with a range of motion between 30 and 130°, that is, 100° of movement [10] (Table 1).

Table 1. Specifications of some current prostheses.

Prostheses	Flexo-extension Elbow [Nm]	Angular velocity [deg/s]	Range of motion [°]
A Gas-Actuated Anthropomorphic Prosthesis for Transhumeral Amputees [17]	30	–	95
Design of a Myoelectric Transhumeral Prosthesis (2016) [18]	16	250	30° to 130° in flexion
The RIC arm - a small, anthropomorphic transhumeral prosthesis (2017) [19]	12	80	–
Diseño y construcción de un mecanismo paralelo para prototipo de prótesis transhumeral (2014) [15]	–	90	20°–125°
LTI Boston Elbow	12.1	113	–
ESTUDIES			
A study of the external forces and moments at the shoulder and elbow while performing every day tasks [20, 21]	5.8	–	N/A
Dynamics of the Upper Limb during Performance of the Tasks of Everyday Living—A Review of the Current Knowledge Base [21]	–	250	N/A

A range of motion can be set from 0° to 120°, with a speed that does not exceed 150°/s that is sufficient to perform ADLs.

Pronosupination

For pronosupination the total range of motion is usually from 0° (intermediate position) to approximately 90° (supination) and 85° (pronation), that is, it has a total range of movement of 175°.

In the following table, we see some torques and speeds of some current prostheses (Table 2).

Table 2. Specifications of some current prostheses for pronosupination.

Prostheses	Pronosupination [Nm]	Angular velocity [deg/s]	Range of motion [°]
A Gas-Actuated Anthropomorphic Prosthesis for Transhumeral Amputees [17]	4.2	–	150
Design of a Myoelectric Transhumeral Prosthesis (2016) [18]	1.5	150	180
The RIC arm - a small, anthropomorphic transhumeral prosthesis (2017) [19]	2.5	500	–
Diseño y construcción de un mecanismo paralelo para prototipo de prótesis transhumeral (2014) [18]	–	–	180
Motion control [16, 22]	0.7	216	180
Otto Bock wrist [19]	–	130–160	–
Utah Arm ProWrist Rotator [19]	1.7	300	–

Therefore, for an average we can find that an adequate speed for pronosupination of the prosthesis would be 150°/s as established in "Design of a Myoelectric Transhumeral Prosthesis" because higher speeds would seem a bit exaggerated to perform life activities daily. A range of motion can be set from 0° to 175°.

Cubital Radius Deviation and Flexion-Extension of Wrist

The gimbal is the part that resembles the movement that the wrist performs in terms of flexion - extension (red) and abduction-adduction (blue), these in their respective axes, this is an analogy to consider developing and designing movement's wrist Fig. 3.

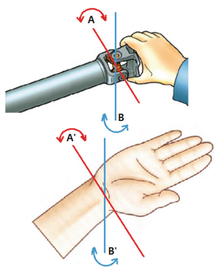

Fig. 3. Gimbal-wrist analogy. A–A′ flexo-extension axis. B–B′ axis abduction - adduction [6]

For the movement of Cubital radius deviation a linear actuator is used that allows us to perform the entire range of motion, which is defined for radius deviation from 0 to 20° and for ulnar deviation from 0 to 40°. The range of motion should be 30° for flexion, and 30° for extension.

3.2 Design

The Autodesk Inventor software developed the design of the prosthesis with the aforementioned movements. In this software, you can load the materials of each part and thus obtain an approximate weight of the prosthesis.

Thus, we have the following movements, taking into account the mechanical analogies and ranges of movement mentioned above Fig. 4.

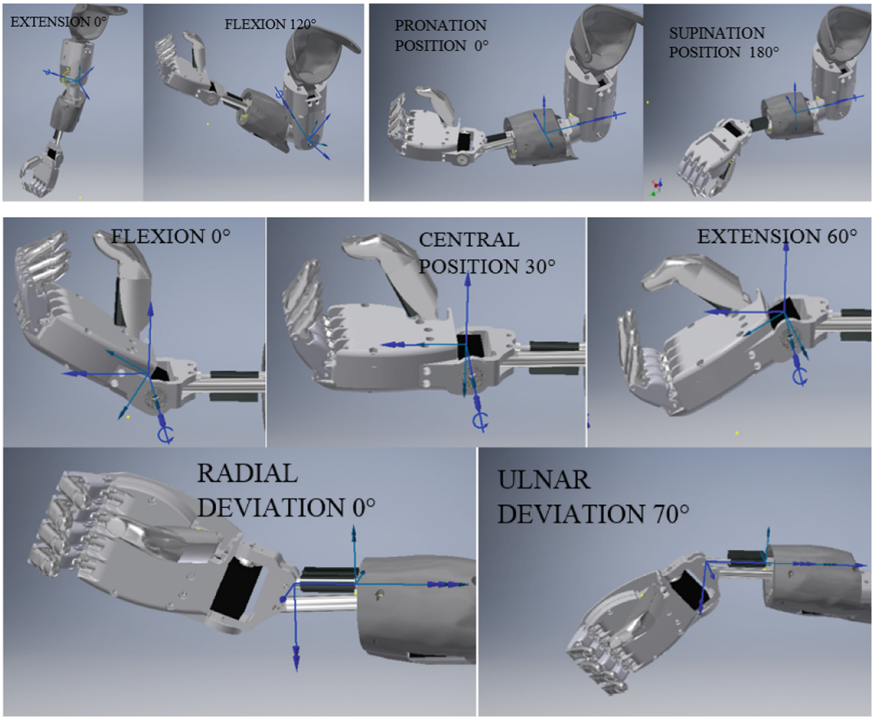

Fig. 4. Design of movements in inventor software.

In addition to this, the prosthesis according to the Inventor software, and placing all the materials that are: aluminum for the support shaft, carbon steel for the gears and pins, and ABS plastic (3D Printing) gives us an approximate weight of 1.85 kg, which is acceptable for the weight of the initially raised prosthesis.

It should be noted that in this design the actuators and batteries to be used have been placed, taking into account that servo motors were used in the movements of elbow flexion-extension, pronation-supination and flexion-extension of the wrist and linear actuators in the fingers and the ulnar radio deviation movement, while the batteries to be used will be about 18650 of 9800 mAh.

4 Discussion and Conclusion

This prototype is endowed with four degrees of freedom for the movements of elbow flexion-extension, pronation-supination, ulnar radius deviation and wrist-flexion extension, the necessary torques and forces must ensure that the prosthesis can lift a kilogram in the palm of the hand, this because this prosthesis is designed to be positioning in space and not specifically to lift large weights, so this prosthesis can lift objects weighing less than a kilogram.

The designed movements were based on mechanical analogies and the real ranges of movement of a person, in addition to considering the aesthetics of the device and the anthropometry for which the prosthesis was designed with an inclination of 12° of the humerus axis with respect to the arm (Fig. 5), very few prostheses realize this small design detail but it is very important to be able to maintain the symmetry of the body and perform movements much more in line with the person's real movements, so the patient will not feel a feeling of strangeness when use the device.

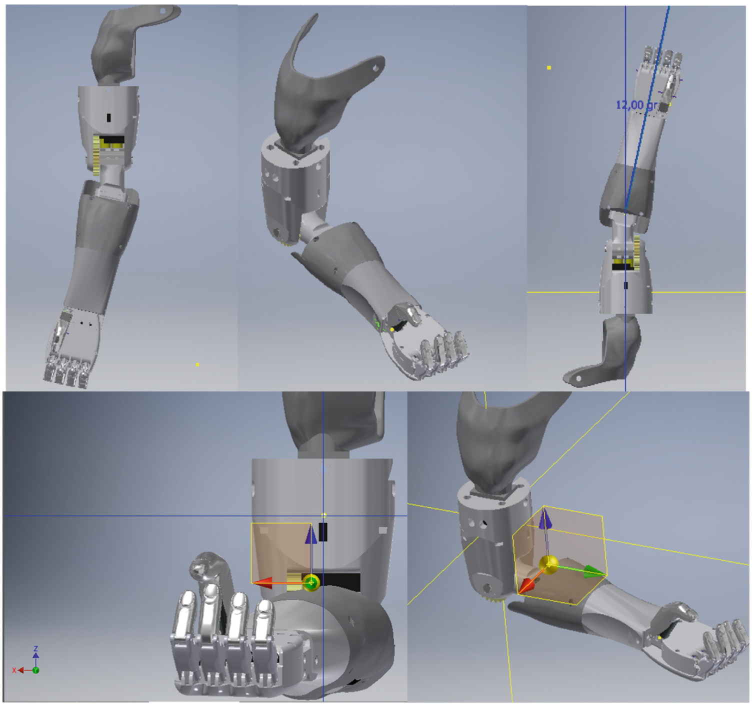

Fig. 5. Transhumeral prosthesis final design.

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Structural Anatomical Study of the Upper Limb to Design a Transhumeral Prosthesis

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Abstract. This document expresses a mechatronic design proposal for a transhumeral prosthesis, including flexo extension in the elbow joint, flexo extension and radial-ulnar deviation in the wrist joint and pronation supination of the forearm, solid models are presented that will perform arch of the movements expressed above.

Keywords: Elbow · Flexo-extension · Pronation-supination · Radial-cubital deviation · Transhumeral prostheses · Wrist

1 Introduction

In Ecuador, there is a registry by CONADIS (National Council for the Equalization of Disabilities) of people who have suffered the amputation of their upper limb, which includes the set of physical disabilities, for further discretization the study is focuses on an age range of 18 to 64 years of male gender within the province of Azuay, it is worth mentioning that the degree of disability of an amputation of this type is from 75% to 84%, with all this, there is a total of 61 people suffering from this type of situation [1].

The purpose in the development of prosthetics is to help people who have suffered the amputation of one of their limbs, so that they can perform and return to their activities of daily living (ADLs), today prostheses that require a degree greater movements, in order to simulate the natural movement of the limb depends on a greater compression of the anatomical study of the human body in reference to the upper limb, taking into account the complexity and the multiple degree of freedom (DoF) of the joints of the arm and the lack of appropriate muscles from which to record the EMG, with these requirements there are two types of upper limb prostheses: the type powered by the body and the myoelectric type [2–5].

For people, the amputation of one of their upper extremities above the elbow would imply a loss in the ability of movements of the elbow and the hand in the activities of daily life, these prostheses make people not feel comfortable in the development of their activities, with this problem raised, the objective of this research is the development of a new prosthesis design based on a structural anatomical study of the limb and goniometric studies of it, with which to have a better understanding of what would be the appropriate mechanisms and technologies to achieve this movement natural and

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 152–157, 2020.
https://doi.org/10.1007/978-3-030-50838-8_21

improve the quality of life of the people who will use it, this prosthesis will take as reference the joint physiology that is expressed in the author Kapandji's book "Joint Physiology", in which he expresses some mechanical diagrams that simulate movements for each joint [6].

The document is divided into three parts, "Theoretical framework", which expresses both commercial and research transhumeral prostheses and a brief description of the advantages and disadvantages of each one, and with which to have a perspective or reference of what currently, "Design" presents already developed parts of the design of the proposed transhumeral prosthesis.

2 Theoretical Framework

At first glance it is observed that commercial prostheses lack some degrees of freedom Dof, this is because they focus on the aesthetics of the prosthesis and an effort to reduce complexity and size sacrificing the ability to act and move them [13], while in a non-commercial sense, research-type prostheses are used; they focus on advances and innovation in control, personalization, materials and technology, in order to obtain results from the best materials and technologies for their development [14] (Table 1).

Table 1. Transhumeral prosthesis specifications

Name/reference	# DOF	Commercial	Flexo-extension elbow	Prono-supination Forearm	Flexo-extension wrist	Radial-ulnar deviation
Gas-actuated anthropomorphic prosthesis [7]	4	No	YES	YES	YES	YES
Design of a myoelectric transhumeral prosthesis [5]	4	No	YES	YES	YES	YES
The RIC arm	3	No	YES	YES	YES	No
Transhumeral mechanical prosthesis [8]	1	No	YES	No	No	No
DynamicArm transhumeral prosthesis [9]	2	YES	YES	No	YES	No
Michelangelo [10]	1	YES	No	No	YES	No
Prosthesis i-Limb [11]	2	YES	YES	YES	No	No
Luke arm [12]	2	YES	YES	YES	No	No

In a quick comparison between this type of prosthesis, we have that the research type, having all the degrees of freedom in mind, these do not tend to have their portable battery because they are only for movement analysis and the development of these achieve a high cost, due to the technology with which you want to implement and this makes them look robust, in turn the commercial type tends to limit them to their basic movements, thereby reducing cost in their production and their weight and concentrate on aesthetics.

3 Design

As a design proposal, it is borne in mind that it must have a balance both in cost of materials, weight, use of light materials, that is functional and has 4 degrees of freedom (DoF).

The critical point in the design of a transhumeral prosthesis is to determine its degrees of freedom (DoFs), this will give rise to the optical balance between the skill it may have and the final weight [15]. Based on these criteria, it was decided to develop a prosthesis with 4 degrees of freedom, 2-DoF in the wrist (Flexo-Extension, radial-ulnar deviation), 1-Dof in the elbow (Flexo-extension), 1-DoF of the forearm (Prone-supination), this prosthesis will be attached to “Maki 3.0”, a right-hand prosthesis that is already developed at the Universidad Politecnica Salesiana, Cuenca, which has 1 degree of freedom with 7 basic movements [16] (Table 2) (Fig. 1).

Table 2. Transhumeral prosthesis movement specifications

Part	# - DoF	Movement name	Range of motion [°]
Elbow	1	Flexo-extension	0° a 130°
Wrist	2	Flexion Extension	30° 30°
		Radial deviation Ulnar deviation	15° 45°
Forearm	1	Pronation - supination	0° a 175°

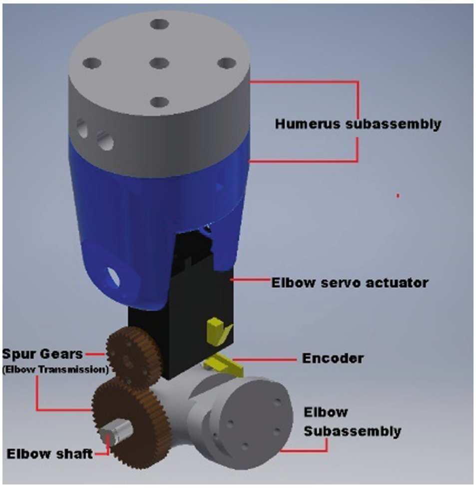

Fig. 1. Solid elbow model flexion/extension

For this type of movement, a 35 kg cm servo motor must be used to simulate the flexion/extension movement of the prosthesis, the material used for the humerus subassembly and elbow subassembly will be PLA, these will be manufactured by a 3D printer, the sprockets will be bronze (Fig. 2).

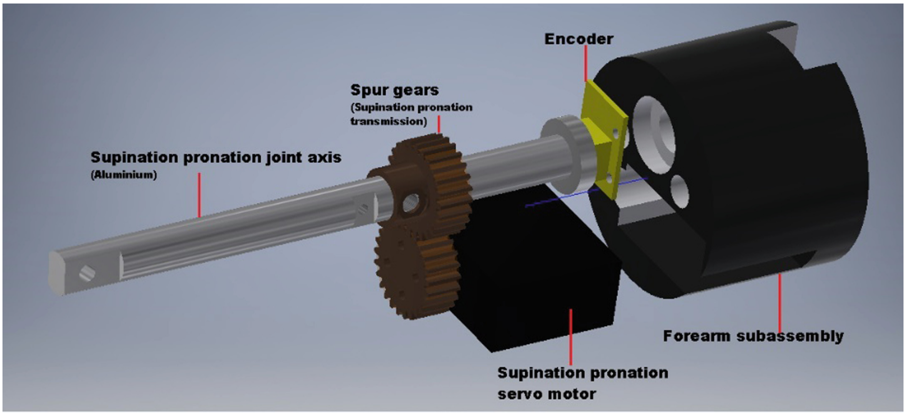

Fig. 2. Solid forearm prone/supination model

For this type of movement, a 35 kg cm servo motor must be used to simulate the prone/supination movement of the prosthesis, the material used for the forearm subassembly will be PLA, this will be manufactured by a 3D printer, the sprockets will be manufactured in bronze, the articular axis will be aluminum (Fig. 3).

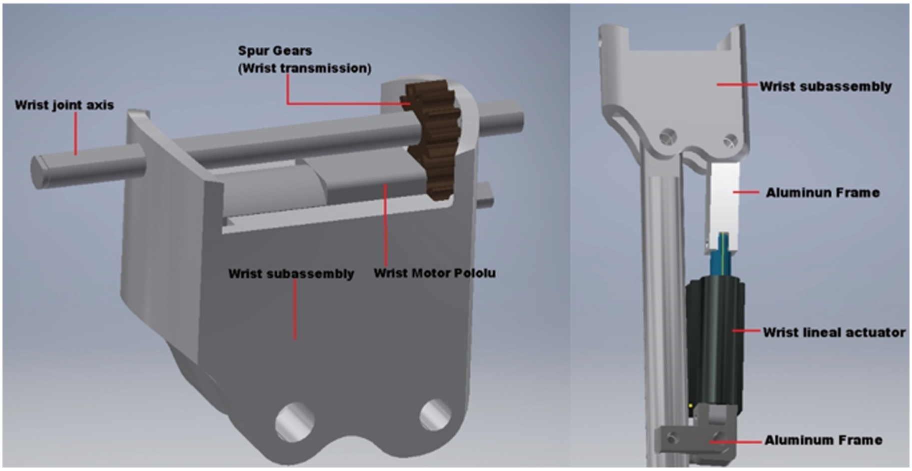

Fig. 3. Solid model of flexo wrist/extension and radial/ulnar deviation

For the flexo/extension movement, a 6 kg cm pololu motor will be used and for the ulnar radial deviation, a 7.6 N linear actuator, the frames will be made of aluminum and the wrist subassembly will be made of PLA, it will be manufactured by a 3D printer (Fig. 4).

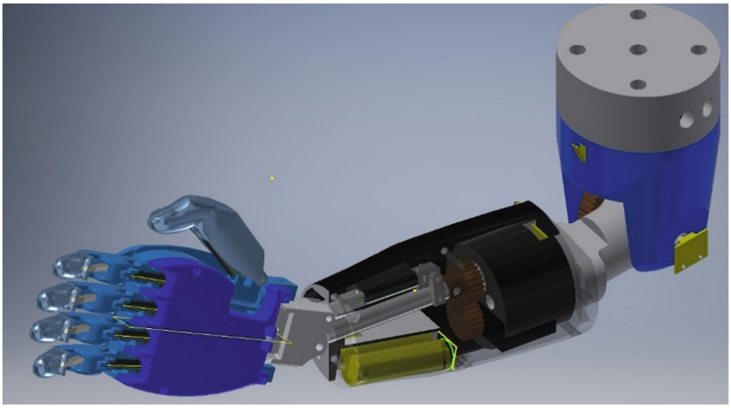

Fig. 4. Solid prototype prosthesis model

4 Conclusion

The article focuses on presenting the design of each of the parts that make up the prosthesis, this prosthesis aims to be an experimental research base of the best materials to use for its manufacture, and in turn allow the evaluation of control strategy to improve the functionality of them, as future work, their manufacture is intended and with this, carry out studies with amputee subjects to evaluate the movements of the prosthesis and verify the validity of the design, and after this, investigate control methods that allow effective manipulation of each movement.

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Clinical Care

Real-Time Video Analytics for Measuring Colonoscopy Performance

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Abstract. We have developed a real-time video analytics system for measuring colonoscopy performance, including total visible surface areas, real-time feedback to the endoscopist about the measurements of visible surface areas, video clarity, preparation, and distention conditions. Our lab experiments show that the correlations between the computer and the experienced colonoscopist are: 76% in visible surface area estimation, 83.9% in clarity evaluation, 90% in preparation condition assessment, and 67.9% in distention condition evaluation. Our algorithm appears to be faster in response to dynamic scope movements compared to a 3D scope positioning device. In addition, the clinical experiment shows the system detected unexpected scope malfunction events in real-time.

Keywords: Endoscopy · Video · Colonoscopy · Real-time · Surface area · Computer vision

1 Introduction

A colonoscopy is a therapeutic screening method for detecting precancerous polyps, colon cancers, and many other diseases. It involves a manually-controlled endoscopic camera connected to a computer and a display. Currently, the procedures are performed based on visual observation and experience. A field survey found that the rate of missing polyps present in the patient can reach as high as 28% [1, 2]. The scope moving speed, fatigue, and vigilance each plays a significant role in the detection of polyps. In addition, the clarity of the colonoscopy video, patients' preparation, and colon distention status are measurable factors. The most critical factor however, is where the scope is aimed to. A colon can be simplified as a cylinder that has four quadrants. A well-trained colonoscopist would make sure all quadrants are thoroughly inspected. Therefore, the visible surface area is an essential measurement to assess whether the operator has missed any quadrants during the screening process, normally during the scope withdrawal period. In order to detect polyps, the scope first needs to be aimed in the right direction. This is important to future AI systems as well. Any AI system would not be able to perfectly detect polyps from the video unless the scope sweeps through all surface areas. Furthermore, it is beneficial to evaluate the colonoscopy procedure performance in real-time, when the colonoscope is still inside the patient's body so that the doctor can go back to examine the missing area.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 161–167, 2020.
https://doi.org/10.1007/978-3-030-50838-8_22

For over a decade, researchers have developed quantitative methods to evaluate the quality of exam (QoE) for colonoscopy procedures [3–7], including measuring the scope moving speed [3], scope rotational patterns, video clarity, preparation conditions, and so on. However, visible surface measurement and comprehensive data visualization are still missing in most literature.

Recently, the author's lab has developed a computer-assisted colonoscopy procedure performance quality measurement system from live colonoscopy videos [8, 9]. The system provides for an objective assessment of the colonoscopy. The system can also be integrated into existing colonoscopy systems without modification. Additionally, it provides real-time feedback so that the operators can reassess areas of potential decreased visibility. The system can be used for quality assurance, training, and improvement of the polyp detection rate. In this study, we focus on the laboratory experiments to compare the measurements between an experienced colonoscopist and the computer. We will also present case studies in the clinical environment to assess the accuracy of the proposed method, including comparing the Olympus' 3D scope position sensor ScopeGuide™ with the computer's result and the system's response to an anomalous scope event.

2 Overview of the System

In this study, we divide the wall of the colon into four quadrants: top left (TL), top right (TR), bottom left (BL), and bottom right (BR). See Fig. 1. In this system, we calculate the measurements per section over a given distance, currently every 5 cm. The display of the measurement results is shown in Fig. 1 on the right. First, we measure the camera orientation by detecting the vanishing point of the scope view to determine which quadrant it is aimed at. Then, we calculate the coverage percentage for the length section, update the accumulated measurements for the section, and repeat until the colon exit is detected.

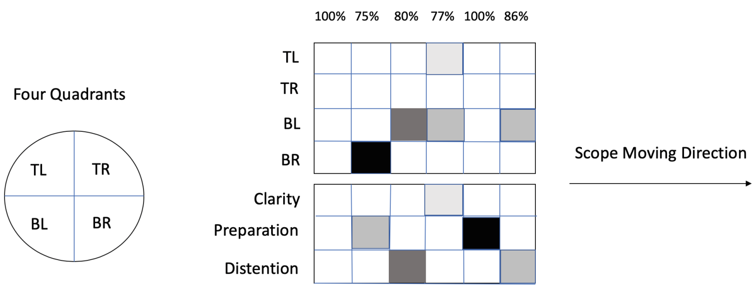

Fig. 1. An illustration of the four quadrants of the wall of a colon and visualization of the measurements of endoscopy performance: visible surfaces, clarity, preparation, and distention

The scope travel distance can be obtained over time with optical flow and *epi*-polar plane projection. Based on the estimation of the scope's orientation and travel distance, we can calculate the total percentage of the examined surface. We visualize the surface in 4 $\times$ n cells, where 4 rows represent 4 quadrants and n columns represent n segments of 5 or 10 cm wide rings of the colon wall. The number of columns varies, depending on the length of the colon. There is a counter for each cell that counts how many frames in the 10 cm segment the cell (e.g. Top Left) that were visible in the video. For example, if we set the minimal number of frames on any 10 cm segment to 500, then a count of 250 would amount to 50% coverage. We then map the percentage value to a color heat map. For example, if the coverage is zero, then the cell color is black. If the coverage is 100%, then the color is white or green (e.g. where the intensity level is 255).

The visualization panel also includes scores for clarity, preparation conditions, and distention level. Clarity is a measurement of the image quality of the video, which measures blurriness with a Gaussian Function. Preparation is a measurement of the existence of food, colored drink, or stool, which can be recognized by a color vision model. Distention is a measurement of expansion of the diameter of a colon when it is filled with pumped air, which is described by a shape model. Those measurements can be mapped into additional grid cells below the surface map, with the same scope location cursor and columns. The multiple measurement maps can be updated in real-time and exported into a log file after the procedure in an XML format.

In this study, we have collected over 60 videos for testing. 22 videos were prepared for surface area evaluation, including good, suboptimal, and bad surface area videos. For distention, we prepared 17 videos, including good distention (i.e. a fully opened colon) and bad distention (i.e. a closed colon). To evaluate the preparation of the colon, we prepared 15 videos that have stool and videos that do not have stool. For clarity, 8 videos were used in our evaluation.

3 Visible Surface Area Measurement

In the surface area evaluation, the software calculates the visibility results of four quadrants every 5 cm. Figures 2 and 3 show the overall average evaluation of surface area of the colonoscopist versus the computer. Here, we found a correlation of around 76%. When we asked the colonoscopist to repeat the evaluation, we found that the computer's results appear to be more consistent than humans.

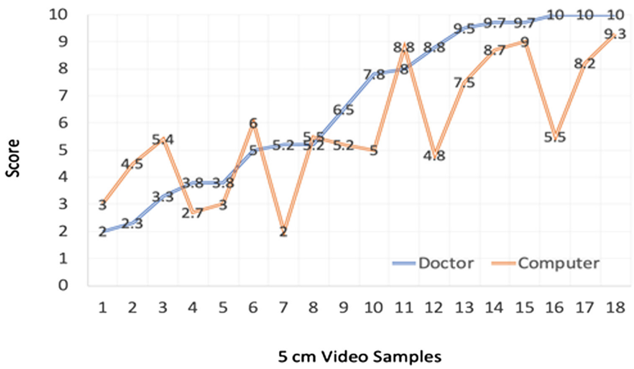

Fig. 2. Average visible surface area scores by the doctor and computer

4 Clarity Evaluation

Clarity is evaluated based upon how the video quality compares from that of the doctor and that of the computer. Eight videos were used to evaluate the software on clarity, and the correlation found between the doctor and the computer was 83.9%.

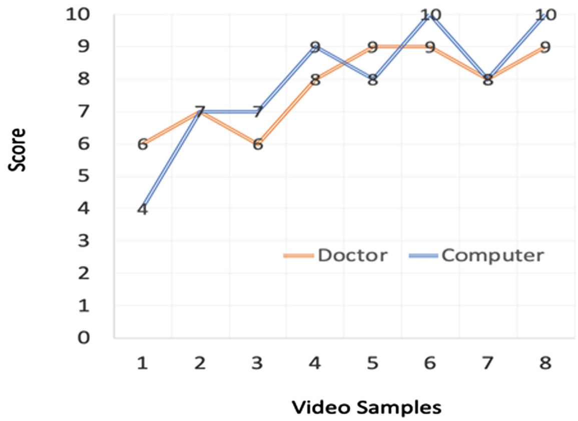

Fig. 3. Clarity evaluation between the doctor and the computer

5 Preparation Condition Evaluation

In this experiment, the preparation condition refers to the detection of stool in a given frame. The videos were scored from 0% to 100%. We found the correlation is around 90%. The computer results are consistent with the expert's assessment (Fig. 4).

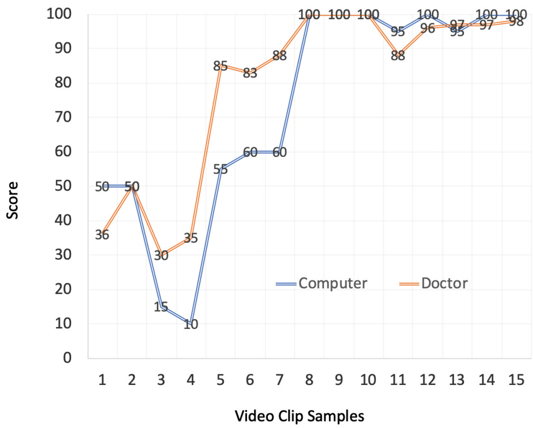

Fig. 4. Preparation scores from the doctor and the computer.

6 Distention Evaluation

Distension calculation is based upon the shape of the cross-section of folds in a given part of the colon. The correlation is 67.9%. The results show that there is room for improvement in the shape classification algorithm, especially in some anomalous cases. A prime example would be the "bad" video segment, where the doctor scores only 1 but the computer scores 6 (Fig. 5).

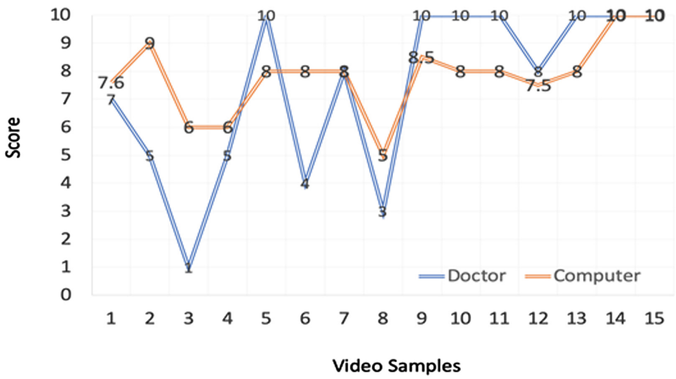

Fig. 5. Distention scores by the doctor and the computer

7 Comparison with 3D Position Sensor

We compared the computer's distance estimation result with the Olympus 3D position sensor ScopeGuide (™) in real-time and recorded the data from both systems (Fig. 6).

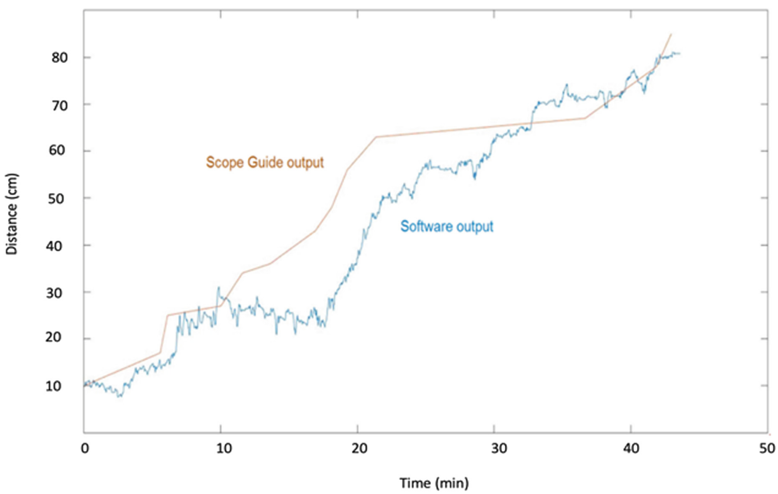

Fig. 6. Comparison of the 3D magnetic tracker ScopeGuide (™) output vs. the software output

We found that our system has a much faster tracking response time (30 frames per second) than the ScopeGuide™ (less than 1 frame per second). Therefore, our system can reveal more dynamic information than the existing equipment. In addition, our system can provide the scope orientation at the quadrant level, but the ScopeGuide™ cannot.

8 Performance Evaluation in Clinical Environment

We tested the system at an endoscopy laboratory. Figure 7 shows a screenshot of the system in normal operation conditions. The visualization shows that the colonoscopy procedure was going well and most scores were perfect. Figure 8 shows an anomalous situation in which the scope cable broke down and failed to tilt its head around. The visible surface area measurement shows high percentages of missing areas.

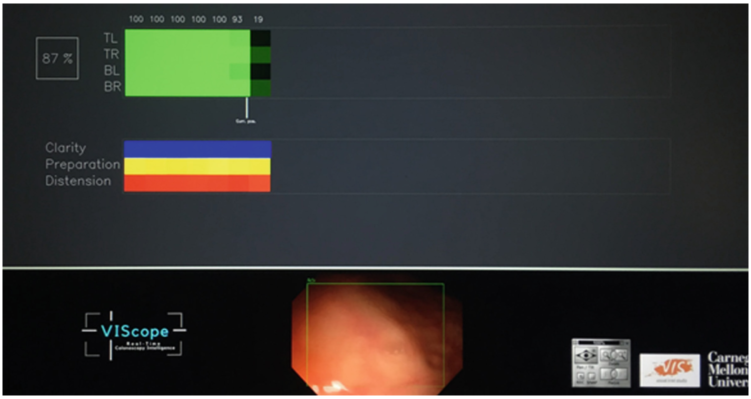

Fig. 7. The screenshot of the display during the real-time experiment in an endoscopy lab

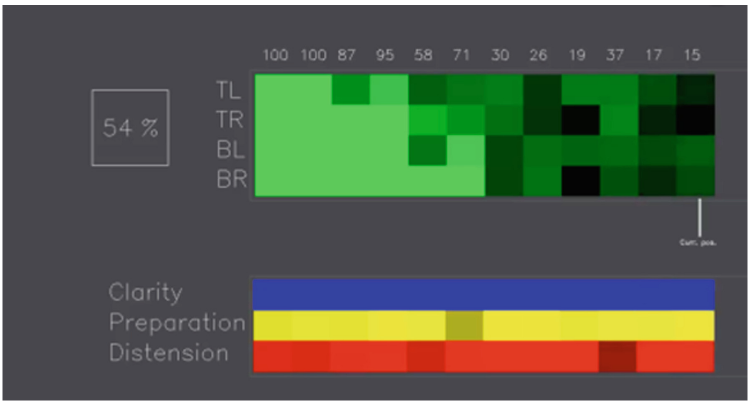

Fig. 8. The display shows the anomalous event where the scope was broken

This kind of incident happened only once a year at most, but we were lucky to encounter such an anomalous incident to prove the effectiveness of our system.

9 Conclusions

We have developed a real-time video analytics system for measuring colonoscopy performance. The quality of the exam evaluation includes the estimation of total visible surface areas per segment, real-time feedback to the endoscopist of areas visualized, and a color-coded display demonstrating exam quality in real-time for clarity, preparation conditions, and distention conditions. Our lab experiments show that the correlations between the computer and the experienced colonoscopist are: 76% in visible surface area estimation, 83.9% in clarity evaluation, 90% in preparation condition assessment, and 67.9% in distention condition evaluation. Our algorithm appears to be faster in response to dynamic scope movements compared to a 3D scope positioning device. In addition, the clinical experiment shows that the system detected unexpected scope malfunction events in real-time.

Acknowledgements. The authors would like to thank Dawit Weldeghergish for data analysis and Dr. Shyam Thakkar for data collection and the quality of exam evaluation. The project is sponsored by Innovation Works, CMU, and the DHTI program.

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High Fidelity and Objectivity in Balance Assessment—A Comparative Study of the 6-Degree Motion Tracking for Body Balance Assessment to the Conventional Paper Test

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Abstract. Body balance is an essential capability for an individual to perform functional activities. There are various performance-based balance measures available to occupational therapists. However, conventional balance measures are limited due to subjectivity. There is a prominent need for a more objective and accurate assessment. NIMBLE, using motion sensing and tracking system was developed for a more objective and accurate measure of body movement with high-resolution recording. A pilot study was conducted in 20 participants for functional sitting balance measures by using both paper-based assessment and the NIMBLE. Results showed substantial discrepancies when the NIMBLE was able to detect balance deficits when the paper-based measures failed. The NIMBLE system can accurately capture the extraction of joint centers and segment orientation, providing the ability to calculate joint kinematics and spatiotemporal aspects of the movement. With this low cost and friendly interface, it has great potential to be widely used in healthcare practices.

Keywords: Balance · Measurements · Motion-sensing

1 Introduction

Body balance is an essential capability for an individual to perform activities of daily living (ADLs). There are various performance-based body-balance measures available to occupational therapy clinicians (OT) such as Postural Assessment Scale [1] for Stroke patients, Sitting Balance Scale (SBS) [2], Berg Balance Scale (BBS) [3], Function in Sitting Test (FIST) [4] and Functional Reach Test (FRT) [5]. However, the sitting balance measure is mostly limited to a paper test that is a scoring system for professionals to conduct the test with a subjective assessment. There is a prominent need for a more objective and accurate assessment. The NIMBLE is such a motion sensing and tracking system developed for objectively assessing patients' body balance in high-resolution motion recording. The system uses a six-degree sensing camera system that integrates depth assessment with traditional two-dimensional images. The patients' body motion is identified through a skeleton structure with key joint points. The program focuses on the patients' spinal movement highlighted by the spine-shoulder joints and pelvis as a base joint.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 168–174, 2020.
https://doi.org/10.1007/978-3-030-50838-8_23

A collaboration between the School of Occupational Therapy (OT) at Texas Woman's University (TWU) and the College of Architecture and Design at the University of Houston (UH) was established in Spring 2017. In Fall 2019, a team of researchers and undergraduate students continued to develop a motion capture system, the NIMBLE by using the Microsoft Kinect system for sitting balance measurement. The purpose of this proposed study is to examine the validity and reliability of this Kinect motion capture system comparing to current performance-based sitting balance measurements. The NIMBLE uses Microsoft Kinect as the main source to detect movement. The Kinect system incorporates an infra-red light and a video camera to create a 3D map of the area in front of it [6] and uses a randomized decision forest algorithm to automatically determine anatomical landmarks on the body, such as joint centers, in close to real-time [7]. The NIMBLE also uses open-source programming to record total travel distance, the velocity of movement, and fluidity during the sitting balance test.

2 Study

2.1 Participants

A pilot study was conducted at a senior activity center in two sessions. A convenience sampling of 20 participants took part in the balance assessment tests. Their age ranged between 60 and 94. Each participant was evaluated by two students simultaneously where one student used the conventional paper-based test and the other student used the NIMBLE system.

2.2 Testing Method

Each participant was tested using the following 5 tests to evaluate sitting balance. Each test was performed with the patient sitting unsupported on a stool with both feet on the floor. The NIMBLE system was set up in front of the patient (see Figs. 1 and 2 for setting).

Fig. 1. The testing setup with the Microsoft Kinect.

Fig. 2. A patient is being tested

Test #1. Sitting Unsupported with Eyes Open for 30 s. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Able to sit safely and securely for 30 s. (3) Able to sit 30 s under supervision. (2) Able to sit 20 s. (1) Able to sit 10 s. (0) Unable to sit without support 10 s.

Test #2. Sitting Unsupported with Eyes Closed for 30 s. The scoring criteria are the same as the first test.

Test #3. Reaching Forward with the Outstretched Arm while Sitting. Patients were asked to make a fist and extend their arm forward to shoulder height (approximately 90 degrees). An object was placed 12 in. from the patient's fist in line with the patient's arm. The patient was asked to try to touch the object with their knuckles without losing balance. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Can reach forward confidently > 10 in. (3) Can reach forward > 5 in. (2) Can reach forward > 2 in. (1) Reaches forward but needs supervision. (0) Loses balance while trying/requires external support.

Test #4. Pick Up an Object from the Floor. An object was placed on the floor 3 in. in front of the patient's toes. The paper test scored each patient between 0 and 4, 4 being the best score. (4) Able to pick up slipper without losing balance. (3) Able to pick up slipper but needs supervision for balance. (2) Unable to pick up slipper but reaches 1–2 in. from slipper and keeps balance independently. (1) Unable to pick up and needs supervision while trying. (0) Unable to try/needs assistance to keep from losing balance or falling.

Test #5. Reaching Laterally with an Outstretched Arm. Patients were asked to make a fist and extend their arm out to the side, laterally, to shoulder height approximately 90 degrees. An object was placed 12 in. from the patient's fist in line with the patient's arm. The patient was asked to try to touch the object with their knuckles without losing balance. The paper test scored each patient between 0 and 4, 4 being the best score. The scores were as follows: (4) Can reach laterally confidently > 10 in. (3) Can reach laterally > 5 in. (2) Can reach laterally > 2 in. (1) Reaches laterally but needs supervision. (0) Loses balance while trying/requires external support.

3 Results

The NIMBLE system captures body movements 10 frames per second and generates a spreadsheet displaying the exact movement increments and illustrating sketches to show movement. All 20 patients obtained a perfect score on the paper tests in all 5 tests which indicated no sitting balance deficits. However, according to the Nimble system, 6 out of the 20 patients showed movement that could not be picked up by eyes and relayed on the paper test. The following illustrations show how Nimble can pick up movement that can help Occupational Therapists be aware of patients' balance problems. Figure 3 shows a screen-capture example (Subject 001) of a perfect sitting test with eyes open unsupported for 30 s (Test#1). As in these displays, the graph on the left shows the testing subject's head movements from a top view. The graph on the right shows the testing subject's body movements in six-degree space representing by moving lines in three colors. The red line shows the forward and backward movement. The green line shows the right to left movement. The blue line shows the up and down movement. In Fig. 3, there are very few signs of any movement. Figure 4 and Fig. 5 show results from subjects 004 and 005 performing the same test but whose body moved backward and forward (the red line) that was nor picked up by the paper test.

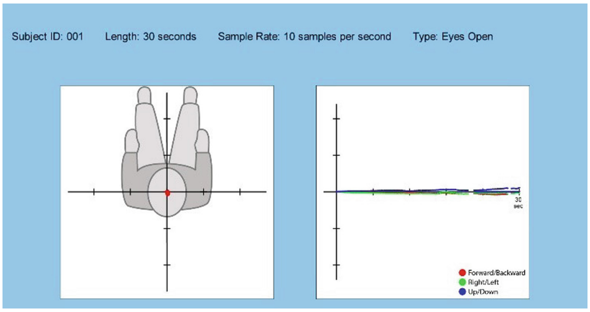

Fig. 3. Screen capture of a normal testing subject's test record. (Color figure online)

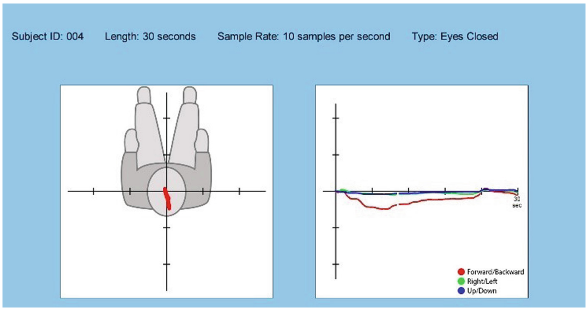

Fig. 4. Screen capture of the testing subject 004. (Color figure online)

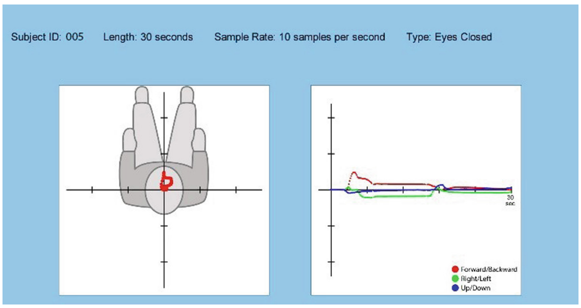

Fig. 5. Screen capture of the testing subject 005. (Color figure online)

Figure 6 shows the subject 011 in a perfect performance of the reaching forward test (Test#3) in a normal person. Figure 7 illustrates subject 004 taking a longer time than expected to complete the test. Figure 8 is an example of one subject leaning backward and returning.

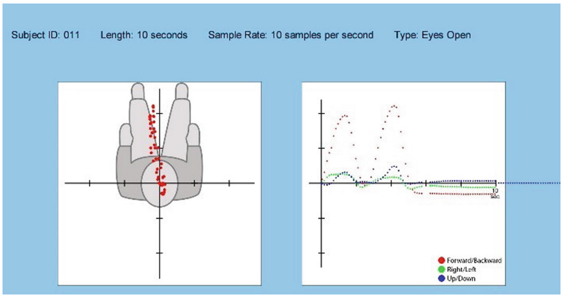

Fig. 6. Subject 011 in a leaning forward test.

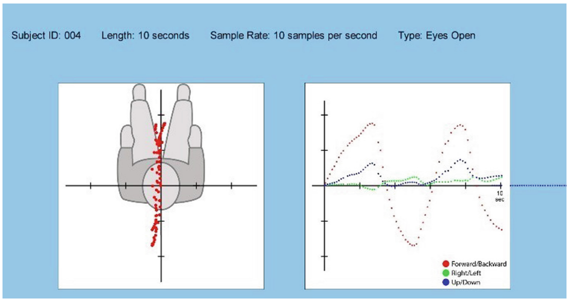

Fig. 7. Subject 004 in a leaning forward test.

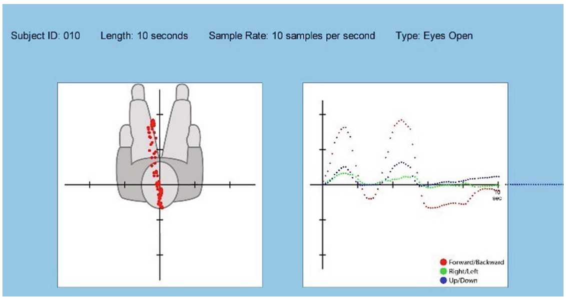

Fig. 8. Subject 010 in a leaning forward test.

Figure 9 is an example of a normal performance to pick up an object from the floor (Test#4). On the contrary, Fig. 10 is an example of participant 005 that moved backward when returned to his starting position. Figure 11 is an example of participant 003 who overshot the target when reaching down.

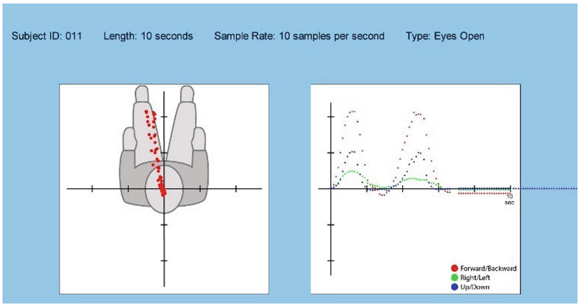

Fig. 9. Normal performance to pick up an object from the floor

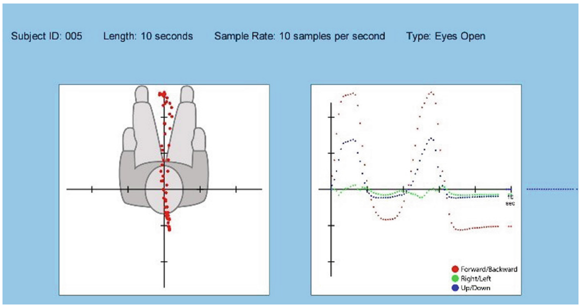

Fig. 10. Participant 005

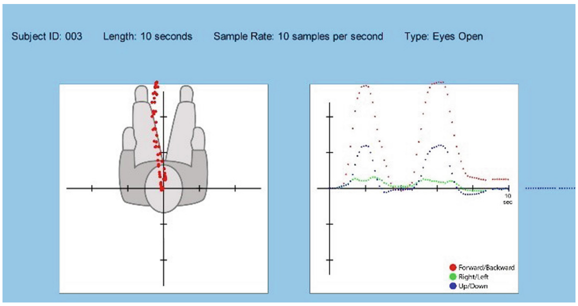

Fig. 11. Participant 003

4 Conclusion

The NIMBLE has shown an excellent capability to capture human body movements when paper-based tests failed to detect balance deficits. The NIMBLE uses a low cost and user-friendly motion sensing and tracking system to measure balance and has a great potential to be used in various healthcare settings. Through the NIMBLE, data is generated and collected on a large scale and the data can be calculated and visualized to show patients' balanced state in a high resolution. The NIMBLE is an objective balance assessment tool that is precise and accurate to measure total travel, velocity, and fluidity of human movement.

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A Unified Framework for Human Centered Design of a Substance Use, Abuse, and Recovery Support System

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Abstract. This research explores the analysis, design, and testing of a software application to support opioid peer specialists working to assist substance users, abusers, those in recovery, and their families. The paper presents a framework integrating best practice approaches from Design Science Research, Community Based Participatory Research, and human centered and user experience design principles for the purpose of: 1) guiding community based, goal-directed software design, and 2) building and evaluating a substance use, abuse, and recovery software application. Focus group findings from 33 participants suggest that using the framework enables alignment between human centered system requirements; personal, family, and community-based program goal achievement; and local/state population health directives. End user feedback indicates that the software application design addresses specific human interaction needs for the complex high-stakes context of opioid use, abuse, and recovery.

Keywords: Human factors · Human-centered design · Design science · Community based participatory research · Substance abuse · eHealth · Health informatics

1 Introduction

Even though opioid prescribing seems to be on the decline, the number of individuals that experience some form of substance abuse each year is staggering [1]. According to the National Survey on Drug Use and Health (NSDUH), 19.7 million American adults (aged 12 and older) battled a substance use disorder in 2017, 8.5 million of these suffered from both a mental health disorder and a substance use disorder, or co-occurring disorders. An estimated 20.7 million people needed treatment for a substance use disorder, while only 4 million (19%) received treatment. Drug abuse and addiction

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 175–182, 2020.
https://doi.org/10.1007/978-3-030-50838-8_24

cost American society more than $740 billion annually in lost workplace productivity, healthcare expenses, and crime-related costs, while also causing life altering consequences to the victims, and victim family members, friends, employers, and the surrounding community [1, 2]. Further, the Centers for Disease Control and Prevention (CDC) reports that 68% of the more than 70,200 drug overdose deaths in 2017 were opioid related, that approximately 10% of those prescribed opioids develop a dependence on the drug, and that approximately 5% of those transition to heroin [3].

While it is generally believed that there is no one solution to combat the opioid epidemic, most believe that tackling this problem from a prevention perspective, so that people do not become addicted, as well as from a treatment perspective to reduce the risk of death, will result in fewer overdoses and deaths from opioids. A recent report noted that current users could be impacted through early identification of addicts and linking people to resources and treatment [4].

Community based and healthcare organizations across the U.S. are working diligently to try and address this epidemic and the core challenges associated with its rise. This research explores the role of information technology design to meet the strategic alignment goals of a community-based organization working to assist substance users, abusers, those in recovery, and their families. This paper presents a unified, human centered framework to guide software design, requirements engineering for substance abuse stakeholders, assessment of human factors associated with sustained utilization of the application, and achievement of community health and societal goals.

1.1 Addressing the Opioid Problem in Jefferson County, Alabama

The Jefferson County, Alabama community has many initiatives to try to attack the opioid related death problem. To address the critical individual, community, and public health issue of opioids, the Jefferson County Department of Health (JCDH) created a Recovery Resource Center (RRC) with Certified Peer Specialists (CPS). CPSs are individuals in recovery from substance use disorders trained by the State of Alabama Department of Mental Health. The training focuses on providing peer support education, and helping others pursuing recovery to access available resources and recovery programs within the community [5]. Support includes regular interactions with peers such as goal setting, regular follow-up, and screening for potential mental health and substance abuse issues. The lack of an adequate data system to support these efforts, during what has been described as a public health crisis, provides motivation for a design science approach to a community based participatory project to enable more effective interactions and analytics for improved peer support efforts. For this study, we worked with the Jefferson County RRC, which provides a range of services, peer support specialists, and mental health/substance abuse counselors to help substance abusers or a family member navigate the substance abuse treatment system. A software system was designed and developed in support of this program as described below.

2 Research Approach and Methodology

This research project combined best practices of design science research with community-based participatory research methods to design a web-based application for opioid addiction support to be used by CPSs. The web-based application is called Data Collection and Reporting Information System for Opioid Peer Specialists (DCARIS-OPS). We use a cyclical and incremental design process to discover, design, develop, test, and evaluate DCARIS-OPS.

2.1 System Design Constructs

Several high-level concepts and organizational constructs were used as a foundation for designing an application in support of the JCDH RRC program. The core requirements for the system to function and accomplish its intended goals include 1) enabling data collection of client activities relative to addiction prevention and treatment; 2) ability for the CPS to conduct consistent, complete and efficient wellness assessments for clients; and 3) the system should facilitate quality peer-client interactions. Other notable requirements include HIPAA compliance, web and mobile responsive interface, interoperability with state Health Information Exchange, access controls and roles definitions, performance and compliance reporting capabilities. These requirements must be built in support of the actions and functions of a core and guiding socio-organizational artifact called the community resource center (CRC). CRCs promote well-being in targeted populations in distinct communities following a social accountability and person-centered care community perspective model [6, 7] to enable positive downstream impacts to the community [8, 9]. These are aligned with an accountable care community (ACC) approach to improving the health of those in the community by integrating community resources [10, 11]. Studies implementing the ACC approach have demonstrated decreased emergency department utilization, decreased hospital readmissions, and increased rates of optimal care delivery for those with ambulatory sensitive conditions such as diabetes and asthma [11]. These centers provide CPSs to provide communication, friendship, counseling, and human-centered empathetic support based on real-world experience with substance abuse and recovery for people trying to recover from opioid abuse [12].

2.2 System Design Process

The overall design science research (DSR) approach and process employed is aligned with that of Peffers, et al. which describes a six-pronged approach as shown in level 1, Fig. 1: 1) problem identification and motivation, 2) defining objective of the solution, 3) artifact design and development, 4) demonstration, 5) evaluation, and 6) communication [13]. A design science approach allows for iteratively designing for performance of an artifact. Because this project includes a community based participatory approach, an iterative and feedback cycle was created that included our community partner, the RRC.

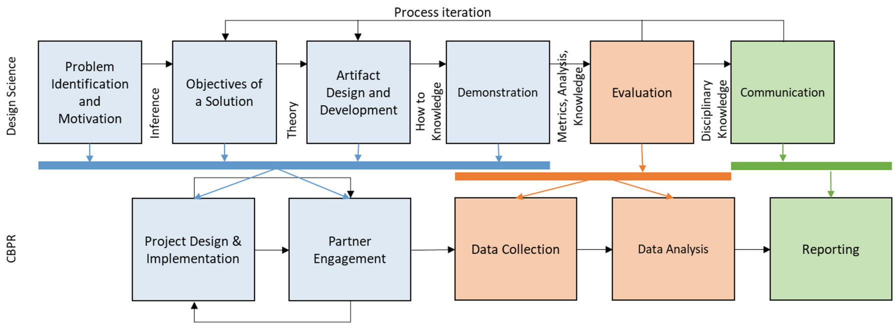

Fig. 1. Unified Design Science Research and Community Based Participatory Research framework

Community Based Participatory Approach. Community based participatory research (CBPR) has been defined by Kellogg Health Scholars as "a collaborative approach to research that equitably involves all partners in the research process and recognizes the unique strengths that each brings." CBPR begins with a research topic of importance to the community and has the aim of combining knowledge with action and achieving social change to improve health outcomes and eliminate health disparities [14] to mutually benefit the academic and community partners [15]. We employed the CBPR process model introduced by Burns, et al. [16] to foster collaboration of the community partner at the problem identification/motivation stage of the project shown in level two of 1.

The CBPR model is primarily linear except for the iterative project design phase. Combining the design science approach illustrated in level 1, Fig. 1 with the CBPR approach in level 2, Fig. 2 enables a combined model that allows the following design process features:

1. Provides an iterative model for community partner engagement through all phases of the combined DSR framework and CBPR.
2. Facilitates agile methodologies through all phases of work, such as engaging in incremental requirements gathering and solutions seeking with the community partner.
3. Identifies partner engagement as a core requirement for success within the planning and design of the artifact.
4. Highlights both artifact and project design features prior to implementation.
5. Infers that community program and technological artifact are bound to one another as an integrated solution.
6. Explicitly specifies data collection, analysis, and evaluation activities as interconnected – a practical conceptual model for artifact design.

Combining DSR and CBPR framework models is meant to complement the action-based methods of health and social action researchers and the rigorous process of artifact creation.

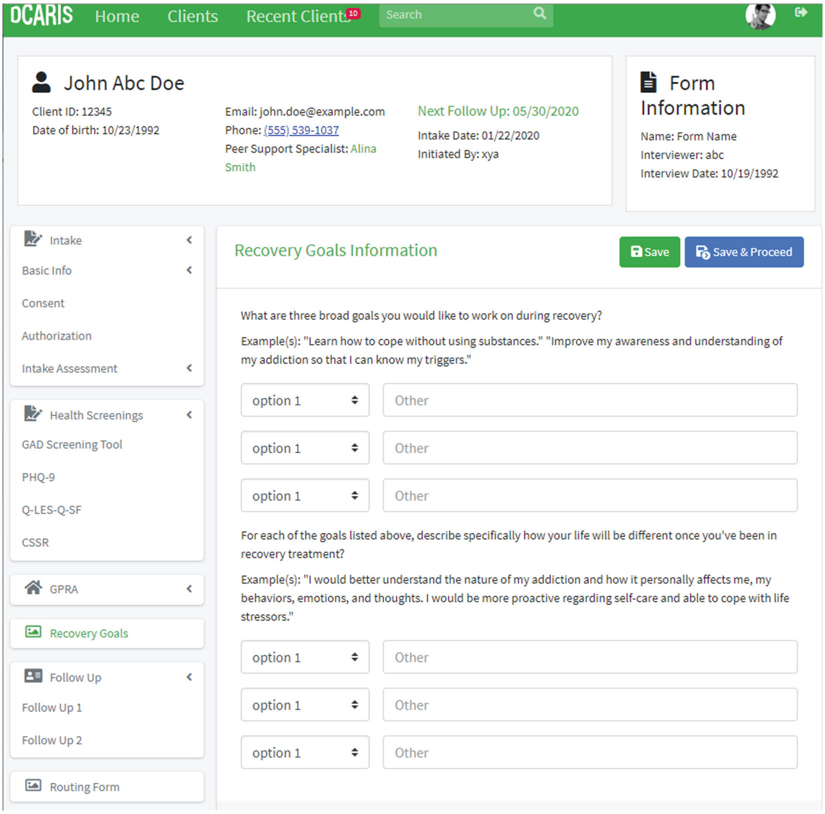

Fig. 2. Modular prototype design. Modules on the left side of the screen include: intake, health screening, recovery goals and care coordination, client interactions and follow up, and reporting. The top portion of the figure provides client information while the main section of this particular screenshot shows the recovery goals section of the application for creating and tracking goals together with clients.

2.3 Artifact Development and Feedback Process

Several meetings were held with stakeholders to gather requirements and understand the goals and needs. The first meeting was a focus group with 13 people that included CPSs (4), counselors (2), administration (3), physician (1), and researchers (3). The goal was to understand the meta-requirements or the system goals. Structured questions were asked to gather feedback to inform the usability, usefulness, sustainability, and scalability [17, 18]. Next we met with only the CPSs to understand requirements from the community partner and the application of theory to those requirements [15]. This focus group included 8 CPSs, only four of whom were in the original meeting: 4 females and 4 males. From this meeting, we learned the meta-design or how the system should behave. During this session, we employed focused questions about the work environment and applied cognitive techniques such as scenario creation and story-boarding [19]. The RRC was consulted numerous times during the design and prototype development stages. Ad-hoc meetings were used to elicit a “blink response” to the prototype design. We found that users wanted a system that would allow them to move in a non-liner fashion, create individual workflows, work efficiently by not inputting redundant data, and be able to use data for state level reporting. Consistent with CBPR, we reconvened with the RRC to present the semi-functional prototype and ensure that an acceptable modular design. Feedback was incorporated into prototype refinements. A final focus group meeting was held with CPSs and administration with the goal to ensure that the functional design aligned with the philosophical and goal-oriented focus of the program stakeholders.

3 Results

Using the document and interview analysis, feedback from meetings, and the design theory process model described earlier, an initial prototype was developed. The prototype followed a modular design to support CPS needs consisting of six modules as shown in Fig. 2. A modular approach fit the essential need for future changes to client wellness tracking, reporting, positive communication methods, persuasive design functionality, and for usability to remain consistently high. Modularity also supported the essential need for both mobility and security/privacy dealing with highly sensitive client data.

4 Discussion and Conclusion

This paper reports on an approach to developing a software application to enable certified peer specialist’s in their pursuit of caring for clients with substance use disorders. Working with the recovery resource center in Alabama, we integrated best practice frameworks from Design Science Research and Community Based Participatory Research to develop a unified framework to: 1) guide community based, goal-directed software design, and 2) build and evaluate a new substance use, abuse, and recovery software application for its capability to support patient centered and population health centered goals. Focus group findings from 33 participants suggest that using this framework enables alignment between human centered system requirements; personal, family, and community-based program goal achievement; and local/state population health directives. End user feedback indicates that the software application design addresses specific human interaction needs for the complex high-stakes context of opioid use, abuse, and recovery. We found the combined model complemented the action-based methods of health and social action researchers and the rigorous process of artifact creation to strengthen the efforts of our interdisciplinary team of technology designers, engineers, social workers, healthcare practitioners, and researchers.

Acknowledgments. This project is funded through a Community Health Scholars Grant from UAB. The UAB Center for the Study of Community Health (CSCH), one of 26 Prevention Research Centers (PRCs) designated nationally by CDC, is an initiative to encourage community-based participatory research (CBPR) by UAB faculty. Additional funding is provided through AL State Medicaid.

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Investigation and Analysis of Ergonomic Risk Factors Associated with Laparoscopic Surgeries Using Rapid Upper Limb Assessment (RULA) Tool

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Abstract. Laparoscopic surgeries are associated with less severe postoperative pain, shorter hospitalization and shorter inability to work. Despite the many advantages for patients, laparoscopic surgery causes certain ergonomic risks for surgeons, such as loss of freedom during surgical maneuvers, maintenance of forced body postures for long periods, and inappropriate arm and wrist flexion, bending, and twisting. Therefore, the aim of this study was to measure, and analyze the working postures during laparoscopic surgeries using rapid upper limb assessment (RULA) tool. Sixteen subjects performed simulated laparoscopic tasks, such as peg transfer, and precision cutting. Two cameras were used to capture the motions occurred on the frontal and sagittal planes. It was concluded that laparoscopic instruments should be designed in a way that reduces arms and wrist inappropriate postures in order to keep upper arms at the sides of their body, and avoiding pressure points on hands and fingers.

Keywords: Laparoscopic · RULA · Ergonomics · Upper limb

1 Introduction

Laparoscopic surgery is one of the rapidly developing fields of minimally invasive surgery and is now used in almost all areas of a general surgery [1]. The idea of laparoscopic surgery was born in the early 20th century. The most dynamic growth occurred during the 90th years of last century. Previous studies had compared the results of laparoscopic surgeries with the results of open ones. The study undoubtedly showed that laparoscopy is safer and cheaper, and it is associated with less severe postoperative pain, shorter hospitalization and shorter inability to work [2]. Regardless of the advantages for patients, laparoscopy involves some ergonomic risks for surgeons, such as, loss of mobility freedom during surgeries, long durations of static postures, and maintenance of awkward postures. This might lead to increased levels of physical and mental stresses imposed on the surgeons [3]. Combining these factors with the nonergonomic design of laparoscopic surgical tools may lead to decreasing the surgeons' accuracy and performance, as well as physical fatigue and musculoskeletal disorders (MSD) in the arms, back and neck [4]. Previous studies showed that several

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 183–188, 2020.
https://doi.org/10.1007/978-3-030-50838-8_25

factors affected surgeon's body posture during laparoscopic surgeries, such as the design of the surgical instruments, the height of the operating table, the use of foot pedals, and the position of the main screen [5–10]. However, the literature provides a few descriptions of the results of research in the field of ergonomics of laparoscopic instruments. Nevertheless, they clearly indicate the problems in this area. Therefore, the aim of this study was to investigate and analyze the ergonomic risks associated with laparoscopic surgeries on the upper body using rapid upper limb assessment (RULA) method. The RULA method was developed to consider biomechanical and postural loads on the neck, trunk and upper extremities caused by the job in order to measure the exposure of workers to risk factors associated MSD [11, 12]. It was developed in order to use it without the need for an advanced or expensive ergonomics equipment.

2 RULA (Rapid Upper Limb Assessment)

RULA posture assessment template provides diagrams of the range of motions of the upper and lower arms, wrists, neck, trunk, and legs from the most optimal to the worst body postures including muscles work during static standing. The first score evaluates flexion/extension of the upper, lower arms, and wrists. The second score evaluates flexion/extension, twisting and side-bending of the neck and trunk, and legs muscle use during static posture. These scores are then added to generate a score between 1 and 7, in which; score "1–2" represents negligible risk, "3–4" low risk, change may be needed, "5–6" means medium risk, task should be redesigned soon, and "7 or above" indicates high risk, and implement changes. Selection of the postures to be evaluated were based on the most difficult postures and work tasks, or the posture sustained for the longest period of time.

3 Equipment and Tools

A Fundamental of Laparoscopic Surgery (FLS) box was used to simulate the activity performed during laparoscopic surgery. The trainer box is a device for practicing surgeons that facilitates the development of skills required during the performance of basic laparoscopic surgery. Moreover, a five megapixel USB camera was attached to the FLS box in order to capture and magnify the simulated activities. The FLS simulator camera was connected to a 20" screen on a tripod that was adjusted based on subject's height. Moreover, the FLS box was placed on a height-adjustable table to provide the best working level for the participant's elbow height. The FLS box is equipped with an endoscopic scissors (i.e. for tissue dissection and transaction), and graspers (i.e. to facilitate both optimal grip on the target tissue and easy retrieval of the sample), as shown in Fig. 1. Moreover, to capture and record the movements on the frontal and sagittal planes, two video cameras were used. The experimental setup is explained later.

Fig. 1. Fundamental of Laparoscopic Surgery (FLS) box, connected to a computer screen, and equipped with an endoscopic grasper (green square), and scissors (red square).

4 Experimental Protocol

Participants performed the simulated tasks given by the FLS Trainer System. Namely, peg transfer, and precision cutting. These simulated tasks are included in the FLS certification exam. The peg transfer task consisted of moving objects from one side to another of the board and then move them back to the other side using the graspers. For the precision cutting task, subjects cut along a stamped circle on a piece of paper held with a clip. They were asked to cut the circle by the endoscopic scissors using their right hands (i.e. dominant hands), and use the grasper with their left hands to hold the paper. Figure 2 shows the simulated tasks.

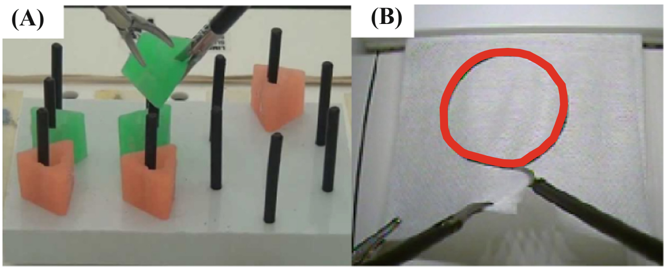

Fig. 2. The simulated tasks of Fundamental of Laparoscopic Surgery (FLS). (A) Peg transferee, and (B) Precision cutting.

Video was recorded via 2 cameras, one facing the subject to capture the movements on the frontal plane, and the second camera directed to the subject's right side to record the motions on the sagittal plane, as shown in Fig. 3. A total of 16 subjects participated in the study. Each subject received training sessions on the FLS trainer box. All 16 subjects were right-handed in order to assure consistency in the experimental settings. Each subjected signed an informed consent before participating in the experiment. The study was approved by the University's Institutional Review Board (IRB).

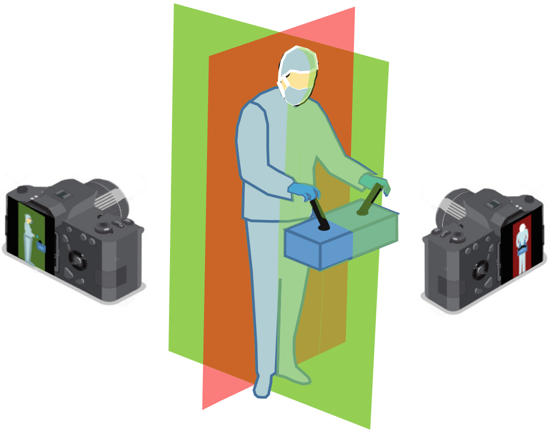

Fig. 3. Setup of the laparoscopic surgery experiment. Two video cameras were used to record the motions on the frontal plane (red rectangle), and sagittal plane (green rectangle)

5 Results

Data from video recordings of each participant's posture were analyzed using RULA method to find the grand score. Table 1 shows the ranges of values for each limb, and the grand RULA score of for all participants.

Table 1. The score of each upper limb position and the grand RULA score of the study for all participants.

Arm & wrist analysis		Neck, trunk, & leg analysis		RULA score
Upper arm position	2–3	Neck position	1	3–4
Lower arm position	1	Trunk position	1	
Wrist position	2–3	Legs position	1	
Wrist twist	0–1	Muscle use score	1	
Muscle use score	1	Neck, trunk, & leg score	2	
Arm & wrist score	4–5			

6 Discussion

The aim of this study was to investigate and analyze the ergonomic risks associated with laparoscopic surgeries on the upper body using RULA method. For the upper arm position, the score ranged from 2–3 based on its degree of flexion. During the experiment, participants flexed their upper arms between 30°–50°. In this study, most of the time the lower arm was flexed between 35°–95°, which was the least stressed posture. Wrist position received a score between 3–4, since there was excessive wrist flexion, extension, and twisting (i.e. higher than ±15°) in maneuvering the scissors and the graspers during the experiment. This could be because of the small opened area for the laparoscopic apparatus, which forced the surgeons to move their wrists excessively. A score of 1 (i.e. straight back) was given to the neck, and trunk positions, because the screen, and the table were adjusted to participants' heights in order to avoid awkward postures. Moreover, since almost all the laparoscopic surgeries are performed while the surgeons are standing statically more than 10 min, the muscle use had a score of 1 during the study. Prolonged standing has been shown to be associated with a number of potentially serious health outcomes, such as lower back and leg pain, cardiovascular problems, fatigue, and discomfort [13]. This result is in line with previous studies that concluded that performance of laparoscopy causes strain on different muscle groups and often requires the surgeon to assume a nonergonomic and awkward postures [14, 15]. After adding all the scores, a grand RULA score between 3–4 was obtained for all the participants. This score indicates that there should be further investigations, and changes might be needed in the task in order to reduce the ergonomic risk factors. The findings of this study confirm the nonergonomic design of laparoscopic instruments, since it is associated with working postures that is not within the preferred ranges of motion that might imposes a risk of injuries to the surgeons. Postures maintained during the experiment were associated with an increased upper and lower arm flexion, and wrist flexion and twisting. In conclusion, laparoscopic instruments should allow surgeons to reduce the flexion, rotation, and ulnar deviation of the wrist, in order to keep both arms at the sides of their body, and to avoid points of pressure on their fingers. Moreover, the one-handed technique should be used during the laparoscopic surgeries in order to avoid the awkward postures. This technique means that the surgeon dissects with one hand and perform secondary tasks (i.e. that doesn't require fine movements), such as holding the camera, with the other hand. The assistant will also use one-hand to perform other activities, such as grasping or cutting.

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Essential Care for Every Baby: Neonatal Clinical Decision Support Tool

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Abstract. Unacceptably high rates of neonatal mortality are an urgent global health challenge. Consistent application of Essential Newborn Care (ENC) interventions reduce newborn mortality. However, ENC has failed to scale-up in low-middle income countries, where the bulk of neonatal deaths occur. The American Academy of Pediatrics designed an evidence-based, simplified training and educational curriculum called Essential Care for Every Baby (ECEB), which includes a clinical practice guideline for the time of delivery through 24 h after birth. However, the scale-up of ECEB has been hampered by the need to provide a wide variety of time-sensitive ECEB interventions to numerous mother-baby pairs. This incurs significant cognitive load among providers who perform varied tasks every few minutes for each baby. In this high-load, stressful situation, there are often profound gaps in the delivery of crucial ECEB strategies. We propose an innovative, scalable, clinical decision support mobile app which prioritizes recognition over recall and addresses existing challenges.

Keywords: Neonatal health · Clinical decision support · Pediatric care · Mobile applications · Cognitive load · Essential care

1 Description of the Challenge and Why It's Important to Address

Globally, rates of neonatal mortality (NMR) are unacceptably high. An estimated 2.5 million children die every year during the first month of life (0–28 days postnatal), with about 1 million of these deaths on the first day. Most of the burden of newborn mortality is shouldered by low and middle-income countries (LMICs) [1], where access to skilled and trained health care providers, well-equipped health facilities, and robust health system infrastructure is often lacking. Within this context, nearly half of all mothers and newborns do not receive skilled care during and immediately after birth. It is estimated that if all mother-baby dyads had consistent access to skilled delivery and immediate postpartum care, we could prevent nearly two-thirds of maternal and neonatal deaths [2]. Essential Newborn Care (ENC) is an evidence-based package of preventative, monitoring, and management interventions that are recommended by

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 189–196, 2020.
https://doi.org/10.1007/978-3-030-50838-8_26

global health partners, including the World Health Organization [3]. These recommendations are supposed to be delivered to every baby, everywhere, around the world, from shortly after delivery through the first month of life. Essential Newborn Care interventions include, but are not limited to, those associated with timely and exclusive breastfeeding, hand hygiene, umbilical cord care, immunizations, and routine monitoring of key vital signs such as the baby's breathing, heart rate, and body temperature. Several key ENC activities are recommended to be delivered on the first day of life, from immediately after delivery and onward.

A key structural barrier to the consistent delivery of crucial, lifesaving ENC interventions in LMICs is a chronic and profound shortage of health care workers (nurses, midwives, physicians, nursing assistants). This is a particularly acute problem in regards to newborn care [4]. Lack of health worker capacity, in turn, impacts the ability of new educational, training, and health service delivery packages to be disseminated and implemented sustainably. Also, the lack of human capacity can lead to cognitive overload and burden among the few health workers who do serve mothers and infants [5]. It may be difficult for in-service health care workers to leave their clinical service duties to attend multi-day training courses. Currently, the WHO ENC training curriculum is a 5-day course. In response to these challenges, the American Academy of Pediatrics (AAP), in collaboration with key partners such as USAID and the World Health Organization, has responded by creating a simplified, evidence-based clinical practice education and training program called *Essential Care for Every Baby* (ECEB) [6].

The ECEB curriculum is designed to be delivered in 1.5 to 2 days and is composed of three main educational and training aids for healthcare providers. These include Facilitator Flip Chart, Provider's Guide, and Action Plan. Our efforts in this project focus on developing a dynamic digitized ECEB Action Plan for mobile devices. The ECEB Action Plan (Fig. 1) constitutes a series of decision support actions and a list of time-sensitive tasks that play a critical role in preventing, recognizing, and managing common problems experienced by newborns within the first 24 h after delivery. The first few days at and around the time of birth are most dangerous for newborns; the risk for death is highest. Thus, equipping healthcare providers with the knowledge, skills, and competencies for essential newborn care directly contributes to improved survival of the neonate within the first 24 h. Based on the ECEB Action Plan, assessments made in the first 90 min after birth assist the health care workers to classify newborns under their care into categories of Normal, Problem, and High Risk. These categories further denote various degrees of monitoring and support that newborns subsequently receive. One key feature of ECEB is a color-coded risk and monitoring assessment schema, in which green denotes "normal," yellow denotes "problem," and red denotes "emergency/urgent care. Drawing upon lessons learned from challenges related to the implementation of other MNCH initiatives (e.g., identification of sick newborns, implementation of KMC) within LMICs, we know that barriers, bottlenecks, and gaps, related to shortages of healthcare providers and high levels of cognitive load and stress among frontline health workers, also confront the ECEB program. This could be one of the reasons that ECEB has not scaled as broadly as originally anticipated when launched in 2015. Also, the current paper-based ECEB Action Plan serves as a static job aid, often mounted on a wall as a poster, provides some ability to guide clinical decision making. However, it does not provide automated, easy access to the tracking of deliveries and mother-infant dyads within high-pressure situations like labor and postnatal wards, where there is an urgent need to better equip harried nurses with the ability to continuously monitor and track the location of babies within multiple wards and across various nursing shifts.

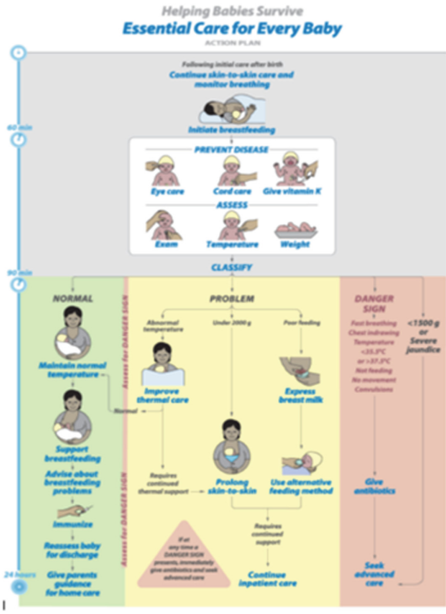

Fig. 1. ECEB action plan [6].

2 Description of the Proposed Solution and Design

The proposed solution is the development of an Android-based mobile Clinical Decision Support Tool (CDST). The solution aims to address the myriad challenges faced by health care providers in LMICs, to equip them to more effectively provide complete essential newborn care for every baby under their purview. This includes the ability to efficiently track and be reminded, of time-sensitive ECEB tasks that are required for each baby, according to each infant's time of delivery. Thus, we designed the ECEB Digital Action Plan to run on a 24-h timer analogous to the ECEB chart, with the same suggested assessments or interventions delivered at specific time points, while maintaining the paper-based clinical decision support tool's suggested sequence of events and branching logic. We have built a solution to have has a threefold functionality beginning with the elimination of the cognitive load resulting from the paper-based system. Secondly, the ECEB Digital Action Plan provides access to data (location, time, the status of the newborn, assessments administered) at the fingertips of the health care workers, at the time of each baby's need. We have also ensured security through password protection.

Thirdly, like all well-designed clinical decision support tools, the ECEB Digital Action Plan sends notifications reminding healthcare providers when a baby needs to receive specific care interventions. In addition, automated algorithms determine, based on information that the health worker adds about key parameters such as birth weight and vital signs, whether the baby is immediate danger and/or requires urgent care. Tapping the alert directs the user to the appropriate phase. Additionally, the mobile application supports automated functionality for ECEB-recommended algorithms and classification schemes for infants as normal, problem, and high risk. The classification is based on information entered by the healthcare providers, and automated, thus reducing the cognitive load for the nurses.

Because The ECEB Digital Action Plan CDST is designed to be deployed and functional within poorly resourced settings, the tool supports an offline push notification system and does not require internet access. This is proposed as a mobile application and not a web application because a preponderance of the evidence has shown that although clinical decision support systems (CDSS) are able to improve the effectiveness of care [7–9], the vast majority of evaluations have been conducted in high-income countries [10–12]. Given the vastly different health systems and infrastructure, the effectiveness of CDSS in LMIC settings is unclear [13]. To maximize the potential for success of the implementation of clinical decision support tools in facilities with infrastructure limitations, it is advisable to build accessible and affordable mobile device-based platforms with reliable offline functionality [14]. More so, mobile apps also provide personalization and notification benefits that make them more useable than desktop interfaces [15].

2.1 Discussion of the Design Steps

The first iteration of the CDST was developed in alignment with the principles of human-centered design to maximize adoption potential. A critical examination of the design and functionality was performed by doing heuristic evaluations and system usability tests in 40 participatory design sessions at 3 different facility sites in Kenya. Analysis of this qualitative and quantitative data from a critical realism [16] epistemological frame of reference has also informed our proposed design. The research and empathize steps for our design process are similar in both the iterations. The steps combined included problem identification, followed by an intensive in-depth literature review on varying topics like essential newborn care, mHealth applications, cognitive load, medical bias, automation, and color stimulation in a hospital setting. Generative methods were used like affinity mapping, user personas, and user journey mapping to understand the user. It was absolutely important to understand the user involved in the design process of the solution. Deep penetration, and adoption of, clinical decision-support tools (CDST) requires aggressively seeking a better understanding of what the right information is and when and how it should be delivered to the right person, at the right time, as well as a critical examination of the unintended consequences of CDST implementation [17]. Enhancements needed around usability and functionality were identified. Detailed documentation along with the think-aloud comments in these testing sessions and engagements rounds were performed, primarily focusing on user experience and ability to follow and complete the given tasks. The evaluation phase of the first iteration included usability testing and the nelson's heuristic evaluation (Fig. 2) (Table 1).

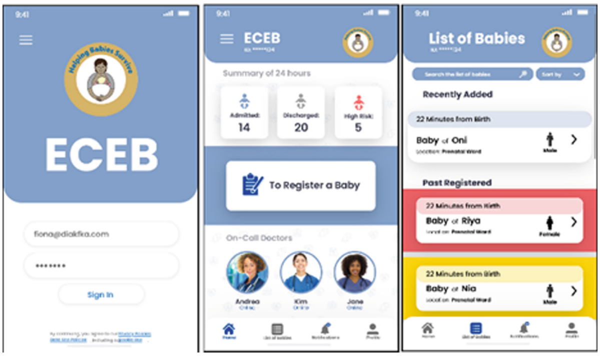

Fig. 2. Mockup showing different colors to denote different levels of emergency, thus reducing cognitive load and promoting recognition rather than recall.

Table 1. Changes in design between the field-testing iterations

	Function	First iteration	Proposed design changes
1	Workflow	Users were not able to differentiate between the primary & secondary function of registering a child and access the list of babies	The primary function is now a part of dashboard highlighted. The other functions are now designed as a part of the tool bar
1.1		Users were not able to switch between the phases of multiple children and lost thread of the workflow	The proposed design has now been re sequenced so as that all the phases of the child is in a collapsible list. A simple workflow and branching logic were established to promote detectability of tasks
1.2		Location of the newborn changes in the first 24 h, this was not captured in the first iteration	The second iteration the location of the newborn can be updated on multiple occasions
1.3		Weight, skin color & multi organ assessments were not a part of the first iteration	All the mentioned components are a part of the proposed design

(*continued*)

Table 1. (*continued*)

	Function	First iteration	Proposed design changes
2	Word Usage	The word "DANGER" coupled with the color red instilled panic among healthcare workers thus increasing cognitive load	The word DANGER in now replaced with "HIGH RISK"
2.1		Generic button design was being used like "NEXT" or "SAVE"	In the proposed design the Action button labels are being used. Ed: "SAVE & MOVE TO PHASE 2"
3	User Interface Design	The users were observed to have problems in the visibility of Icons, use of colors, labeling and navigation	The proposed design now has clarity, consistency, legibility, and comprehensibility
3.1		The user could not differentiate between the radio buttons and checklists	The new proposed design is consistent, and uniform and we have now removed the options radio buttons

The proposed design is heavily influenced by the review of the collected data and discussions were held to achieve a group consensus with research and technical team members. Meetings were held with domain and content experts in the fields of Pediatrics and Bio-Health Informatics to further inform the technology team of the health landscape, use cases, as well as discuss technology constraints related to app development for low power, low resource settings [18] along with brainstorming individually and as a group to allow emergence and articulation of the design criteria. Understanding that this tool would be used in high-pressure situations, the basic proposed theme is light blue and white, thus eliciting a calm and kind response from users. However, the tool that follows the ECEB algorithm classifies the child into different phases is color-coded and saved, propelling the feature of recognition vs recall health care worker. A convergence of ideas led to the identification of core features, including the need to establish a link between the mobile Helping Babies Survive powered by DHIS2 app (mHBS/DHIS2; [19]) and ECEB Digital Action Plan.

Strengths & Weakness of the Design. The design is simple and graphical to comprehend and use, with bold displays and large lettering. The texts and graphics have been arranged in different sizes of the importance of the information conveyed. Dynamic buttons that change colors on touch have been provided to give a confirmation of the option being active. The majority of the options are also accessible in multiple ways. The Clinical Decision Tool aims at classifying, as well as organizing the tasks based on a timestamp. These are converted as alerts and reminders and provided to the health workers. Features such as offline alerts and live locations help tremendously to reduce the cognitive load and helps multiple health workers to perform activities on the same baby even if the location is changed. The weakness of the design includes Multiple information display, lack of flexibility, reductant options and lack of universal accessibility.

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Ontological Description of the Skills of Colonoscopy

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Abstract. Colonoscope insertion can be difficult due to the complicated anatomy of the large intestine. However, clinical training in colonoscope insertion remains hands-on, and introducing Artificial Intelligence (AI) to training and skill certification in colonoscopy will require ontological and semantic descriptions of the clinical procedure. Therefore, the total colonoscopy procedure was described ontologically to develop a strategic education and simulation program. We propose an ontological analysis method comprising colonoscopy procedures and techniques and investigate the feasibility of an ontological approach to the training and evaluation of clinical colonoscopy skills.

Keywords: Colonoscopy · Medical education · Ontology

1 Introduction

The demand for endoscopic diagnosis and treatment of colorectal disease is rapidly increasing, but clinical education in colonoscope insertion remains hands-on. Introducing Artificial Intelligence (AI) to colonoscopy training and certification will require ontological and semantic descriptions of the procedure. Ontologies are explicit formal specifications of terms in a domain and the associations among them. Total colonoscopy procedures were categorized and described ontologically to develop a strategic education and skill evaluation program. This study proposes an ontological analysis of colonoscopy techniques and procedures and investigates the feasibility of an ontological approach to the training and evaluation of clinical colonoscopy skills.

2 Materials and Methods

We analyzed procedures and techniques used by physicians during total colonoscopy and developed appropriate ontological descriptions. Analysis was based upon the clinical colonoscopy and simple training simulator for colonoscopy (Fig. 1, Fig. 2).

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 197–202, 2020.
https://doi.org/10.1007/978-3-030-50838-8_27

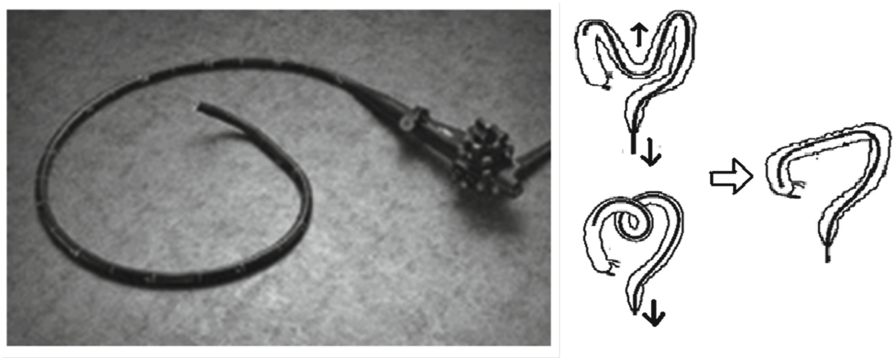

Fig. 1. Colonoscope and its insertion technique

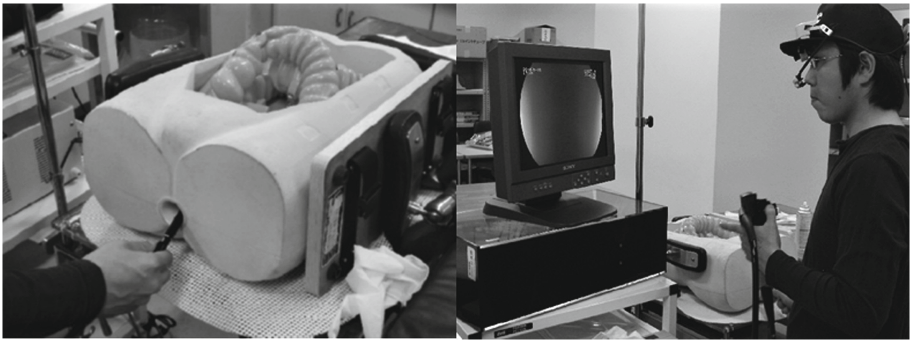

Fig. 2. Training simulator for insertion of colonoscope

3 Results

The basic techniques used by physicians during colonoscopy (pushing, pulling, tilting, bending, suction, and insufflation) were classified and described using ontological concepts. They were shown in Fig. 3. Ontological description of search the insertion route and problem solving during the insertion procedure were described and shown in Fig. 4. Ontological descriptions of insertion procedure from rectum to ascending colon were described and shown in Fig. 5 and Fig. 6.

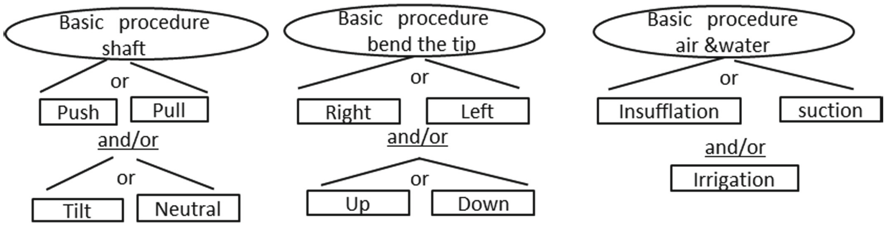

Fig. 3. Ontological description of basic procedure of colonoscope

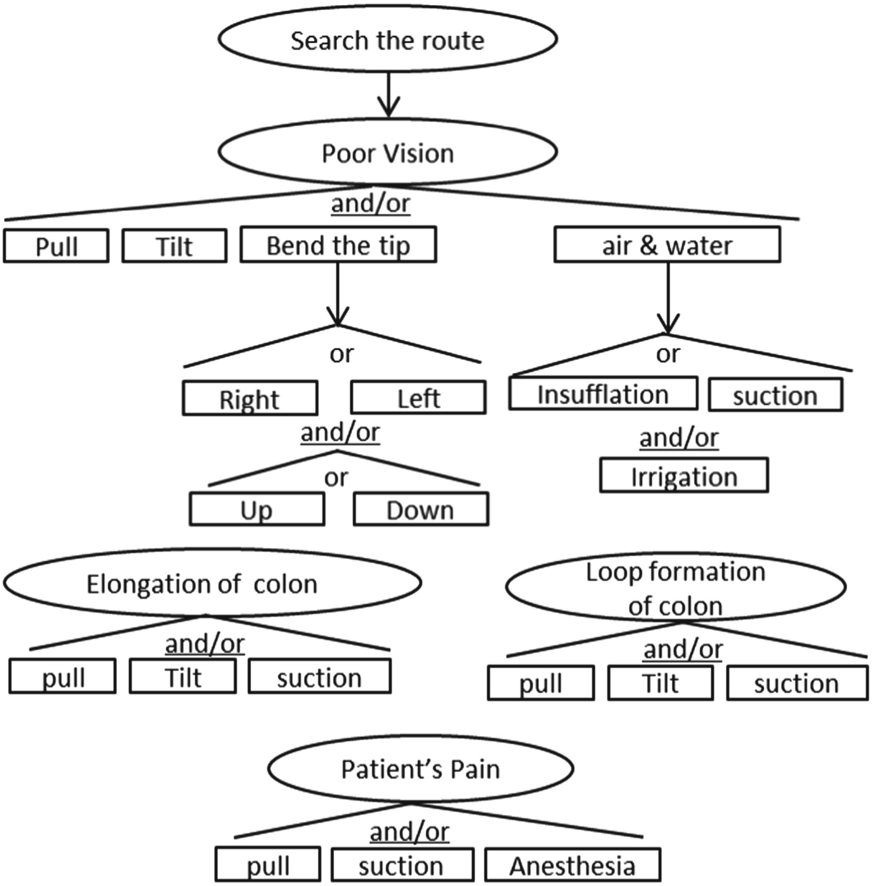

Fig. 4. Ontological description of search the insertion route and problem solving during the colonoscopy

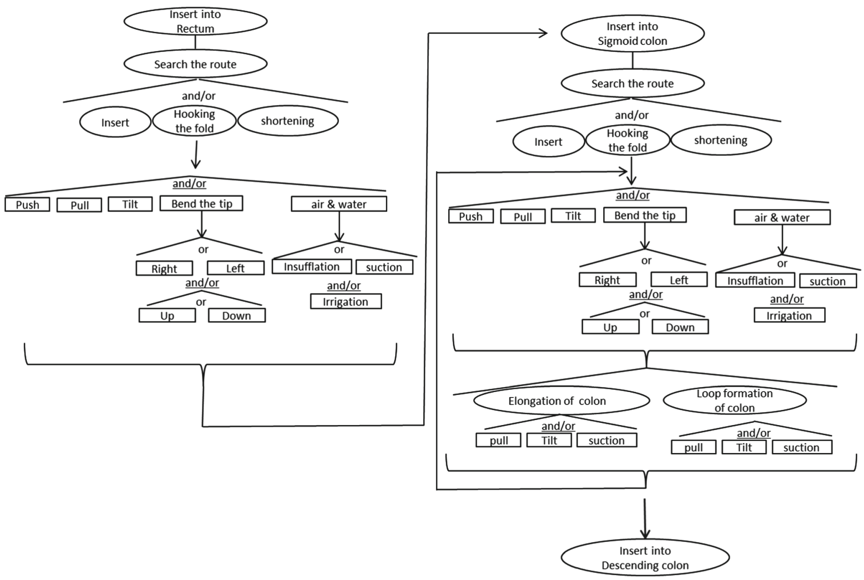

Fig. 5. Ontological description of insertion procedure (rectum to descending colon)

4 Discussion

As previously noted, there is increasing demand for endoscopic diagnosis and treatment of colorectal disease. Difficulties in colonoscope insertion result from the complicated anatomy of the large intestine. The shape and length of the large intestine from rectum to cecum varies greatly according to physique, eating habits, and race, and anatomical shape varies by location. The rectum is fixed to the pelvis with many folds and curves. The sigmoid colon is convoluted and can be adjusted and elongated freely during endoscope insertion. The descending, transverse, and ascending colon are relatively straight; the descending and ascending colon are fixed to the retroperitoneum and are not elongated by endoscope insertion forces. However, the sigmoid and transverse colon are suspended by mesentery and can change form and be extended easily by colonoscope insertion forces (Fig. 7).

Excessive extension of the large intestine can cause pain, injury, and perforation of the intestinal wall. The colonoscope insertion techniques used to avoid this are pushing, pulling, and tilting. Combining these motions allows shortening and straightening of the flexible large intestine (Fig. 1). Clinical education for colonoscope insertion remains hands-on and employs simple training simulators and on-the-job training. Developing strategic education and skill evaluation programs and clinical colonoscopy simulators will require ontology and AI.

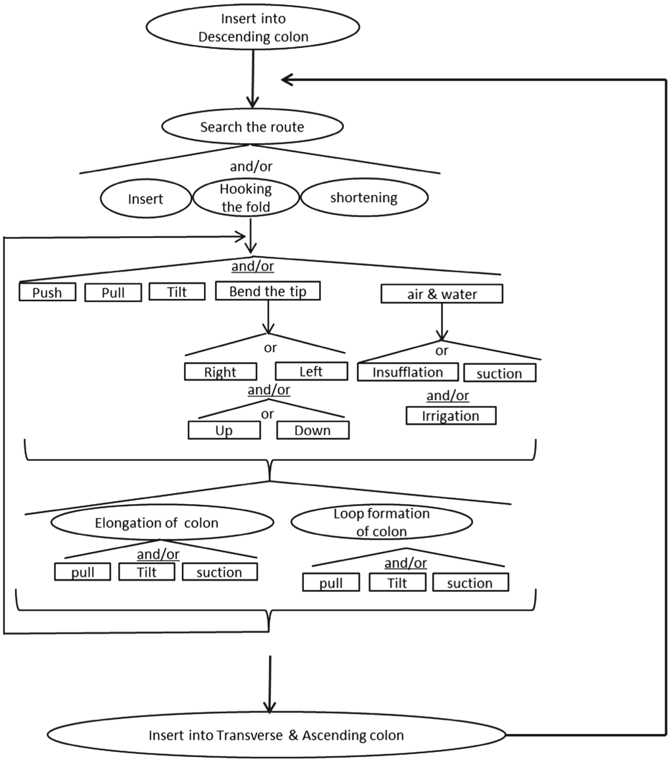

Fig. 6. Ontological description of insertion procedure (descending colon to ascending colon)

AI application in medicine has been attempted since the 1960s, with automated diagnosis of laboratory data and diagnostic radiology employed in medicine and radiology. Ontological approaches have also been applied to defining disease and clinical guidelines, with several ontologies proposed for medical information systems [1–3]. Nevertheless, there have been few successful applications of AI to clinical endoscopy. Ontological descriptions and analyses of endoscopic procedures will be indispensable for successfully applying AI to endoscopy training and evaluation [4].

This study revealed that ontological descriptions of colonoscopy procedures are possible and clarified the need for simple and practical methods for ontological descriptions in clinical medicine.

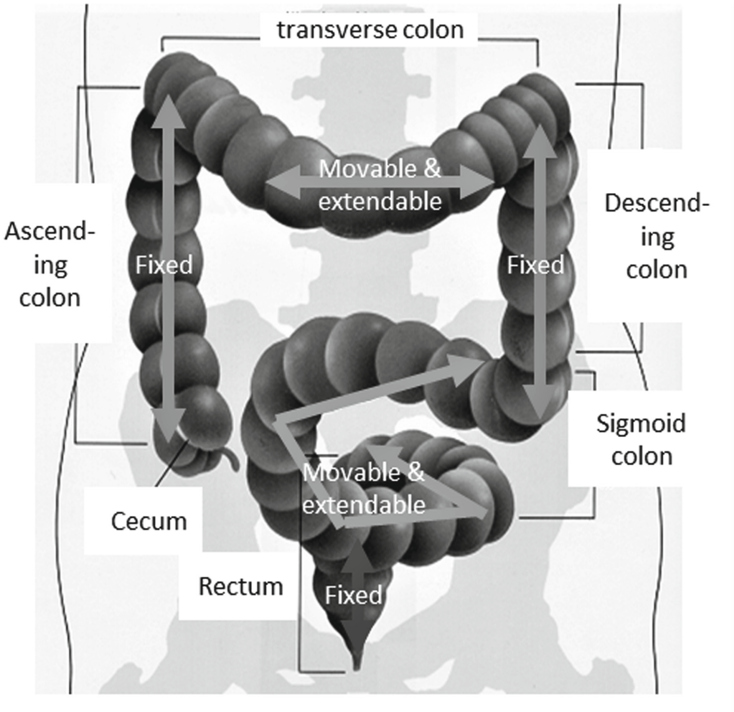

Fig. 7. Anatomy of the large intestine

5 Conclusion

Ontological descriptions of colonoscopy procedures and techniques are feasible and potentially widely applicable to computerized skill evaluation and certification, training simulations, patient safety medical alert systems, and automated endoscope development.

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Should Electronic Medical Records Be an Alternative to Reference Intervals for Interpretation of Laboratory Results in Geriatric Subjects?

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Abstract. Reliable reference intervals (RI) and clinical decision limits (CDL) are indispensable for correct interpretations of laboratory results. The problem becomes more evident in geriatric population as these people are often affected by comorbidities, polypharmacy, and atypical disease presentations. With the advent of electronic medical records (EMR) and its wide availability, it becomes a possibility that, some baseline lab and clinical data would always be available which could be used as references, especially, in geriatric people, to evaluate them for chronic diseases. For the meaningful usage of EMR, the records need to be harmonized and available to the health care providers. These records can then be used to differentiate clinically relevant changes in lab investigations over periods of time. Hence, we need to define the percentage differences per unit periods of time or personalized CDL rather than absolute values based on population-based RI especially in the geriatric population. However, issues regarding security and ownership of EMR need to be well defined to prevent unwanted breaches in privacy.

Keywords: Reference Intervals · Electronic Medical Records · Geriatric · Clinical decision limits · Machine learning tools · Artificial intelligence

1 Introduction

In the era of 'Evidence based Medicine', the overall management of patients is overtly dependent on the accuracy of laboratory tests followed by their correct interpretation. Reliable and accurate reference intervals (RIs) are essential to the process of correct interpretation of clinical laboratory test results. The International Federation of Clinical Chemistry (IFCC), since the 1980s, has been proactive in establishing the framework for development of RIs, selection of appropriate reference population and statistical analysis of the data. The C28-A3 guideline published by the Clinical and Laboratory Standards Institute (CLSI) and IFCC is still the most widely used source of reference in this area. Recently, the Committee on Reference Intervals and Decision Limits (C-RIDL) have also published guidelines about clinical decision limits (CDLs).

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 203–206, 2020.
https://doi.org/10.1007/978-3-030-50838-8_28

RIs are specific for a defined population and is derived from the distribution of usually 95% of the same population. The reference individuals form the reference sample group and are used for the measurement of the values of defined analytes. The values obtained are then analyzed statistically and the distribution of the same are used to define the reference limits. These limits then define the RI. Ideally, RIs are determined based on a healthy population using direct methods. However, indirect data mining methods, based on previous laboratory data are also used [1]. RIs are descriptive in nature and specific for a defined population, whereas CDLs are thresholds above or below which a specific medical decision is recommended. These are generally derived from Receiver Operating Characteristic (ROC) curves and predictive values [2]. Confusion regarding RIs and CDLs remains an issue. The purpose of both, however, is to facilitate interpretation of laboratory data and aid clinical decision making. In practice, often this is done based on changes in laboratory results over a period of time.

2 The Problem Statements

The need for partitioning reference intervals has long been recognized in populations when there are significant physiological changes like in neonatal period, childhood, puberty, pregnancy, menopause and ageing. Geriatric population is often the victim of misinterpretation of lab results due to lack of appropriate reference ranges which are age, sex and population specific. Besides, often these patients are also suffering from some comorbidities like kidney dysfunction which may affect some other lab parameters. Since the last two decades, it has been agreed upon that aging and its associated physiologic changes often impact the interpretation of laboratory data [3]. Laboratory tests which are frequently ordered in the primary care or hospital settings include complete blood count, arterial blood gases, erythrocyte sedimentation rate, kidney and liver function tests, glucose, calcium and phosphates. Many of these oft-prescribed laboratory parameters have been observed to increase or decrease with advancing age; some remain unchanged, and the effect of age on others remain unclear. Moreover, the increase or decrease in the laboratory parameters are often not uniform between subjects. Hence, interpretation of lab data in the elderly based on reference intervals often becomes difficult. Furthermore, the geriatric population is often affected by multiple comorbidities, polypharmacy, and atypical disease presentations which often confound the laboratory data all the more [4]. Hence, during the last two decades a lot of thought have gone into the problem of discriminating between truly abnormal test results and those caused by aging with the focus mostly being towards reevaluation of adult reference ranges [5].

3 Electronic Medical Records

Electronic Medical Records (EMR) or Electronic Health Records (EHR) as it was known earlier came into being in the early 1990s. Initially, EHRs were developed and used only at academic inpatient and outpatient medical facilities. Besides, these were partial and only complemented paper records [6]. Gradually in the late nineties with the wider use of computers, EHR systems got more robust. Still, the widespread use of EHRs was delayed by high costs, data entry errors, poor initial physicians' acceptance, and lack of any real incentive. With the advent of technological advances in the form of portable computers (laptops) and other gadgets useful for data transfer EHR gained more popularity in the early 21^{st} century. In the era of internet connectivity this becomes even more relevant due to easy sharing of data between distant locations instantaneously.

With the advent of EMR and its wide availability over the internet, it becomes a possibility that, some baseline lab and clinical data would always be available to the health care providers. These could serve as references, especially, in geriatric people because during the lifetime of any individual there will be multiple contacts with the health care system. If all these records are seamlessly archived and unmistakably identifiable with a person, and available to the health care providers when needed at the point of care, then these records could be used to differentiate clinically relevant changes in lab investigations from those which may have been due to compromised physiology in old ages.

4 Challenges Involved

Several challenges however need to be addressed before EMR can be effectively used for clinical decision making instead of RI. The foremost amongst them is to define the percentage differences per unit periods of time which should trigger clinical decisions. For this purpose, large EMR datasets obtained from geriatric age groups, may have to be studied using artificial intelligence and machine learning tool pipelines to link it with outcomes in terms of diagnosis and disease outcomes. This may be studied retrospectively with already existing data and may be further confirmed through well designed prospective studies. Multi-centric models would make the development of personalized clinical decision limits even more robust. This would lead to the development of personalized decision limits for individuals especially in geriatric age group in the era of precision medicine rather than using absolute values based on population-based RI.

The other biggest hurdle to move towards personalized CDLs is harmonization of laboratory data across technologies, platforms and geographies. IFCC has initiated several measures to sensitize people with regards to the needs, benefits and the process of harmonization of lab results. But it is easier said than done as multiple stakeholders need to come on board.

The other issues involving widespread usage of EMR concerns the safety of the data. Since, these records may be used for different purposes and with mala fide intentions by third parties, it is important to ensure security of the data over the internet. This would only lead to confidence of people on the system and lead to wider usage of the same. Besides, issues regarding ownership of EMR need to be well defined to prevent unwanted breaches in privacy.

5 Probable Solutions

The use of machine learning tools to comprehend large datasets may lead us to develop optimal personalized clinical decision-making limits. These may then be delivered through smart phones or portable devices at the point of care directly to peripheral health care workers guiding them through interpretation of laboratory data in the geriatric patients.

6 Conclusion

Summarily, EMR can become a viable alternative to population-based reference intervals especially in geriatric population. However, it needs to be worked out judiciously. Artificial intelligence and machine learning tools may be used in conjunction with big data sets to define the criteria for clinical decision limits. These in the era of internet connectivity and smart phones may be made available at the point of care for ready use to health care workers guiding them through difficult lab data interpretations in the elderly, who are often having comorbidities and polypharmacy.

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Advances in Medical Devices and Techniques

Human Factors Components of Invasive Medical Devices in Non-clinical Environments

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Abstract. The National Research Council's Healthcare Comes Home Report encourages system engineering involvement in homecare research and development to provide medical device designers information on demands associated with homecare and the capabilities needed for non-clinical caregivers to perform successfully The objective of this study was to develop invasive therapy evaluation techniques with human factors considerations for pediatric medical devices, specifically home parenteral nutrition and home mechanical ventilation, to minimize undesirable outcomes in non-clinical settings. The method used was the case study approach to qualitative research through expert interviews, environmental observations and document review data collection methods as well as cross-case themes analysis. This discussion reviews the rated impact of human factors consideration on the safety and effectiveness outcomes of invasive therapy devices use on pediatric patients in non-clinical environment.

Keywords: Human factors · Medical devices · Invasive therapy · Parenteral nutrition · Mechanical ventilation

1 Topic Introduction

In 2016, the Food & Drug Administration (FDA) released the latest Human Factors and Usability Engineering Guidance for Medical Devices that enhances focus on diverse users including lay caregivers and inclusive environments such as residential homes [1]. The FDA also has expanded the focus on the medical device user interface to heighten the impact of devices inputs, processing/reactions, and outputs on user information perception, cognitive processing, and control actions.

The advantages of these modifications are that they increase device developer's focus on tasks such as set up, use, and maintenance as well as interactions with visual, auditory, and tactile components involved in user use. It also encourages developers to conduct human factors analysis through preliminary hands-on studies to assess risk controls for critical tasks. Developers are expected to validate device risk controls with

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 209–216, 2020.
https://doi.org/10.1007/978-3-030-50838-8_29

intended user populations in practical environments to develop instructions and training intended to ensure appropriate use by users.

The disadvantage is that for invasive medical devices, the user interface development and evaluation would primarily focus on interactions with the infusion device or ventilator pump. This focus would assist with device instructions, caregiver training on the circuits as well as medical device sources, but could neglect the invasive interface between the pediatric patient and invasive therapy. The relevant research on invasive medical devices identify patient device interface and the lay caregiver tasks associated as the interactions that create the greatest risk. The purpose of this study was to apply the FDA Human Factors Considerations to parenteral infusion devices and ventilators used in the home by pediatric patients.

2 Research Methodology

The book Qualitative Inquiry & Research Design, explains that case study "research is a qualitative approach in which the investigator explores a real-life, contemporary bounded system or multiple bounded systems over time through detailed, in-depth data collection involving multiple sources of information and reports a case description and case themes" [2]. This approach is a common social science research methodology in anthropology, sociology, law, medicine, and political science, and might involve a single or multiple cases within a study.

Case studies can be descriptive, explanatory, or exploratory. They are defined by several characteristics and the type of research can be focused either on an individual and group or on a general process or project. It is important to define the scope as well as the objective of case studies and to research existing situations to ensure information accuracy. Good case studies are also characterized as providing a deep understanding of the scenario by obtaining numerous forms of qualitative data through documents, interviews, and observations. This qualitative data would then be analyzed within a single case or across multiple cases for comparison that would involve case description of themes and issues discovered during research. Additionally, "themes or issues might be organized into a chronology by the research, analyzed across cases for similarities and differences among the cases, or presented as a theoretical model" [2]. These findings lead to conclusions about the meaning of these case(s) that can be identified as assertations or explanations of discoveries made during the research study.

There are various types of case studies based on the research scope as well as participant involvement. Instrumental case studies focus "on an issue or concern, and then select one bounded case to illustrate this issue" and in a collective case study "the researcher might select for study several programs from several sites or multiple programs within a single site" to provide various perspectives [2]. When using multiple cases, researchers are encouraged to replicate procedures within the study design. Intrinsic case studies focus "on the case itself because the case represents an unusual or unique situation" [2].

There are multiple steps involved in conducting a case study that starts with deciding if the problem is best researched through the case study method. The researcher then finds cases through purposeful sampling after determining the type of case study best for investigating the problem. Next, data for cases are collected in the form of “documents, archival records, interviews, direct observations, participant observation, and physical artifacts” [2]. Once collected, that data is evaluated in its entirety or based on certain aspects to develop descriptions and identify themes within a case or across cases. Finally, findings regarding common issues or abnormal situations are summarized about the case(s).

3 Study Design

The FDA’s User consideration was divided into the binomial considerations of User Expertise (UE) with factor level options of Low or High and User Capability (UC) with factor level options of Limited or Extensive. Using the Cambridge Dictionary, the researcher defined Expertise as level of skill or knowledge and determined that a device requiring Low UE could be operated by lay people or family caregivers, and one requiring High UE should be operated by a licensed practitioners or clinical technicians [3]. Capability was defined as ability to use and it was determined that devices involving Limited UC could be used by individuals with low cognition or biological challenges, and those involving Extensive UC should be used by individuals who are highly insightful or physically enabled. For safety evaluation purposes, the Low EU and Limited UC rating for a medical device could range from 0 (minimally challenging) to 1 (somewhat challenging). Similarly, the High EU and Extensive UC rating could range from 2 (moderately challenging) to 3 (very challenging).

Similarly, the FDA’s Interface consideration was divided into binomial considerations of Interface Task (IT) with factor level options of Easy or Difficult and Interface Interactions (II) with factor options of Simple or Complex Interactions. The Clinical Human Factors Group defines a Task as a “set of physical and mental actions that are required to deliver, or fulfill a function, and achieve a goal” [4], so the researcher determined that an Easy IT could involve cleaning equipment or disposing supplies; a Difficult IT would involve equipment installation and device calibration. No official human factors definition was identified for interaction, but was defined by the 2019 Cambridge Dictionary as when people or things communicate or react, so it was determined that Simple II would include device interfaces with moderate screens or alerts, and Complex II would include devices with intricate connections and knobs. For safety evaluation purposes, the Easy IT and Simple II rating for a medical device could range from 0 (minimal challenging) to 1 (somewhat challenging). Similarly, the Difficult EU and Complex UC rating could range from 2 (moderately challenging) to 3 (very challenging).

The FDA’s Environment consideration was also divided into the binomial considerations Environment Residential (ER) with two factor level options Non-Clinical or Clinical and Environment Public (EP) with two factor level options Non-Mobile and Mobile. The 2019 Cambridge Dictionary defined Residential as where people live, so the researcher determined that Non-Clinical ER could be patient homes or caregiver apartments, and Clinical ER would be assisted living facility or long-term care building. Public is defined by the Cambridge Dictionary as somewhere anyone can access, so the researcher determined that Non-Mobile EP could include office spaces or retail stores, and Mobile EP would include automobiles or planes. For safety evaluation purposes, the Non-Clinical ER and Non-Mobile EP rating for a medical device could range from 0 (minimal challenging) to 1 (somewhat challenging). Similarly, the Clinical ER and Mobile EP rating could range from 2 (moderately challenging) to 3 (very challenging).

Lastly, the FDA Model's Medical Device Outcomes were expanded to three segments for this dissertation evaluation that includes Effective and Safe (ES), Effective and Unsafe (EU), and Ineffective and Unsafe (IU). The ES Device Outcome means that it has a low risk level, should result in a correct user outcome, and should probably result in a result in the desirable patient outcome of good health. The EU Device Outcome means that it has a moderate risk level, could result in a questionable user outcome, and could possibly result in the undesirable patient outcome of a near miss. The IU Device Outcome means that it has a high-risk level, would result in incorrect user outcome, and would potentially result in the undesirable patient outcome of an adverse event. The Medical Device Outcome is determined by the Risk Score calculation range for ES is 0-6, for EU is 7-12, and for IU is 13-18. The Risk Score Range calculation is determined by adding the Medical Device Human Factors Consideration Input ratings determined for each device. These scores could be used by the FDA or corporations to determine whether a device should be approved, improved, or denied.

4 Data Analysis

Family caregiver, social worker, and pharmaceutical vendor interviews as well as user manuals, vendor videos, and organizational documents for these devices were then evaluated to analyze the user, interface, and environmental components of the devices. These data sources were used to determine human factor consideration ratings for the mechanical ventilation and parenteral nutrition devices in the FDA model areas of user, interface, and environment. The devices were rated by the sub-considerations for invasive medical devices developed for this study based on findings within those data sources.

The Curlin 4000, Curlin 6000, and CADD 6101 Home Parenteral Nutrition (HPN) devices evaluated by the researcher for this study. These devices were selected because they were the primary devices ordered by pediatric gastrointestinal clinicians for family caregivers to perform HPN in non-clinical settings. Cross-case analysis for HPN device evaluations included interviews with four patient caregiver families, two pharmaceutical vendor representatives, and a review of ASPEN and AAMI reports. Evaluation of these devices also included review of Curlin and CADD user manuals and training videos.

Table 1 provides human factor component scores associated with the aforementioned Curlin and CADD HPN pumps based on the rating structure explained in the previous section. A thematic review of available HPN data sources revealed that the Curlin 4000 and 6000 only requires low user expertise and limited user capability, but the CADD 6101 requires extensive user capabilities due to more challenging physical capabilities required to maneuver the lever to change the power sources' battery. Similarly, the Curlin 4000 and 6000 only involves easy interface task and simple interface interactions, but the CADD 6101 involves difficult interface tasks and complex interface interactions due to the difficult contraption used to change the nutritional fluid circuit. Parenteral nutrition pumps received its best ratings for environmental considerations due to its small size and portability in non-clinical residential facilities and non-mobile public settings.

Table 1. Parenteral nutrition human factor consideration ratings [1]

NRC variable	Input	Rating	Factor Level	FDA consideration	PHD consideration	Factor description	Curlin 4000	Curlin 6000	CADD 6101
Operators	UE	0-1	Low	User	Expertise	Lay person, Family caregiver, etc.	1	1	1
Operators	UE	2-3	High	User	Expertise	Licensed practitioner, Certified technician, etc.			
Operators	UC	0-1	Limited	User	Capability	Low cognition, Biologically challenged, etc.	1	1	
Operators	UC	2-3	Extensive	User	Capability	Highly insightful, Physically enabled, etc.			2
Care tasks	IT	0-1	Easy	Interface	Tasks	Easy cleaning, Maintenance, Disposal, etc.	1	1	
Care tasks	IT	2-3	Difficult	Interface	Tasks	Difficult installation, Assembly, Calibration, etc.			2
Care tasks	II	0-1	Simple	Interface	Interactions	Simple screens/displays, Alerts/Alarms, etc.	1	0	
Care tasks	II	2-3	Complex	Interface	Interactions	Complex connections/components, Knob/Dials, etc.			2
Home health	ER	0-1	Non-clinical	Environment	Residential	House, Townhouse, Condominium, Apartment, etc.	0	0	0
Home health	ER	2-3	Clinical	Environment	Residential	Rehabilitation, Assisted living, Long-term care, etc.			
Home health	EP	0-1	Mobile	Environment	Public	Car, Plane, Train, Bus, Ambulance, Medevac, etc.	1	1	1
Home health	EP	2-3	Non-mobile	Environment	Public	Office space, School, Retail store, Outdoors, etc.			

Additionally, the HT50, HT70, LTV950, and the LTV1150 ventilators were the Home Mechanical Ventilation (HMV) devices evaluated for this study in that they were the primary devices ordered by pediatric pulmonology clinicians for HMV overseen by family caregivers in non-clinical settings. Cross-case analysis for HMV device evaluations included interviews with seven patient caregiver families and two pharmaceutical vendor representatives, as well as review of AARC and AAMI reports. Evaluation of these devices also included review of HT and LTV user manuals and training videos.

Table 2 provides human factor component scores associated with the aforementioned HT and LTV HMV pumps based on the rating structure explained in the previous section. Thematic review of HMV data sources revealed that the all the devices permit for low user expertise and the LTV950, LTV1150, and the HT70 allow for limited user capability, but the HT50 requires extensive user capabilities due to the physical demands of the weight of the device. Alternatively, only the HT70 has easy interface tasks and simple interface interactions, but the HT50, LTV950, and the LTV1150 involve difficult interface tasks and complex interface interactions. All the HMV devices were appropriate for non-clinical private facilities, and the LTV devices could be used in mobile public settings, but the size and shape of the HT devices and circuit connectors are more appropriate for non-mobile public settings.

Table 2. Mechanical ventilation human factor consideration ratings [1]

NRC variable	Input	Rating	Factor level	FDA consideration	PHD consideration	Factor description	HT50	HT70	LTV 950	LTV 1150
Operators	UE	0-1	Low	User	Expertise	Lay person, Family caregiver, etc.	1	0	1	1
Operators	UE	2-3	High	User	Expertise	Licensed practitioner, Certified Technician, etc.				
Operators	UC	0-1	Limited	User	Capability	Low cognition, Biologically challenged, etc.		1	1	1
Operators	UC	2-3	Extensive	User	Capability	Highly insightful, Physically enabled, etc.	2			
Care tasks	IT	0-1	Easy	Interface	Tasks	Easy cleaning, Maintenance, Disposal, etc.		1		
Care tasks	IT	2-3	Difficult	Interface	Tasks	Difficult installation, Assembly, Calibration, etc.	3		2	2
Care tasks	II	0-1	Simple	Interface	Interactions	Simple screens/displays, Alerts/Alarms, etc.		1		
Care tasks	II	2-3	Complex	Interface	Interactions	Complex connections/Components, Knob/Dials, etc.	3		3	3
Home health	ER	0-1	Non-clinical	Environment	Residential	House, Townhouse, Condominium, Apartment, etc.	1	1	1	1
Home health	ER	2-3	Clinical	Environment	Residential	Rehabilitation, Assisted living, Long-term care, etc.				
Home health	EP	0-1	Mobile	Environment	Public	Car, Plane, Train, Bus, Ambulance, Medevac, etc.			1	1
Home health	EP	2-3	Non-mobile	Environment	Public	Office space, School, Retail store, Outdoors, etc.	2	2		Home health

5 Findings Discussion

The User, Interface, and Environment Human Factor Component Input Variable Ratings for each HPN and HMV device was aggregated to calculate the Medical Device Outcome Scores for the Curlin, CADD, HT, and LTV devices. An outcome score between 0–6 meant that the device had a Low Risk Level, a score of 7–12 meant the device had a Moderate Risk Level, and a score of 13–18 meant the device had a High Risk Level. A medical device outcome score calculation and risk level translation for HPN and HMV devices are displayed in Table 3 and Table 4 respectively using the following equation:

$$\begin{aligned}&\text{UE Rating} + \text{UC Rating} + \text{IT Rating} + \text{II Rating} + \text{ER Rating} + \text{EP Rating}\\&\quad = \text{ES, EU or IU Score}\end{aligned} \tag{1}$$

Human Factors Component evaluation of the HPN devices revealed that most of the variation involved the device interfaces of the CADD6101 due to its difficult tasks and complex interactions. Summation of the Curlin 4000 total User score of 2, total

Table 3. Home parenteral nutrition human factors findings

FDA outcome	Output	Score	Risk level	Device outcome	User outcome	Patient outcome	Curlin 400	Curlin 600	CADD 610
Approve	ES	0-6	Low	Effective and safe	Correct use	Desirable: probable good health	5	4	
Improve	EU	7-12	Moderate	Effective and unsafe	Questionable use	Undesirable: possible near miss			8
Reject	IU	13-18	High	Ineffective and unsafe	Incorrect use	Undesirable: potential adverse event			

Interface score of 2, and total Environment score of 1 resulted in an overall risk score of 5: this indicates that it is appropriate for family caregiver users, invasive device interfaces, and non-clinical environments. Addition of the Curlin 6000 total user score of 2, total Interface score of 1, and total Environment score of 1 led to an overall risk score of 4: this indicates that it is also appropriate for family caregiver users, invasive device interfaces, and non-clinical environments. Calculation of the CADD 6101 total user score of 3, total interface score of 4, and total Environment score of 1 resulted in an overall risk score of 8; this signifies it has a questionable use within these cases, meaning that though it may be effective, it could be unsafe in these current applications by a family caregiver. Hence, this prototype tool would suggest that the CADD 6101 equipment developer consider improving the device to mitigate the risk of an undesirable near miss patient outcome.

Alternatively, human factors component evaluation of the HMV devices revealed that the HT70 was the only device determined to be appropriate for family caregiver users, invasive device interfaces, and non-clinical environments. Summation of the HT50 total user score of 3, total Interface score of 6, and total Environment score of 3 resulted in an overall risk score of 12: this indicates it has a questionable use within these cases, meaning that although it may be effective, it could be unsafe for existing applications by a family caregiver. Addition of the HT70 total user score of 1, total Interface score of 2, and the total Environment score of 3 led to an overall risk score of 6: this means that it is the most safe and effective of the four options. Hence, this prototype tool would suggest that the HT50 equipment developer consider improving the device to mitigate the risk of an undesirable near miss patient outcome.

Table 4. Home mechanical ventilation human factors findings

FDA outcome	Output	Score	Risk level	Device outcome	User outcome	Patient outcome	HT50	HT70	LTV950	LTV1150
Approve	ES	0-6	Low	Effective and safe	Correct use	Desirable: probable good health		6		
Improve	EU	7-12	Moderate	Effective and unsafe	Questionable use	Undesirable: possible near miss	12		9	9
Reject	IU	13-18	High	Ineffective and unsafe	Incorrect use	Undesirable: potential adverse event				

Finally, human factors component evaluation of the LTV devices revealed that both involved questionable use due to moderate risk; this means that although they could be effective, but unsafe. Calculation of the LTV950 total user score of 2, total Interface score of 5, and total Environment score of 2 resulted in an overall risk score of 9: this indicates it could be inappropriate for family caregiver users, invasive device interfaces, and non-clinical environments. Similarly, summation of the LTV1150 total user score of 2, total Interface score of 5, and total Environment score of 2 resulted in an overall risk score of 9: this also indicates it could be inappropriate for family caregiver users, invasive device interfaces, and non-clinical environments. Hence, this prototype tool would recommend that the LTV950 and LTV1150 equipment developer improve the device to mitigate the risk of an undesirable near miss patient outcome.

In conclusion, this study confirmed the case study approach as a useful method for evaluating of the FDA and additional human factor considerations provided by this study impacting the outcome of HPN and HMV devices and users. This approach also provided insight on the factor levels that influence the risk level of invasive medical devices. Hence, this study was effective at addressing the NRC's research request for a "Tool for Assessing Home Health Care Tasks and Operators." The FDA model analysis of these pediatric cases revealed that the NRC's Home Health research variable was more so impacted by the Public Environment consideration. Additionally, it found that the NRC's Care Task research variable was more so impacted by the Interaction Interface and Task Interface considerations. Lastly, it discovered that the NRC's Coordinator research variable was more so impacted by User Capability consideration.

As a result, the preliminary findings of this study identified several future research opportunities. Those opportunities include expanding the evaluation of this tool to include additional devices used for invasive medical therapies, as well as non-invasive devices used in various environments and numerous users. These findings contribute to the limited body of knowledge on pediatric home health patient safety.

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Plasma Treatments to Boost the Biocompatibility of the Textile Medical Devices

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Abstract. The recovery of the defects due to surgery incisions requires the use of prosthetic implants, which may cause various complications on the long term, such as: the rejection/infection of the used graft, the development of fistulas or the recurrence of hernias. The use of the surgical meshes made up of synthetic polymers demonstrated a significant reduction of the recurrence rate, the minimization of pain and the improvement of general post-surgery results. The textile structures of the synthetic polymers made up of PES, PA and PP for hernias were treated in plasma to boost their biocompatibility. A low-pressure plasma installation with the oxygen gas allows for the treatment of the textile materials in a cubic chamber of 40 cm side in a roll-to-roll system. The contact angle measurement was applied according to ASTM D7490-08 Standard, in order to identify any surface modifications following the plasma treatment, respectively their hydrophilic properties. All plasma treated structures were hydrophilic. A MTT assay, a LDH – quantification of dead cells and a FDA staining analysis were performed before and after the plasma treatment, in order to establish the biocompatibility of the hernia meshes. The quantitative and qualitative results of the biocompatibility tests highlighted that the plasma treated textile structures improved the level of biocompatibility, characterized by high levels of MTT and low levels of LDH (when compared to the test control – HCT8 cells). These results were confirmed by the microscopic analysis too – for the cells grown on these structures had a high density and an unaltered morphology.

Keywords: Surgery · Hernia · Plasma · Biocompatibility · Hydrophilic

1 Introduction

The recovery of the defects due to surgery incisions requires the use of prosthetic implants, which may cause various complications on the long term, such as: the rejection/infection of the used graft, the development of fistulas or the recurrence of hernias [1]. The use of the surgical meshes made up of synthetic polymers

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 217–223, 2020.
https://doi.org/10.1007/978-3-030-50838-8_30

demonstrated a significant reduction of the recurrence rate, the minimization of pain and the improvement of general post-surgery results [2, 3]. An essential aspect of the tissue engineering is to design the polymeric scaffolds with the specific mechanics and biology, which are similar to those of the Native Extracellular Matrix (ECM). *In vivo*, the majority of cells are in contact with the ECM, which is made up of a network of proteins of nanometric dimensions and glycosaminoglycan. A series of interactions occurs between the cells and the ECM, which model cellular activities such as: the migration, proliferation, differentiation, genetic expression and the secretion of various hormones and growing factors [3]. In this context, the cellular scaffolds have to reproduce as much as precise the *in vivo* medium from the point of view of the chemical composition, morphology and the functional groups. Natural polymers are often used in constructing the scaffolds due to their high biocompatibility and out of bio-functional reasons [4].

The purpose of the PLA is to replace the current petro-chemical polymers, with the advantage that the Polylactide or the Polylactic acid, (the PLA) is a synthetic, aliphatic polyester (without any benzene ring), produced based on the monomer of the lactic acid [4, 5] The lactic acid may be found in plants, as a byproduct or an intermediary of the metabolism of the plants. The lactic acid may be industrially obtained based on a whole range of farming products containing starch or sugar, such as the cereals. There are three mechanisms which are used to produce the lactic acid [5].

The plasma contains ions and electrons in an excited state (a superior energetic level). These particles may produce different surface effects on the textile materials: cleaning, activation, etching, bonding and coating. The plasma modifies the surface morphology and increases its roughness. The plasma treatment influences the biologic response too, due to the fact that the plasma treated surfaces have an improved proliferation of fibroblasts [6]. This phenomenon occurs due to creation of new functional groups and modification of the surface morphology. Several studies have shown that the plasma treatment significantly improves the biocompatibility properties of the polymeric materials. Some studies highlighted that cells preferentially bond to the polymeric surfaces with moderated hydrophobicity when compared to the hydrophilic or the super-hydrophilic surfaces.

The required properties of the hernia mesh are a pore size larger than 0.75 mm, a 80–110 g/m^2 mesh weight and a tensile strength of at least 32 N/cm.

2 Materials and Methods

Monofilament yarns made up of PES, PA and PP, with a diameter ranging between 0.04 and 0.15 mm, polyfilament PES yarns with a 74 dtex fineness and nonwoven PLA yarns produced based on the spun-bonding technology [7], with a 25 g/m^2 weight and 88.3° hydrophilic at 60 s, were used.

The mesh made up of the monofilament PES, PA and PP and polyfilament PES yarns, with 75 dtex fineness and a rectangular or trapezoid geometry (Fig. 1) and a size of 0.18–0.64 mm was produced using the warp-knitting process, which comprised the following stages: reeling onto spoolers with a normal reeling tension; sectional warp on cylinders; knitting on RJSC Jacquard warp knitting machines.

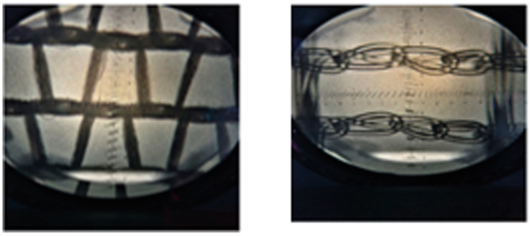

Fig. 1. The geometry of the pores

Thermofusion was used with the PES, PA and PP and nonwoven PLA knitted mesh to create composite structures, with an EVA type membrane of 30 g/m^2 weight (Fig. 2).

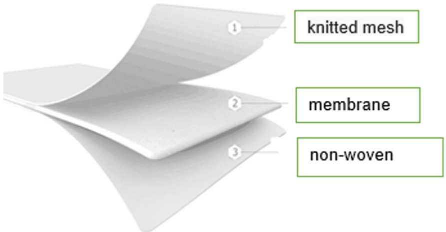

Fig. 2. The structure of the textile composite

The porosity was determined using the pycnometric method and is expressed as the following:

$$P_z = [(\gamma_r - \gamma_a)/\gamma_r] 100\% \tag{1}$$

where: γ_r – the relative density of the textile material [g/cm^3]; γ_a – the apparent density of the textile material [g/cm^3].

The plasma treatment was performed on the Magnetron INFLPR in a low-pressure oxygen atmosphere, using the following working parameters (Table 1):

In order to identify the surface changes obtained through the plasma treatment as well as the hydrophilic tendency, respectively, the contact angle determination method was used, according to the ASTM D7490-08 Standard. This testing method describes a procedure to measure the contact angle between two surfaces: a liquid and, respectively, a solid one, in order to calculate the surface properties of the solid material (the surface tension and the dispersion and polarization components).

Table 1. Physical and mechanical features of the composites

Knit mesh composition	Weight	Breaking farce, N		Elongation %		Thickness	Vapor perm.	Air perm.
	g/m^2	Orz.	Vert.	Orz.	Vert.	mm	%	$1/m^2/s$
PES-polifilamentary Finesse 75 dtex	109	154.6	304	78.8	19.4	0.49	33.4	1997.5
PA Monofilament Diameter = 0.15 mm	135	180.0	278	69.6	26.8	0.73	10.2	59.33
Pes-Monofilament Diameter = 0.15 mm	84.0	125.7	352	101.6	24	0.37	4.1	9.28
PP-Monofilament Diameter = 0.15 mm	94.0	113.3	255	45.2	32.2	0.53	9.8	34.47

The device used is a goniometer – which is made of a controlled light source, a plate supporting the testing sample and a microscope or camera to see the drop on the sample.

To determine the degree of biocompatibility, the MTT and LDH assays were carried out. The cells were grown in classical conditions, in 25 ml flasks on the MEM growth medium, where 10% SFB and 1% Pen/Strep were added. The growth conditions were complied with: 37 °C temperature, 5–10% CO_2 enriched atmosphere, and 96% humidity. The growth medium was changed after 48 h, the transition occurring at 80–90% confluence.

The MTT test is a *viability assay*, which enables the quantitative assessment of the living cells, which are active metabolically in the growth medium. The MTT compound [3-(4,5-dimethylthiazol-2-il)-2,5-diphenyl tetrazolium bromide] is permeable for the living cell membranes. Following the biotransformation of the MTT compound, formazan crystals are formed, which are soluble in isopropranol. The result is a (purple) solution whose optical density may be read at 570 nm.

The Lactate dehydrogenase (LDH) is an oxidoreductase (E.C. 1.1.1.27), which is present with most of the living bodies. The cells which do not have membrane integrity anymore release in the growth medium the cytoplasm where this enzyme exists (LDH). It is a quantitative assay, which indicates the number of dead cells in the cells. The solution, as a result of the reaction, may be read spectrophotometrically at 490 nm.

The cell cultures were examined with a microscope by applying the cytochemical staining techniques. The following were monitored, in general: the morphological changes, the vacuolation, the support detachment, the lysis of the cells and the integrity of the cellular membrane. Any deviation from the normal morphology must be recorded and described in the assay report (*ISO Standard 10993:2005*).

3 Results and Discussion

Table 2 shows the physical and the mechanical features of the composites made up of knitted mesh as follows: layer 1 – PES, PA, PP knitted mesh; layer 2 – thermofused membrane and layer 3 – the nonwoven PLA layer.

Table 2. Contact angle values

Knit mesh composition	Weight	Breaking force, N		Elongation %		Thickness	Vapor perm.	Air perm.
	g/m^2	Orz.	Vert.	Orz.	Vert.	mm	%	$1/m^2/s$
PES-polifilamentary Finesse 75 dtex	109	154.6	304	78.8	19.4	0.49	33.4	1997.5
PA Monofilament Diameter = 0.15 mm	135	180.0	278	69.6	26.8	0.73	10.2	59.33
Pes – Monofilament Diameter = 0.15 mm	84.0	125.7	352	101.6	24	0.37	4.1	9.28
PP-Monofilament Diameter = 0.15 mm	94.0	113.3	255	45.2	32.2	0.53	9.8	36.47

The characteristics of the composite structures: weight: 84–109 g/m^2 (usually, 80–110 g/m^2), thickness: 0.34–0.81 mm, tensile strength: horizontal – 113.3–180 N and vertical – 19.4–32.2 N (usually 32 N/cm), elongation at break: horizontal – 45.2–101.6% and vertical – 19.4–32.2% (usually 32%), air permeability: 9.28–1997.5 $l/m^2/s$, water vapors permeability: 4.1–33.44%, thickness: 0.37–0.73 mm.

The difference between the characteristics is determined by the composition of the knitted mesh, which forms the first layer. Thus, the smallest mass (84 g/m^2), the thickness (0.37 mm), the vapors permeability (4.1%) and the air permeability (9.28 $l/m^2/s$) are obtained for the composite with the PES monofilament mesh, with 0.15 mm diameter.

Table 2 shows the values of the contact point for the composite structure variants.

The Fig. 3 shows the evolution of the contact angle, with values over 120°, which highlight the strongly hydrophobic character of the composite materials made up of the polyfilament PES yarn and monofilament PA and PP yarn mesh. The higher hydrophilic version is that of the first layer made up of the monofilament PES knitted mesh (60 s-left – 81.8° and right – 93.9°).

The composite porosity had the following levels: polyfilament PES mesh support – 85.48%, monofilament PA – 83.23%, monofilament PES – 80.13%, monofilament PP – 82.34%.

The plasma treatment has been performed in a glass reactor of 25 cm height and 20 cm diameter, using a parallel-plate configuration of electrodes. The Hernia nets have been placed on the grounded electrode (bottom) facing the textile towards the discharge, while the RF powered electrode was situated 10 cm apart. The chamber was pumped by a fore pump down to a pressure which was highly dependent on the dimension of the samples, suggesting strong outgassing originating from the samples.

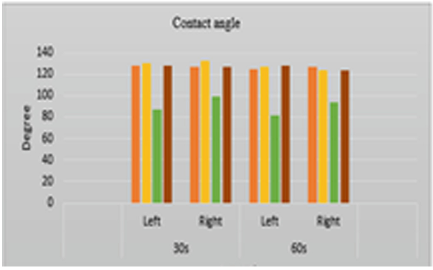

Fig. 3. Evolution of contact angle

Respectively, pressures down to 1.7 mbar were obtained for the samples with 1 × 5 cm, while for the samples of 5 × 5 cm the base pressure was around 5 mbar.

The experiments have been performed in a mixture of Ar/Oxygen using 60 sccm/30 sccm ratio gas flows and a RF power of 50 W, in a capacitively coupled discharge configuration.

Preliminary experiments showed that a treatment time of 1 min is changing the water contact angle from a hydrophobic behaviour to a super-hydrophilic behaviour of the surface.

After the treatment in low pressure oxygen plasma and the hydrophilic assay, the value of the contact points was null for all the composite variants.

The Fig. 4 shows the results of the evolution of the MTT and LDH values for the initial textile composites and after their plasma treatment.

According to the results, the MTT values have a tendency to increase after the plasma treatment by around 15%, with the highest value for the first layer composite – the monofilament PP mesh and the lowest with the first layer composite with the polyfilament PES mesh. For the LDH the tendency to decrease is lower, around 5%. In order to confirm this both to tendency more analyses will be carry out by using *in-vitro* and *in vivo* tests.

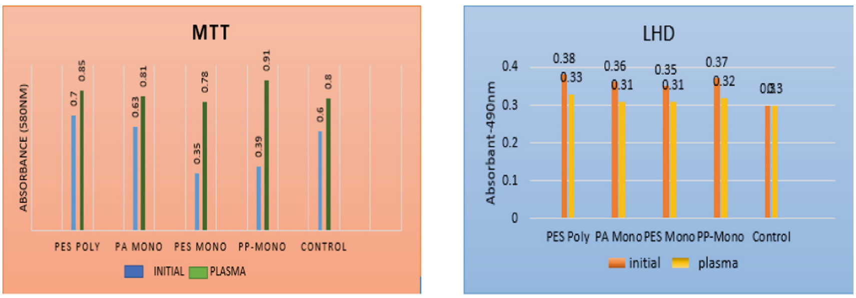

Fig. 4. Evolution of MTT and LDH

4 Conclusions

- The textile composites for hernias were made up of 3 layers – the first layer – polyfilament PES, PA and PP yarn knitted mesh, with a fineness of 75 dtex or made up of the 0.04–0.15 mm diameter monofilament yarns
- The difference between the characteristics is determined by the composition of the knitted mesh which forms the first layer. Thus, the smallest weight (84 g/m^2), thickness (0.37 mm), vapors permeability (4.1%) and air permeability (9.28 l/m^2/s) is obtained for the monofilament PES mesh composite, with a 0.15 mm yarn diameter.
- The plasma treatment of the hernia composites leads to a change in their surfaces, thus the contact angle gets very low values, which highlights the hydrophilic character acquired through the applied treatment.
- The MTT and LDH for the composites treated in the low pressure oxygen plasma change, have a tendency to change their the values that be confirmed by more multiple analyses *in vitro* and *in vivo* of the biocompatibility.

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User Preference and Comparative Workflow Evaluation of a Next Generation Vital Signs Monitor Designed for a Low Acuity Setting

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Abstract. Multiparametric automated vital sign monitors are slowly becoming the standard in outpatient practice settings where users value solutions that provide efficiency and simplify their clinical workflows. In order to evaluate whether our new to market device would meet expectations and requirements of device design we designed a study to look at the use of our new device in these settings and thereby quantify usability, preference and acceptance by clinicians.

Keywords: Comparative workflow evaluation · Vital sign monitors · Ease of use · User satisfaction · Technology Acceptance Model · User preference · Multiparameter patient monitors

1 Background

Healthcare providers and clinicians value solutions that are easy to use and simplify their daily clinical evaluations Clinicians often evaluate and monitor several patients in rapid serial succession all the while performing many tasks simultaneously [1]. This is true for the hospital and alternate care areas that include outpatient facilities, diagnostic labs, rehabilitation and primary care offices [2]. In these lower acuity settings, there is a reliance on configured multiparameter monitors, where the user has extensive control over included parameters but limited capacity to change the vital signs to be monitored [2]. Increasingly healthcare providers are looking for medical device data to be standardized, accurate and interoperable to integrate and be used by various clinical information systems With the growing significance of healthcare digitalization, and need for medical device connectivity, a major challenge is the legacy of devices not capable of outbound communication and limited features [3]. In an era where larger healthcare organizations are expanding into outpatient networks, there is a need to streamline devices to include multiparametric features with connectivity, to realize processes and efficiencies.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 224–230, 2020.
https://doi.org/10.1007/978-3-030-50838-8_31

2 Methods

2.1 Objective

To ensure that a new to market vital signs monitoring device (Welch Allyn® Spot Vital Signs® 4400) (Fig. 1) would satisfy expectations, enhance efficiency and fit in with the majority of clinical practices, we balanced device design features (targeted for the outpatient and private practice segment) with cost and quality, to provide optimum clinical value. In order to ascertain that our new to market device met customer requirements and expectations, we tested our new device in a comparative evaluation within the context of existing practice workflows and existing predicate devices to better understand our clinical use environment, quantify clinician preference, device usability and determine customer acceptance and intention to use or switch to the new device for their medical setting.

2.2 Compliance with Ethics Guidelines

This study was conducted in accordance with Hillrom's standard procedures. Accordingly, we sought and received approval from IntegReview IRB that determined this to be an exempt low risk study.

2.3 Study Design and Setting

A prospective observational user preference study conducted over a period of 6 months at 10 outpatient centers and private/group practice clinics located regionally in New York, Texas and Maryland among 57 clinicians involved with patient vital signs collection.

2.4 Participants and Groups

This included clinicians in settings with an automated/semi-automated multiparameter vitals collection workflow who were users of the predicate Spot Vital Signs® device (available in configurations to include Step BP, Step BP and temperature, or Step BP, temperature and Spo2) (Fig. 2) as well as those with a completely manual workflow using disparate independent devices for individual vital signs collection, sometimes shared among clinicians and exam rooms. Participants were prompted to operate the device with minimal assistance initially, followed by a demonstration of device operation. This included a review of touchscreen features, modifiers, saved data from past collections, change from adult to pediatric modes, screen indicators for data sources of collected parameters, Wi-Fi/USB connectivity for transmitting data and ability to perform blood pressure averaging. Staff was then prompted to try the device and collect a second set of vitals on an actual patient after having obtained an initial set by their traditional method for capture in their medical record. The user experience of participants was evaluated using a paper based modified System Usability Scale (SUS) survey [4]. Using a modified Technology Acceptance Model (TAM) [5] we assessed device usefulness, ease of use and intention to use the device compared to their current partially automated or completely manual workflows. We provided a positively and negatively worded questionnaire to assess the resulting themes associated with the new device in the context of their clinical practice and use.

Fig. 1. Welch Allyn® Spot Vital Signs® 4400

Fig. 2. Legacy Spot Vital Signs® Device

3 Data Analysis

Based on the formative validation results of users' interaction with the new device, for our user preference and workflow evaluation study with a power of 80 and an alpha variance of 0.05 we estimated we would need 57 subjects for an acceptance criteria of 90% Confidence Limits.

For user experience, a modified version based on the original System Usability Scale [4] was utilized. Since the original SUS score was designed to be applicable to a wide range of technologies, we adapted this survey for our device and study. The wording on the original questionnaire, was modified to be applicable to our device with very small variation, to be able to cover the three main areas of effectiveness, satisfaction and efficiency as originally designed. The positive and negative question format was retained to avoid a response bias and theoretical values ranging from 0–40 were scored and multiplied by a factor of 2.5 to result in values ranging from 0–100. A score of 70 and above is deemed as acceptable.

The proposed theoretical framework for the second survey used in our study is based on the widely used Technology Acceptance Model (TAM). TAM proposed by Davis in 1989 [5] is based on the Theory of Reasoned Action [6, 7]. We adapted this framework and devised relevant questions specific to our device. TAM suggests that the acceptance of behavioral intention to use (IU) of a new information technology (in our case device) is affected directly and indirectly by a user's attitude towards use, and two internal individual beliefs: Perceived Usefulness (PU) and Perceived Ease of Use (PEU). PEU has a direct effect on PU, but an indirect effect on IU. Since ours was also a workflow comparator study, we included specific questions to assess this theoretical domain (DC) and asked users to answer these questions based on differences perceived in their workflow with use of the new device. We hypothesized that the device and hence workflow benefits achieved (DC) with a consolidated multiparameter device would drive a direct relation with the intention to use and to perceived usefulness (Fig. 3). Participants on the TAM questionnaire were asked to rate items through a 7-point Likert scale ranging from "extremely satisfied" to "completely dissatisfied". Correlational analysis was done using the SUM for each individual item (PEU, IU, PU, DC) computed for both automated and manual users. Among our respondents we had 27 clinicians with a complete manual workflow and 30 that had some automated multiparameter predecessor devices.

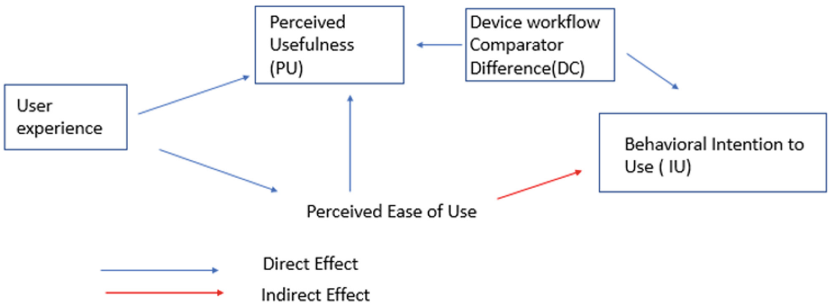

Fig. 3. Theoretical model

Our word survey questionnaire was developed using a process to randomly generate a list of both positive and negative connotations that may be associated with the new device's operation and impact on everyday clinical workflow. Additional data analysis for this paper was generated using R.

4 Results

Among our clinicians, majority were female (95%). Most were licensed as LPN's (44%), RN/BSN (28%) and MA (19%). Though unusual and a small percentage, we had MD's (7%) who were a group of private practice pediatricians used to collecting their own patient vital signs also participate. 57% were aged 41–50 years, 25% aged 31–40, 25% aged 51–60+ and 16% aged 18–30. Mean years of clinical experience was 11.4 years with a SD of 4.

- Among both groups' user experience was very high (mean SUS score = 88.37 SD11.08), and slightly higher among the manual users versus automated (90.27 vs. 86.66) (Fig. 4).
- The internal consistency of TAM was evaluated using Cronbach's alpha with values of 0.92 for PU (perceived usefulness), 0.82 for PEU (perceived ease of use), 0.81 for IU (intention to use) and we introduced questions asking predicate device and workflow comparator questions (DC) with a score of 0.82. Correlational Analysis was done using the SUM and verified using the medians of all responses for each theoretical element.

- Among manual users, using Pearson's coefficient (r), we saw a strong correlation between DC and IU (0.76), perceived usefulness(PU) and IU (0.91) of the device, as well as PU and DC (0.82) In this group PEU was strongly correlated with IU (0.71), as well as for PEU and DC (0.79). Hence, we can surmise the strong impact that device comparator differences, perceived usefulness as well as ease of use play in a completely manual environment. (Table 1.)
- Among automated/semi-automated users, we saw strong correlation between IU and PU (0.73), a good but weaker correlation between (b/w) DC and IU (0.49), leading us to assume that for automated users, device and workflow comparator differences were less apparent. (Table 1.)
- Regression analysis of the entire sample showed a positive significance between theoretical element Perceived Usefulness (PU) and the dependent variable Intention to Use (IU) ($p < 0.00$) in both groups, with a non-significant decrease from the automated to manual users (Table 2).
- The most common positive words selected by participants corroborating themes that emerged during our observation were Easy to Use (79%), Efficient (67%), Time Saving (65%), Convenient and Accessible (51%), Fast & Helpful (49%) and High Quality (46%).

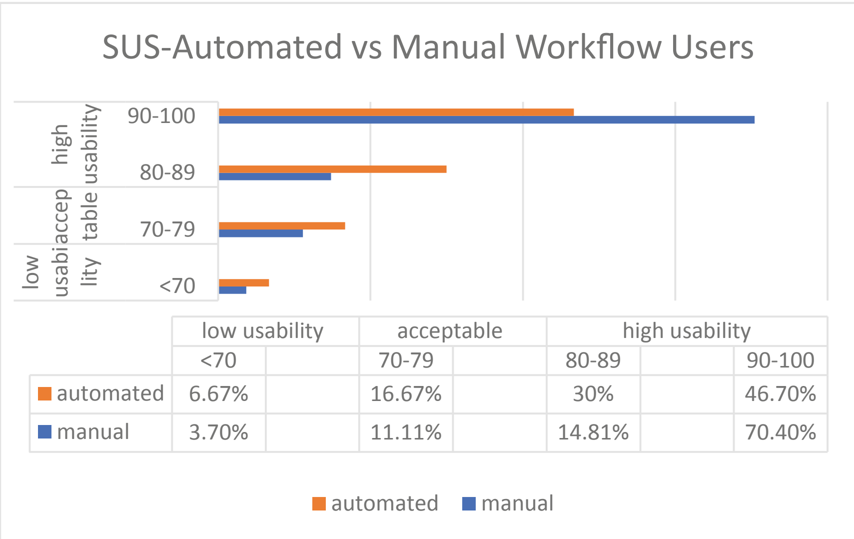

Fig. 4. Modified SUS survey

5 Discussion

Our study showed a high usability for the new touchscreen consolidated multiparameter device, especially among users with a completely manual workflow and validation of the perceived usefulness (PU) of included design features among both groups driving the intention to use the device. However, we saw a stronger correlation among manual users responses, between device and workflow differences and intention to use the device, as for device and workflow differences and perceived usefulness, validating the benefits of a consolidated multiparameter device enabling efficiency and driving the intention to use or switch over to a new device and workflow in these settings. Among those with an existing automated or semi-automated setting, we saw a weaker correlation between device and workflow difference and intention to use the device, even though a strong correlation was seen for the overall usefulness. From both regression and correlation analysis as well as quantified results of responses obtained in each group, we can assume that manual users are as likely as automated users in their intention to use and adopt the new device and workflow. However, for automated users having previously vetted the benefits of existing devices and workflows, the probability to switch devices and adopt a newer workflow is even higher.

Table 1. Pearson correlation analysis

Combined				
	IU	PU	PEU	DC
IU		**0.86**	**0.57**	**0.72**
PU			0.54	0.71
PEU				0.68
DC				
Manual				
	IU	PU	PEU	DC
IU		**0.91**	**0.71**	**0.76**
PU			0.69	0.82
PEU				0.79
DC				
Automatic				
	IU	PU	PEU	DC
IU		**0.73**	**0.2**	**0.49**
PU			0.21	0.52
PEU				0.53
DC				

Table 2. Regression analysis

SUMS_IU = SUMS_PU + SUMS_PEU + SUMS_DC + Manual User				
	Estimate	Std. Error	t value	Pr(> |t|)
(Intercept)	−0.98117	2.21387	−0.443	0.659
SUM_PU	0.30315	0.04235	7.158	2.77e−09***
SUM_PEU	0.13322	0.13284	1.003	0.321
SUM_DC	0.13022	0.12484	1.043	0.302
Manual = Yes	−0.50269	0.65973	−0.762	0.450

Multiple R-squared: 0.767, Adjusted R-squared: 0.7491
F-statistic: 42.8 on 4 and 52 DF, p-value: 7.443e−16

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Healthcare Software Applications

A Comparison of the User Experiences of Primary Care Electronic Health Record Systems

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Abstract. Digital health records play an important role for the information flow in primary care organizations that carry out services at patient's home. Mobile digital solutions have improved the access to up-dated care information at the patient's home, facilitating new ways for clinical workflow and care delivery. This paper presents a study comparing the user experiences of two electronic health record systems in two primary care organizations in Norway. Qualitative research methods were applied with interviews and observations made between 2017 and 2019 where clinical end-users of primary care electronic health records participated. The study showed that the systems had an important function for the daily operations, both from a care and administrative perspective, and that the introduction of mobile devices had changed how individual digital care plans were used in the clinical work process, even though there were issues that could be improved.

Keywords: User experience · User studies · Electronic health records · Primary care · Individual digital care plan

1 Introduction

For primary care services, the electronic health record plays an important role for the information flow and management of care [1]. The introduction of care information displayed and available in mobile devices has enhanced the access to up-dated medical information at the patient's home [2], which also facilitates new ways for the clinical workflow and decision making in the care delivery process [3]. In Norway, there is a national strategy for strengthening the digital communication and information exchange within and across health organizations [4, 5]. The adoption of electronic health records among primary care organizations, hospitals and General Practitioners (GP) in Norway is close to 100% and with information exchange through a national health network infrastructure [6]. For primary care services, there are several electronic health record systems available and with a few of them having the largest market share.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 233–238, 2020.
https://doi.org/10.1007/978-3-030-50838-8_32

Primary care electronic health record systems have been linked to usability issues such as lack of integration and with limited possibility for communication across organizations [7, 8]. In this context, this study was made to compare the user experiences of primary care electronic health record systems. This paper presents a qualitative study on the user experiences of care professionals from two primary care organizations using two different technical systems. The research questions stated were:

RQ1: What are the user experiences among health care professionals regarding primary care electronic health record systems?
RQ2: What are the benefits and drawbacks of the primary care electronic health record systems?
RQ3: What are the lessons learned that are transferable and applicable to other clinical care contexts?

Following the introduction, the methodology is described. In the third section, the results of the study are presented. Finally, the discussion and conclusion reflect on the lessons learned and study contributions.

2 Methodology

A qualitative research approach [9, 10] was used in this study of the user experiences, with semi-structured interviews and observations of technology use made in the period from November 2017 and until November 2019. Field visits were made to two primary care organizations that used different electronic health records, System A and System B. A total of seven informants contributed to the study, six female and one male that all had a clinical profession.

The interview-guide targeted user experience with primary care electronic health record systems, documentation routines and information flow. The aim of the interviews was to study the user experiences in the care organizations and map how technology was used for communication and information sharing purposes. All interviews were performed at the working place of the informants. One super user in each organization made a thorough demonstration of the user interface and functionalities available in a test version of System A and System B. Observations in staff room were also made to provide insights regarding the daily use of electronic health records in a clinical context and in teamwork.

The data collection consisted of audio-recordings that were transcribed and annotations that were thematically analyzed and categorized into sub-groups.

2.1 Ethical Considerations

The informants were selected and recruited in collaboration with a manager in each organization. Participation in the study was voluntary and the informants received written information about the study and an individual consent form was signed. The Norwegian Centre for Research Data approved the study, with project number 53771 [11]. No confidential patient data were collected. The author declares that there are no conflicting interests with any of the participants, organizations or industry.

3 Results

The results are presented in two categories: System A and System B, each one describing the functionality and the user experiences.

3.1 System A

System A had the overall aim of focusing on the functions of the patients and long-term care. The key functions were statutory documentation of care and management of selected paid-services. In terms of information flow, the system could receive and send digital messages about patients to other primary care services and GPs, but only receive information from hospitals. The user interface was guided by keywords in banners at a side menu. The documentation was mainly made in free text and there was a limitation of the number of letters and a progress note might therefore become divided into two parts. The system was available om mobile devices and used in care delivery at patients' homes.

Regarding the user experience, the informants described a lacking overview of patient's status because the visualization of information became fragmented when data from the same shift had to be divided into multiple banners as some information might be entered to "Nutrition" or "Communication" and other things to "Personal Care". A mouse click was needed to visualize the content of each banner. The informants expressed that they missed a status overview of clinically complex patients with a function that could simultaneously visualize the content from all the banners of a particular shift, day or week. The progress notes often had focus on interventions made, but less information about the patient status or the progress. The informants mentioned an information overload in the user interface, with limited visibility of important information, such as discharge letters. They explained that it was difficult to obtain the overview of care trends over time for evaluating the progress of a long-term individual care plan. Decision support was lacking, such as reminder of "injection every third month", and this was solved by a manual calendar book beside the system. The informants told that there were few courses for user training, mainly learning from each other and with different ways of using the system across the units within the same organization.

3.2 System B

System B was also used for management within the organization and having a billing function for selected care services that had been carried out. The user interface had standardized key words for statutory documentation organized in banners. The system was available on mobile devices for home care services delivering services at patients' homes. The working list was dynamic and could be changed remotely during a shift. The system received digital messages from GPs and hospitals, but that could only be accessed on desktop at office and not on mobile devices. The procedures and goals for a patient were often described in a detailed way. There were not standardized terms, free text was used for progress notes.

About the user experiences, the informants expressed that the mobile version was user-friendly and supported a dynamic workflow. It was stated that *it had changed the way the care was carried out*. The care was planned in advance with a detailed long-term individual care plan, containing different procedures and providing an up-to-date overview of the patient's status. When a home visit was done and the instruction for a procedure had been followed, a box was ticked-in to confirm the action and only when not performed or something extraordinary occurred a free text was entered. When several tasks or procedures had been made at a patient's home, only one tick-in a box was made covering all of them, instead of ticking-in several boxes. For this reason, it was important to up-date the care plan regularly. Tasks during a shift could be transferred to a colleague within the team. In a care team, internal messages could be sent to the colleagues in the team for communication purposes, but no reply could be sent. Before attending a patient, the tasks and procedures were usually read on the mobile device, and only in specific cases the medical history was accessed and read. It was expressed that the systems had functionalities that supported the workflow, even though it could be more intuitive and integrated.

4 Discussion

This work was made to study the user experiences of two primary care electronic health record systems, by observing and interviewing health care professionals in clinical practice. The research questions (RQs) are answered based on the results.

Regarding RQ1, that asked about user experiences of primary care electronic health records: the study showed higher user satisfaction of System B compared to System A, and System B seemed to better support the clinical workflow and user needs of primary care services.

RQ2 addressed benefits and drawbacks of the systems. A benefit of both systems was the use of mobile devices to access information at the point-of-care, which was introduced around three years prior to this study. Worklists on a mobile devices for home care service was an advantage as the workflow was dynamic and often modified during a shift. The introduction of the mobile devices had changed the working routines, with extensive individual digital care plans, particularly for System B. The function of both systems with ticking-in a box for confirming performed care is moving towards standardization of nursing interventions and with less use of free text, in line with [12]. A constraint of System A, was the fragmentation of information with a limited overview of long-term trends for clinically complex patients and lacking decision support to remind on regular interventions. For System B, better integration of the available functions was suggested.

About RQ3 that targeted lessons learned and transferability. The findings of this study are an example of how technology and mobile devices can impact on the clinical workflow. Attention was made on creating detailed individual digital care plans at the office, and with confirmation of tasks and interventions performed at the point-of-care, instead of writing detailed daily progress notes in free text. Further, the study showed that both systems had multiple aims, billing purposes and progress of long-term care, and how demanding the performance of such a system can be in terms of userfriendliness and user satisfaction for multiple end-user groups with divergent user needs. This highlights the importance of involving end-user groups in design, development and refinement of primary care digital systems [13], but also the value of user training for using the support functions of a system correctly in an organization, congruent with [14].

This study had some limitations such as the number of informants. However, the informants from both care organizations had several years of working experience and meaningfully represented the clinical end-users of primary care electronic health records. They contributed with sharing their user experiences and interactions with technology.

5 Conclusion

This paper has presented the user experiences of two primary care electronic health record systems. The study showed that the systems had an important function for the daily operations, both from a care and administrative perspective, and that the introduction of mobile devices had changed how individual digital care plans were used in the clinical work process. The main contribution of this study lies on the descriptions of the user experiences by health care professionals in primary care organizations, generalizable and with implications to other health care contexts. Primary care electronic health records focus on the patient's functions, needs of health care support and initiated individual care plans with visits of home nursing services, and how those systems are designed has an impact on their use and how they can be adapted for diverse contexts. For successful implementations and operation of primary care electronic health records, a close collaboration is needed between the user groups of health organizations and vendors to systematically analyze the information- and workflow. This might cause fewer usability problems and enhance a functional system adaption that supports an efficient information flow within the clinical work process.

Future work would target a larger number of primary care organizations across different countries and compare the user experiences and their use of electronic health records and individual digital care plans.

Acknowledgments. The author thanks the informants of the study for their contribution. Financial support was provided by the Faculty of Engineering and Science at the University of Agder in Norway and from the research project 3P–Patients and Professionals in Productive Teams [15].

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Usability Evaluation of an EHR to Improve Physician Performance

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Abstract. This study aims to determine usability issues experienced by primary care resident physicians when using an electronic health record (EHR) to improve physician performance. Primary care resident physicians participated in two rounds of usability tests to identify changes in the learning curve associated with the EHR. Sub-task analysis was instrumental in identifying multiple usability concerns. Novices and expert resident physicians experienced significantly fewer usability issues in round 2 than in round 1. These results highlight the areas of difficulty resident physicians with different experience levels are currently facing, which may increase physicians' performance when using an EHR.

Keywords: Human-computer interaction · Usability · Primary care · Residents · Electronic health record

1 Introduction

The expansion of health information technology's functionality in clinical practice and physicians' extensive adoption of EHRs are a result of the financial incentives guaranteed by CMS [1]. Research on EHR use convey that adopting an EHR allows for better remote access to patients' visit note, accurate, comprehensive, and up-to-date patient information, access to crucial lab values, and an enhancement to overall patient care [2, 3]. Despite these improvements, there are drawbacks to EHRs such as financial burdens, increased patient risk and harm, misrepresentation of workflow, diminished physicians' time, and productivity loss. These drawback can also be linked to usability issues [4, 5]. Usability is one of the major factors hindering the widespread adoption of EHRs [6]. Usability is defined as the "extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 239–245, 2020.
https://doi.org/10.1007/978-3-030-50838-8_33

satisfaction in a specified context of use" [7]. The objective of this study is to compare usability issues experienced by expert and novice primary care physicians when using an electronic health record (EHR) to improve physician performance.

2 Method

This study was conducted at a tertiary care academic medical hospital. Novice and expert primary care resident physicians were distinguished based on clinical training level and number of years using the EHR. First year residents were grouped as novice physicians because they had the least amount of clinical training and the least number of years using the EHR. Expert physicians were grouped as second year residents and above. Family and Community Medicine (FCM) and Internal Medicine (IM) physicians were selected for the sample because, as primary care residents, they have equivalent clinical roles and duties. Twelve FCM, four IM residents volunteered to participate and were compensated for their involvement in the project. Based on a review of the literature, ten participants were judged suitable in explorative usability studies to discover 80% of pertinent usability problems [8, 9].

Two realistic scenarios were employed that were equivalent in difficulty, workflow, and functionalities. Round 1 scenario was, "a scheduled follow up visit after a hospitalization for pneumonia." and round 2, was, "a scheduled follow up visit after a hospitalization for heart failure." Two different scenarios were used to reduce any bias from recall of previous study. Tasks commonly performed by resident physicians were developed and met the EHR certification criteria 45 CFR 170.314 for meaningful use stage 2 [10]:

1. Note Creation *(§170.314(e)(2))* Start a new note
2. Visit Information *(§170.314(e)(2))* – Include visit information
3. Chief Complaint *(§170.314(e)(2))* – Include Chief Complaint
4. History of Present Illness *(§170.314(e)(2))* – Include History of Present Illness
5. Current Medications *(§170.314(a)(6))* – Review current medications in your note
6. Problem List *(§170.314(a)(5))* – Include problem list in your note
7. New Medication Allergy *(§170.314(a)(7))* – Document new medication allergy.
8. Review of Systems *(§170.314(e)(2))* – Include the following Review of Systems
9. Family History *(§170.314(a)(13))* – Include Family History
10. Physical Exam *(§170.314(a)(4)* and *§170.314(e)(2))* – Include Physical exam
11. Medical Decision Making *(§170.314(b)(5))* – Include last CMP
12. Save Note – Save the note
13. Diagnosis *(§170.314(a)(5))* – Include diagnosis
14. Chest X-Ray *(§170.314(a)(1)* and *§170.314(e)(2))* – Place order for chest x-ray in one month
15. BMP *(§170.314(a)(1)* and *§170.314(e)(2))* – Place order for BMP today and in one month
16. Change Medication *(§170.314(a)(1)* and *§170.314(a)(6))* – Change medication: lisinopril from 10 mg 1 tab daily to lisinopril 5 mg 1 whole tab daily

17. Medication Renewal *(§170.314(a)(1)* and *§170.314(a)(6))* – Renew one of the existing medications for 1 year (30 day supply & 12 refills)
18. Medication Creation *(§170.314(a)(1))* – Create a medication favorite.
19. Finalize Note *(§170.314(a)(1)* and *§170.314(a)(6))* – This clinic visit occurred on [date] and was at a Family Medicine Clinic.
20. Sign Note – Sign the note and forward to attending for signature.

2.1 Data Collection

Participants had three months of EHR use between usability rounds. Usability testing was conducted in conference rooms. The resident physician and the facilitator were the only two individuals in the testing room. The testing was completed in approximately 20 min on a 15-inch laptop using Windows 7 operating system. The test environment of the EHR was used during data collection to avoid potential disruptions in the live EHR. The testing environment gave the resident physicians access to all the functionalities of the EHR but did not include any personal customizations, such as, favorites and macros that would have been available under their personal login. Morae Recorder® captured audio, video, on-screen activity, and inputs from the keyboard and mouse as the physicians interacted with the EHR to complete the tasks. After resident physicians completed the tasks, they completed the System Usability Scale (SUS) and a demographic survey followed by a debriefing session. The university's Institutional Review Board approved this study.

2.2 Data Analysis

The recorded sessions were analyzed with Morae Manager® to identify difficulties and errors the physicians had. Sub-task analysis recognizes subtle usability issues, workflow, and navigation pattern variability that would have otherwise been unnoticed. To determine whether novice and expert resident physicians experience fewer usability issues in the course of two EHR usability tests, Wilcoxon signed rank test was used to identify a significant difference in number of usability issues experienced by resident physicians in round 1 and round 2.

3 Results

3.1 Usability Issues Identified by Sub-task Analysis

Six expert physicians and 10 novice primary care physicians participated in the usability test. Because the study was voluntary, some participants declined to participate in round 2.

Sub-task analysis was instrumental in identifying multiple usability concerns. Between both rounds, there were 33 usability issues observed among novice and expert resident physicians.

Novices experienced 63% of the usability issues identified in both round 1 and round 2. There was a statistically significant difference (w-value = 18, $P < 0.05$)

between the number of novices experiencing usability issues in round 1 than the number of novices experiencing usability issues in round 2. In round 1, experts experienced 75% of the usability issues identified and in round 2, experts experienced 50%. There was a statistically significant difference (w-value = 5, $P < 0.05$) between the number of experts experiencing usability issues in round 1 than in round 2.

Table 1. Usability issues repeating across two rounds identified from sub task analysis. R1-round 1, R2-round 2, N-novice, E-expert

Usability issue	Example	R1		R2	
		N	E	N	E
Task 8: Structured data not utilized	Physicians rarely expanded the 'short list symptoms' to access more structured codes for symptoms. They just clicked 'OTHER' and type it in	7	6	6	3
Task 8: Unawareness of functions	Include Review of Systems - Some physicians were *not* able to add a comment to a symptom by right clicking the symptom	4	4	3	3
Task 10: Structured data not utilized	Physicians rarely expanded the 'short list symptoms' to access more structured codes for symptoms. They just clicked 'OTHER' and type it in	7	5	4	4
Task 11: Unclear difference between 'All Results' and 'Lab Results'	Include last Comprehensive metabolic panel (CMP) - Physicians try to find CMP results from 'All Results' subsection but it is located in the 'Lab Results' subsection	2	2	1	1
Task 12: Meaningful title for note not required	Save the note - Did not change title. Physicians were not required to change the generic title, provided with the progress note template, to a meaningful (specific) title when saving or when creating the note	6	2	7	0
Task 13: Unawareness of functions	Include diagnosis - Physicians were not able to move 'hypertension' from the problem list to the current diagnosis list so they re-added 'hypertension' as a new problem	5	2	1	1
Task 13: Unclear import function	Include diagnosis - Physicians do not know they should highlight all the diagnoses before clicking 'Include' to get the entire list of diagnoses into the visit note	4	1	0	1
Task 13: Unawareness of functions	Include Diagnosis - Physicians don't use the most efficient Diagnosis (IMO TM) Terminology Search field to add a diagnosis	10	6	3	4
Task 15: Extra steps to complete multiple orders	Place order for Basic metabolic panel (BMP) - Novice physicians did not know how to create two orders at the same time	9	1	1	0

(*continued*)

Table 1. (*continued*)

Usability issue	Example	R1		R2	
		N	E	N	E
Task 15: Unexpected terms in date fields	Place order for Basic metabolic panel (BMP) - One expert physician did not create a future order for one month because the terminology used was 'four weeks' and the user kept searching for 'one month'	0	1	0	0
Task 15: Unawareness of functions	Placed future order in using Comments field instead of "date" field	0	1	1	0
Task 16: Unclear menu options	Change a Medication - Unclear option that says 'Change Medication'. To change a medication you either use 'Renew', 'Cancel/DC', or 'Cancel/Reorder'				
	Modify without resending	6	2	4	2
	Cancel/Reorder	4	2	4	2
	Cancel/DC	3	1	0	2
	Renew	1	1	0	1
Task 18: "Indication" field not required	Physicians *do not* usually input the 'Indication' when prescribing medication. Physicians were not required to provide a diagnosis to justify a medication and therefore some users did not feel it was important or necessary to enter a reason for prescribing the drug	6	6	9	4

The most common usability issues identified was found by physicians attempting to complete Task 7: Document new medication allergy, Task 13: Include diagnosis, Task 15: Place order for Basic Metabolic Panel (BMP), Task 16: Change a Medication, Task 17: Add a medication to a favorite list.

In round 1, 3 out of 7 expert resident physicians and 4 out of 10 novice resident physicians did not successfully complete Task 7: Document new medication allergy. To complete this task, physicians have to use a drop down box to change the status from 'canceled' to 'active'. We had previously used the same drug, canceled it, and thus that ('canceled') became the default setting for that drug. The issue would not have arisen if we never labeled the test patient allergic to that drug. The physicians gave up completing Task 7. Two novice physicians tried to type in the text field labeled 'Substance' which was not meant for typing. One novice physician went into the Histories tab first to find Allergies, which is incorrect, then found Allergies below the patients' name. In round 2, each physician was given a task of making new medication order and was to add the allergy "hives." With this change in round 2, all novice and expert resident physicians were able to successfully complete Task 7 because the status of the medication allergy was automatically populated to 'Active' instead of 'Canceled' when adding a medication allergy to an already existing medication.

When completing Task 13: Include diagnosis, resident physicians were unclear on how to import a list of diagnoses from the Problem List into the visit note. In round 1, 4 novice resident physician and 1 expert resident physicians were unaware that they should highlight all the diagnoses before clicking 'Include' to get the entire list of diagnoses into the visit note. In round 2, all novice resident physicians were able to correctly import the diagnoses from the Problem list into the visit note; however, an expert physician still had difficulty importing the diagnoses from the Problem list into the visit note.

When completing Task 15, 9 out of 10 novice resident physicians and 1 out of 6 expert resident physicians in round 1 did not place two orders concurrently. In round 1, a novice resident physician mentioned that there was a way to order them both at the same time but did not know how. In round 2, only 1 novice resident physician did not place the two BMP orders concurrently.

When completing Task 16: Change a Medication, resident physicians had to choose from the right click menu options 'Renew', 'Cancel/DC', or 'Cancel/Reorder.' In round 1, novice resident physicians may have spent extra time on this task because they were unclear of what option to use among the multiple options. The right-click of a medication brought up a menu list with a menu item labeled "Modify without resending." In round 1, 6 out of 10 novice and 2 out of 6 expert resident physicians attempted to use this menu option although it was not the correct menu item. In round 2, 4 out of 10 novice and 2 out of 6 expert resident physicians attempted to use this menu option although it was not the correct option. To change a medication, the recommended menu item to choose was 'Cancel/Reorder.'

When completing Task17: Add a medication to a favorite list, resident physicians were asked to add a medication to a list of their frequently used medications. In round 1, 3 out of 7 expert resident physicians and 4 out of 10 novice resident physicians did not successfully complete. A novice and an expert resident physician did not even attempt to add the medication to their favorites. In round 2, 2 out of 9 novice resident physicians and 1 out of 5 expert resident physicians were not able to complete this task. An expert resident physician mentioned not knowing how to add a medication to their favorites list. Adding a medication to a favorites list can only be done when the order detail view is open, where medications' specifics, such as, dosage, are included.

The SUS showed that in round 1 novice physicians ranked the system's usability at a mean of 69 (high marginal) compared to 68 (high marginal) in round 2. Experts rated the system's usability at a mean of 74 (acceptable) in both rounds.

4 Discussion

Both novices and experts experienced less usability issues across 2 rounds of usability testing. Novices experienced more usability issues in round 1 than in round 2. Novices experienced 63% of the usability issues identified in both round 1 and 2. In round 1, experts experienced 75% and in round 2, experts experienced 50%.

Although users experienced less usability issues, the SUS score did not increase, which demonstrates that achieving a certain level of proficiency from continued EHR use is not representative of a more usable system. The higher SUS scores by expert participants indicate that they may be more confident using the EHR compared to novice participants because of their prolonged use. The similarity in SUS scores between round 1 and 2 implicates that longer exposure to the EHR does not equate to users finding the system easy to use.

There were some methodological limitations in this study. First, this study involves the primary care resident physicians in one health care setting where only one EHR is operated. Therefore, there may be limited generalizability to other clinic settings where different types of EHR applications are used. However, the EHR platform used in this study is one of the top commercial products with substantial market share.

These results may assist EHR vendors in improving the user interface. Improvement in the EHR's usability may enhance user satisfaction and proficiency, which may increase physicians' competency when using the system.

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The Development of Traditional Thai Massage Chatbot Application for Hypertension Treatment

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Abstract. Hypertension is one of the significant health problems from chronic health conditions, which may cause serious health issues and sudden death. Thai massage or Nuad Thai, which is a Thai traditional healing practice and a well-known therapy, can be applied as a treatment for some chronic health conditions. There are various Thai massage courses available for people who are interested, but the problems of participation schedules, massage therapy techniques, and how to practice it correctly are difficult for non-experts to follow and improve the knowledge and skills by themselves. Thus, we would like to develop computer instructional lessons of Thai massage for high blood pressure treatment by giving basic information through a media service or an application, which is a chatbot application. Then, we evaluated the quality of graphics and video content as well as the chatbot application using an online survey. The results showed that the media was easy to follow and understandable. The users mentioned that after they used the chatbot application and saw the Thai massage video clips, they were able to perform the massage by themselves.

Keywords: Chatbot application · Thai massage · Instructional design

1 Introduction

Nowadays, Thai people have suffered or negatively affected by their daily activities such as working or sitting in a poor posture for a length of time, consuming foods and beverages contained too much sugar, or lack of exercise. These can cause chronic health conditions such as high blood pressure, diabetes, high cholesterol, heart disease, and obesity. Hypertension is one of the significant health problems from these chronic health conditions, which may cause serious health issues and sudden death. A number of Thai people who have a high blood pressure condition had grown up during the last 10 years. The number of hypertension patients was 17% of Thai population in 1992.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 246–252, 2020.
https://doi.org/10.1007/978-3-030-50838-8_34

It increased to 24.7% of the population in 2014. Major problems of treating hypertension are that the patients are not aware of their condition. [1]

Health care facilities in Thailand have been promoted in the last few years, and massage therapy is an alternative treatment for many diseases. Thai massage is a Thai traditional healing practice and a well-known therapy that has been taught for more than a thousand years. Thai Massage can support both inside and outside health benefits, and can be used as a treatment for some chronic health conditions. There are various Thai massage classes available for people who are interested, but the problems of participation schedules, massage therapy techniques, and how to practice it correctly are difficult for non-experts to follow and improve the knowledge and skills by themselves. Thus, in this study, we would like to develop computer instructional lessons of Thai massage for high blood pressure treatment by giving basic information through a media service or an application, which is a chatbot. We hypothesized that this media would help users easily access information anytime, conversational responses based on what users need to know, and users can learn about Thai massage by themselves.

2 Traditional Thai Massage

Traditional Thai massage or Nuad Thai is a whole-body massage that can support both inside and outside health benefits, makes people feel comfortable, helps relieve pain feeling, and can be applied as a treatment for many health conditions. It has been listed as intangible cultural heritage by Unesco in 2019 [2]. The massage process starts with supine position on the feet and up along to both inside and outside of legs and arms. Then, a masseur or a masseuse will massage both sides of legs and up to hip until arms again. After that, he will change a position for massaging the back of the whole body. Lastly, the massage will end at face. The entire process takes about 1–2 h to complete. Thai herbal compress and Thai medicine may be used while massaging. Massage can be applied for rehabilitation or relieving some health conditions and Fig. 1 shows a neck and shoulder massage. However, some cautions should be concerned while practicing Thai massage. First, a masseur or a masseuse should not press on superficial nerves or ganglion areas such as armpits and collarbone, and second, he should not crush the pulse areas, lymph and saliva gland.

Fig. 1. A masseur gives a neck and shoulder massage.

Consequently, it is difficult for novices to follow and improve the knowledge and skills by themselves. The chatbot application may assist the beginners practicing Thai massages and also promote this cultural heritage around the world.

3 Chatbots

Chatbots are an Artificial Intelligence or AI software that can interact with users using natural languages by communicating through an application, a website or social media. Initially, chatbots were developed for fun such as ELIZA [3, 4] or A.L.I.C.E. [5] using simple pattern matching techniques, which attempted to match answers to texts or message inputs.

Currently, Chatbots have an important role in human's life since they can respond to people's needs immediately and automatically. Many advanced technological companies have developed their own chatbots in order to support costumer services and user's lifestyles such as Siri and Cortana [6, 7]. Neural networks and machine learning techniques have also been integrated to the systems for better conversations in natural languages.

Furthermore, many researchers proposed ideas of how to use chatbots to support health care services and treatments, as well as promote wellness. For example, [8] proposed an AI chatbot for healthcare providers to engage patients in tracking their medication for chronic conditions overtime. It also records patients' lifestyles, activities and emotional states, which help medication adherence and controlling chronic conditions. Another study from [9], suggesting that chatbots should be used for educating health awareness as a virtual doctor. [10] proposed the idea of AI chatbot that can predict diseases based on symptoms and provide treatments for those symptoms. [11] also designed a primary care chatbot for recording patient symptoms and submitting it to doctors for further diagnosis. In the study, we would like to implement chatbots using LINE (a social network platform from LINE cooperation: https://line.me/en/) and Dialogflow (a Google service that helps developers creating natural language conversational platform for communicating between human and machine: https://dialogflow.com/) for hypertension treatment.

The design of the Chatbot functionality is a simulation of chat situations that responding to questions in specified patterns. We designed a process of receiving data from users and a process of finding the matched keywords, which will respond back to users.

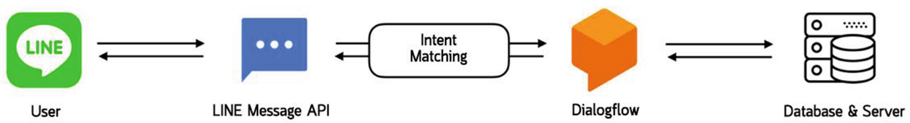

Fig. 2. The workflow of the Thai massage chatbot application

The development process of the chatbot started that we collected the questions that users would ask in Thai in the scope of Thai massage and hypertension such as "What is hypertension?" or questions about different types of Thai massage. Then, we created answers in Thai for each question in various formats, i.e. pictures, video clips and texts. After that, we implemented the chatbot using LINE Application Programming Interface (API), Webhook and Dioalogflow API. The chatbot workflow is shown in Fig. 2. When users typed a question or words in LINE application, it was sent to Dialogflow. Dialogflow tried to find the best answer that matches the question using pattern matching and some natural language methods. This example of chatbot interface is shown in Fig. 3.

Fig. 3. The screenshots of Thai massage chatbot interface.

4 Material and Method

To evaluate a quality of Thai traditional massage chatbot application for hypertension treatment, we asked 25 participants who are 2nd-year students at faculty of Thai Traditional Medicine at Kanchanabhisak Institute of Medical and Public Health Technology about the application. There are 13 males and 12 females in this group, and their ages were ranged from 20 to 30 years old.

The data collection was conducted in Google form. The questions were about the quality of the answers from the chatbot, interface design of the application, font size, font color, audio and graphics in the video clips, and the content relating to the massage. The type of the questionnaire was a 5-point Likert's scale, including 5 (very satisfied or very good), 4 (satisfied or good), 3 (neither satisfied nor dissatisfied, or neither good nor bad), 2 (dissatisfied or bad) and 1 (very dissatisfied or very bad).

We separated the questionnaire into 2 groups, which were a satisfaction of the chatbot application, and a quality of graphics and video clips of Thai massage. The list of Likert's scale statements was shown in Table 1.

Table 1. Statements for evaluation in the questionnaire

Statement ID	Statement
Satisfaction of the chatbot application (A)	
A1	Questions in the chatbot represent what you are curious or interested
A2	The answers from the chatbot are the content that you would like to know
A3	The answers from the chatbot are completed and can be applied in real life
A4	After watching video clips, you can apply the content from the clips for further benefit
Quality of graphics and video clips of Thai massage (B)	
B1	The formats of the videos and chatbot are interesting and easy to understand
B2	Font size, theme and color are suitable for reading
B3	Animations in the videos are consistent with the content
B4	Learning from videos is practical and easy to understand
B5	Illustration and its size are appropriate and consistent with the content
B6	Audio and narration can motivate and trigger audiences to learn

We computed average scores and standard deviation of each statement for data analysis. Then, the rating results of the satisfaction and the quality of the application were interpreted as follows shown in Table 2:

Table 2. Interpretation of the rating scales

Average score	Satisfaction level	Quality level
4.50–5.00	Very satisfied	Very good
3.50–4.49	Satisfied	Good
2.50–3.49	Neither satisfied nor dissatisfied	Neither good nor bad
1.50–2.49	Dissatisfied	Bad
1.00–1.49	Very dissatisfied	Very bad

5 Results and Discussion

Table 3 shows a summary of the satisfaction results of each statement. The participants thought that the Thai massage chatbot application was useful. They were able to practice and apply the content in videos or answers from the chatbot in reality.

Table 3. Satisfaction results of the chatbot application

Statement ID	Mean ± SD	Level
A1	4.16 ± 0.74	Satisfied
A2	4.20 ± 0.50	Satisfied
A3	4.04 ± 0.67	Satisfied
A4	4.36 ± 0.48	Satisfied
Total average	4.19 ± 0.59	Satisfied

Table 4 shows results of the quality of graphics and video clips. The participants liked audio and narration in the video clips. The illustration and its size were appropriate and consistent with the content, which helped and motivated them to learn.

Table 4. Quality of graphics and video clips of Thai massage

Statement ID	Mean ± SD	Level
B1	4.20 ± 0.81	Good
B2	4.44 ± 0.50	Good
B3	4.16 ± 0.37	Good
B4	4.12 ± 0.52	Good
B5	4.44 ± 0.50	Good
B6	4.56 ± 0.58	Very Good
Total average	4.32 ± 0.54	Good

6 Conclusion

In this study, we developed the Thai massage chatbot application to help non-expert masseurs or masseuses practicing the massage correctly and be able to improve their knowledge and skills by themselves. We asked participants who were undergraduate students aged between 20–30 years old to interact with the chatbot and watch video clips about Thai massage. Then, we evaluated the quality of video content and the chatbot application using an online survey. The results showed that the media was easy to follow and understandable. The users also indicated that graphics and audio in the video are persuasive and their quality was at a good level. The chatbot made the Thai massage video more engaging. Moreover, the users mentioned that after they used the chatbot application and saw the Thai massage video, they were able to perform Thai massage by themselves. We will add more functions to the chatbot application such as tests, and also improve performance of question – answer matching for using it in reality.

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The Adoption of mHealth Apps Testing the UTAUT Model with Gamification Impact

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Abstract. The rising movement in technology led to an increase in mobile health (mHealth) applications (apps). Users are adopting these applications for several reasons, however, there is still no consensus on which factors affect user's adoption the most. This study aims to identify and prioritize factors affecting the usability of mHealth apps using Analytic Hierarchy Process. The main goal is identified first then six main criteria and twenty-three sub-criteria are selected from existing literature review based on the Theory of Acceptance and Use of Technology and Gamification framework. The findings suggested that trustworthiness is the most important factor among the rest, following that competition, hence users prefer the opportunity to compete with others. Additionally, learnability was found the third important factor as the easiness. Moreover, the results suggested that the users' feelings of enjoyment lead to motivation hence adoption. These findings are important to articulate the adoption behavior of mHealth apps.

Keywords: mHealth · Smartphone · Mobile apps/applications · Technology acceptance · Gamification

1 Introduction

The recent development in Information Technology and the increased use of smart devices have significantly impacted the mobile application industries. The health sector is among the areas that are facing a revolution as it adopts the use of technology for healthcare by the use of Mobile Health Applications to be subsequently known as mHealth apps [1]. Users adopt health apps as they enable them to monitor their health and measure different health-related factors such as calories burned, body temperature, sleeping duration, exercise such as walking [2], as well as the bodyweight among other indexes [3].

Recently, many mHealth apps were widely used with over 3.7 billion downloads such as Fitbit and Jawbone [4]. However, these applications end up remaining unused due to their unfriendly interface, lack of motivation or the necessary physical guidance that the user may not have access to [5]. Thus, with the rising movement from traditional healthcare to use technology, it is critical to study the factors influencing the consumer's behavior in the use of mHealth apps [6].

This study employed The Unified Theory of Acceptance and Use of Technology (UTAUT) model [7] to simplify the adaptability on health technology, and it consists of

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 253–259, 2020.
https://doi.org/10.1007/978-3-030-50838-8_35

four constructs, namely; Effort Expectancy (EE), Performance Expectancy (PE), Facilitating Condition (FC) and Social Influence (SI) [7]. Gamification has also been used in designing health apps by integrating game features [8]. Overall, this study focuses on understanding the factors that influence the use of mHealths apps from a consumer's standpoints by narrowing down to most preferred elements that influence a choice of mobile technology. The objective of this study is to prioritize those factors to provide insights for apps developers. The study was applied in the United Arab Emirates (UAE) as it is considered as one the developing countries [9].

The remainder of this paper is organized as follows: the following section consists of an in-depth analysis of the existing relevant literature to choose the main criteria and sub-criteria. Section 3 presents the research method. Then results are presented and discussed, finally, findings, limitations and various recommendations are provided.

2 Related Work

2.1 Theoretical Background: An Overview of mHealth Technology

mHealth is defined as using mobile communication devices for the advantages to obtain health care services [10]. For the context of this research mHealth apps are defined as mobile applications deployed to mobile phones and handheld devices for delivering self-health care support and management. Consumers use mHealth apps to increase healthy behavior [11]. While others prefer this technology because they are connected to social media [12].

There are various domains of technology implemented in adoption contexts using UTAUT model such as e-books [13], e-banking, [14], e-government services [15], document workflow management system [16] and mobile health services [9]. This is due to the robustness, comprehensiveness, statistical validity, reliability and accuracy of the UTAUT model to predict the technology acceptance in different disciplines that are using technology in various contexts [13]. Hence, it is assumed that this model can be used to understand the behavioral intention towards the use of mHealth.

Recently, most of system designs are utilized by some or all gamified features. Technology acceptance factors are integrated with gamification to study about the behavior change [13]. People use this technology because of its simple design and positive impact on social influence [9]. While customized messaging, feedback, intangible rewards, reminders and goal setting are important components of mHealth interventions [17]. mHealth apps can fit into people's busy lives effectively to offer health care solutions and provide ubiquitous health support [18].

Furthermore, there are little confidence and security assurances on user data [19] because sensitive users' medical information is prompted to be entered during apps registration. The minimal assurances that the data uploaded are safely and confidentially kept has bared many users from these applications [5]. Users consider security, privacy and reliability when using this technology [20].

According to the objective of this study, factors were primarily chosen from the UTAUT model, gamification features and security determinants that influence the mHealth app usage as indicated by past studies. These factors are used as the main criteria in this study which are explained as below:

2.2 UTAUT Model's Factors

Venkatesh et al. (2003) elaborate efforts expectancy (EF) as the ease of effort that is required by a user to operate a tool, as the lesser the effort needed to run the app, the more the preference by the intended consumers. mHealth apps reduce the amount of work as compared to the traditional healthcare system, hence the user will feel the reduced effort for the same service [7, 21]. Performance Expectancy (PE) is the degree of belief in a system's capability to perform and gain a job performance by an individual as based on the work of [7]. Facilitating conditions (FC) refers to the degree that the user may adopt in an app and accept the rules and infrastructure present to support the system [7]. The service provider of the health service should be capable of providing continuous support by ensuring all time communication with the user regardless of the time or location [22]. The apps are also flexible enough to adapt different personal profiles request by different users to meet the user needs [23]. Social influence (SI) refers to the belief that a person can be influenced by other people the truth about using technology (Venkatesh et al., 2003). Human beings are social, and their need to meet the desire to be sociable is an excellent trait in the adaptation of a behavior (Chang et al., 2007). mHealth apps provide social influence in that users can boost up their social image [13] and may create competition for users as a motivation towards the achievement of certain health goals [7].

2.3 Gamification Factors

Gamification is to employ the components of game designs in the non-gaming applications [8]. Health designers incorporate gamification and social media features into the application to increase engagement of the users, which translates to retention as well as a behavioral change [13]. Gamification association with behavioral health theory serves for creating motivation [17] which can be extrinsic or intrinsic. The behavioral change from gamification as the gameplay to observe the results of the games and a keen eye on logic and rules of the game is used in to use to monitor the changes keenly as well as adhere to the health service that the user is enrolled at that moment [8].

2.4 Security Factors

The technology of mHealth provides solutions to empower people to be responsible for their health. However, there are still some security issues that need to be resolved [20]. mHealth is a relatively new technology as users need to be convinced on the safety of their health information that they are required to submit when they are signing up [24]. Also, users have concerns regarding privacy according to their health information and the ease of accessing it when the need arises [19]. mHealth presents both new risks and benefits to users, and therefore, the service providers ought to improve awareness and offer training to them on how to maintain privacy [20].

3 Methodology

The analytic hierarchy process (AHP) was used in numerous studies due to its ability to collect a large amount of heterogeneous by using empirical data and subjective judgments [25, 26]. AHP is considered a successful technique to identify issues related to quantitative, qualitative and conflict factors and to make the overall best decision [27–29]. This study focuses on illustrating critical factors affecting the adoption of the mHealth apps; therefore, the AHP approach was used to prioritize factors by determining the priority weights based on users' preferences and judgments towards factors (main criteria) and the sub-factors (sub-criteria).

4 Results and Discussions

A hierarchical structure was established which comprises 6 main components and 23 characteristics. According to the analysis results, the following discoveries were pointed out:

This technology is commonly self-selected and used by a various range of people who have different levels of priority according to the characteristics in the model (see Figs. 1 and 2 for an overall idea).

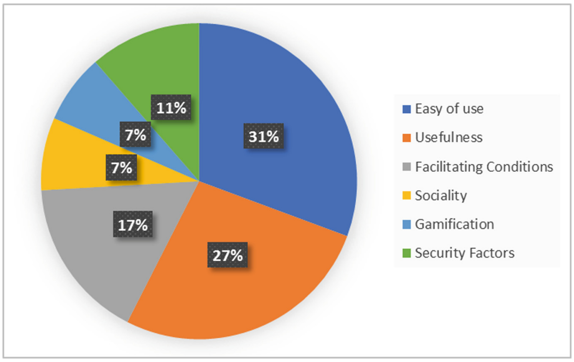

Fig. 1. Priorities of six main criteria with respect to the goal

The results showed that ease of use (31%), usefulness (27%) and facilitating conditions (17%) had the most important impact which is similar to the findings of [9]. It is clear that once participants find the benefits from using technology, the change on user's behavior will be positive [13]. While security factors (11%) deemed by users as the average important component. This result is the same as in previous studies. It is asserted that security has been one of the primary issues with mobile applications that affect the adoption of mHealth apps [20]. The least priority factors based on the responses were given to sociality (7%) and gamification factors (7%) which inconsistent with studies of Maduku [13].

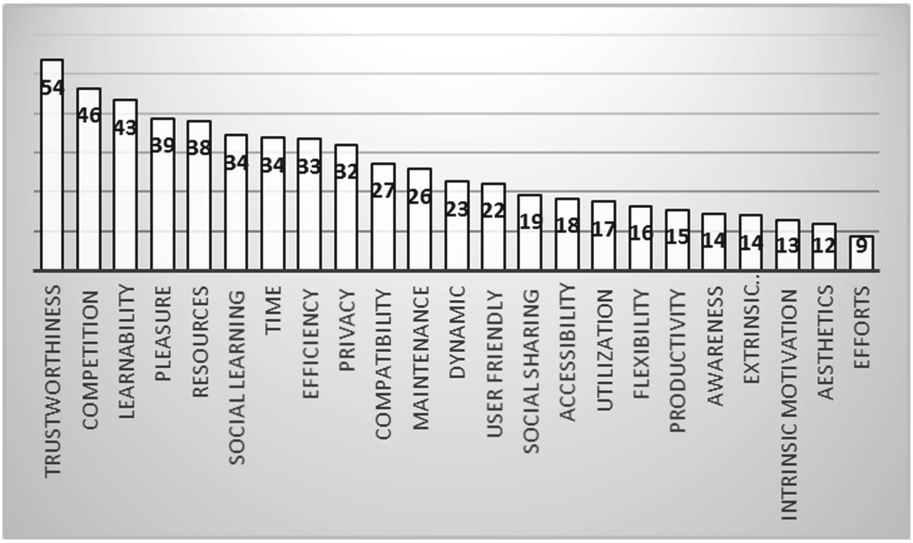

Fig. 2. Priorities of sub-criteria with respect to the goal

The more sense of trustworthiness (54%) available on the apps, the more likely to be used by people which is similar to the findings of studies conducted by Munro [24]. In contrast, based on the users' ratings, competition (46%) was perceived relatively as learnability (43%), while pleasure (39%), resources (38%), social learning (34%), time (34%), efficiency (33%) and privacy (32%) were also perceived to be very helpful in behavior change in the health apps. Hence, these factors had the next impact based on the findings. A study found that users are more motivated when they compete with others and thus encourage them to continue using mHealth app [7]. While people prefer to use the technology even if they do not have a strong technology background [21].

Furthermore, various gamification techniques are used in some mobile health wellness apps, and this gamification inspired users to use mHealth. Many studies agreed that flexibility is liked and mostly used by mHealth apps' consumers [17] which is dislike findings in this study.

5 Conclusion and Future Works

Even with a large number of relative researches on the factors affecting the usability of mHealth apps, there is still a lack of agreement among those researches, hence this study was conducted to fill this gap. Many past studies employing UTAUT model found that usefulness as one of the most important factors affecting technology acceptance [13, 32], however in the context of this study usefulness was ranked the second, hence this study contributes to the theory by providing an argument to be investigated in future researchers. It also contributes to previous studies by combining the technology acceptance along with gamification features and security factors using the AHP model which has not been explored through applied research.

There are still factors remain unexplored, thus it is recommended to explore more features that may impact the adoption and usage of those apps [33]. Therefore, the study suggests future researches to conduct the study using more sample size and different countries to enhance the generalization. A research model can be developed to explain the most important factors that affect the continuity using mHealth apps. Whilst considering these limitations it is important to recognize that research have suggested that many themes resulting from surveys can resonate strongly with findings from comparable research studies [11].

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Relieving Children's Fear During Medical Process by Gamification Medical Navigation Application

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Abstract. Medical fear is an emotional response caused by medical experience and related events. It can reduce children's treatment compliance and affects their adaptation to diseases to some extent, making them unable to deal with the stress effectively. In this study, we introduce a brand-new idea for children's medical guide that benefits from the combination of gamification and traditional medical navigation application to create an immersive and interesting medical experience for children. The research shows that our app has a significant effect on relieving children's fear of the environments, devices, operations, and staffs of hospital during the routine. In addition, this app also improves the operating efficiency of children's hospitals to a certain extent, reduce the burden on guardians, and enhance the triangular interactions between children, guardians and medical staff. It also has preventive and educational effects on the health care of children after rehabilitation.

Keywords: Children · Gamification · Medical fear · Medical navigation application

1 Background

1.1 Medical Fear

Medical fear, a common psychological response to the current medical procedures of most child patients, has a series of negative effects on children's treatment, such as weakening treatment compliance, reducing adaptive capacity, affecting treatment results, and even bringing psychological trauma to children, leading to delayed development and other negative effects [1]. Research shows that 80% of children are prone to negative behaviors during medical procedures, 54% of them continued to experience a series of psychological problems after 2 weeks of diagnosis and treatment, including depression, anxiety and even severe physical problems such as insomnia, nightmares and anorexia.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 260–266, 2020.
https://doi.org/10.1007/978-3-030-50838-8_36

1.2 Gamification

As an indispensable and significant factor in the growth of children's physical and mental health, games not only play a role in entertainment, but also affect children's development in cognition, emotion and personality. Gamification refers to the method of applying the game thinking and game mechanic to other fields, promoting users to participate and share, guiding them interact by influencing users' psychological tendencies when using products. The word was first proposed by British programmer called Nick Pelling in 2002. Early gamification was mostly used in children's education, such as traditional Chinese toys Tangram, Klotski and Chinese Rings [2]. In recent years, gamification represented by digital game media is affecting children's growth on an unprecedented scale. It has been widely used in fields other than entertainment, such as software, education, commerce, health and medical. Using gamification to help the sick children through the treatment period is not only an effective treatment, but also a humanistic care practice.

However, the existing medical game generally choose medical environment and artificial coaching as carrier, which has high cost, low flexibility and generous space requirement. It is only focus on the diagnosis and treatment stage, and the pre-diagnosis and post-diagnosis stages have not been considered. At the same time, the initiative of this gamification method lies in the hospital staff, which can not be adjusted according to the characteristics of child patients. Therefore, the aim of this paper is to gamify the traditional children's medical navigation application, including registered appointment, treatment guide and feedback after treatment. The completion, satisfaction and efficiency of users was tested in order to test the effectiveness of the application in relieving children's medical fear.

2 Application Introduction

2.1 Optimizing the Experience of Children Based on Gamification Theory

Intrinsic and Extrinsic Motivation of Gamification. The key factor in the addiction model is behavior, which is a combination of motivation, ability, and incentives [3]. The motivation is the focus of gamification design. Therefore, in order to make users addicted to products in gamification design, we need to use intrinsic and extrinsic motivations.

Intrinsic motivation is divided into three categories: ability need, relationship need, and autonomy need. These three major needs are both independent and interconnected. External motivation can be divided into two categories: rewards and feedback. When users with high game levels get promotion, reward system will give them certain rewards, which can arouse people's expectations and give them the motivation to continue playing. The feedback motivation is exactly the same as the reward motivation, but the only difference is that the feedback motivation gives users positive feedback when they are unprepared, prompting their dopamine secretion and making them more fascinated by the game.

Core Driver of Gamification. Gamification has eight core driving forces: responsibility and mission, progress and achievement, creativity and feedback, ownership and possessiveness, relationship and connection, scarcity and desire, unknown and curiosity, loss and moral psychology [4]. The gamification design framework is driven by the awareness of human nature, focusing on the induction of behavior and the development of psychological habits. It is necessary to continue to call the user's spontaneity at different stages with different core driving forces to apply this concept to an actual product as a basis for improving a product or service (Figs. 1 and 2).

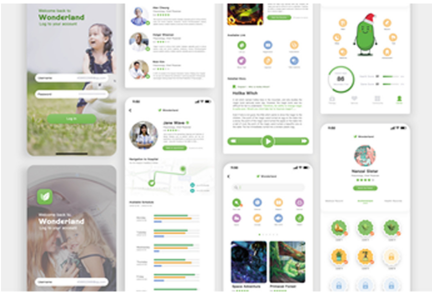

Fig. 1. Wonderland's main operation interface.

Fig. 2. AR navigation in scenarios of hospital

2.2 Design Analysis of Wonderland

Interactive Mode. Interaction design is closely related to the use environment. The interface design according to the use environment and user status can make the application more easy to use on the basis of satisfying the functions, help users reduce the cost of thinking and unify experience and usability [5].

Wonderland makes full use of the advantages of Mobile Internet Information technology, integrates the hospital's medical service process by gamification navigation application, and optimizes the experience of child patients based on actual use scenarios. The theory of intrinsic motivation of relationship demand and the theory of relationship and connection driving force are fully utilized in this respect. The game of Wonderland is managed by medical staff, participated by children, and fed back by guardians. The three parties in the interactive mode participate in the game process together, providing users with efficient and convenient medical services with low-fear while enhancing the fun and ease of interaction.

Visual Element. Children's perception of the color of objects precedes the recognition of the shape, and the stimulation they obtain from the color greatly promotes their brain development. When children use digital products such as apps, color, as the most direct visual language of the mobile terminal interface, needs to be valued by designers. Appropriate color design of the children's application interface can optimize user experience and cultivate their aesthetic judgment [6].

Wonderland combines a clean medical industrial style with a bright childlike-sense. The interface color is based on bright gray, with grass green as the main color and Macaron color system as the auxiliary. It clearly expresses abstract things with the flat illustration style. This visual style draws on the tone of children's storybooks, cartoons and toys, which is in line with children's emotional cognition, triggers their gamification associations, conveys color messages that make children calm in the medical environment, relieves anxiety and creates a comfortable atmosphere.

Game Flow. Wonderland has three major game flows, game mode, level-based breakthrough mode and scoring mode. For the system game, it is divided into three difficulty levels: low, medium, and high. Players can play games that cover medical and health knowledge through online team battles, which can be played during long medical intervals (such as receiving infusions and waiting for reports) or during weekdays to promote children's corresponding knowledge reserve, familiarity and confidence in medical health based on ability needs in intrinsic motivation.

In the level-based breakthrough mode, players need to break through layers to get the treasure and win the game. Each checkpoint corresponds to a corresponding medical project, which realizes the visualization of medical procedure. It is identified by the medical staff as successful entry after medical project completed. The child's driving force of unknown and curiosity and progress and achievement empowers them to continue to work hard.

The setting of the scoring mode is based on the rewards and feedbacks of external motivations and the driving force of ownership and possessiveness. Players get more coins as the game deepens, and the coins will increase after each victory of game. Players can use coins to purchase clothing, equipment, props, and more exciting story lines in the game mall to enhance their own game strength and increase the fun of experience (Fig. 3).

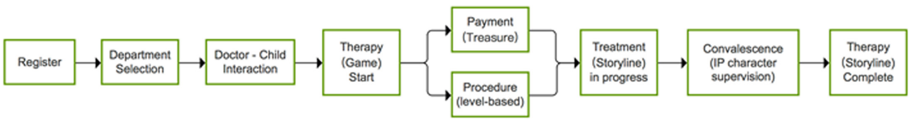

Fig. 3. User journey mapping of Wonderland.

3 Method

3.1 Participants

A total 21 participants were recruited for this study. Ages of participants ranged between 3 and 9, with education levels concentrated in kindergartens and elementary schools. The 21 participants were divided into two groups to participate in the study. The researchers used the first group (i.e. experimental group, n = 12) as users of the gamification medical navigation application, and compared with second group (i.e. control group, n = 9) on datas. 21 participants have experience and ability to use APP.

3.2 Tasks

This study set up a simulated medical scenario with the assistance of pediatric medical stuff in the First Affiliated Hospital of Nanchang University without disturbing the normal order of the hospital. All simulation scenarios included major pediatric medical items and related medical equipment, such as from appointment registration to the hospital, from auscultation and treatment to blood tests. Both the experimental group and the control group used medical navigation applications to assist in simulating medical treatment. The experimental group used Wonderland and the control group used the application of the First Affiliated Hospital of Nanchang University. The number of participants who completed the entire simulated medical treatment process was 18, and the user completion rate was 90%.

3.3 Measures

Participants completed paper questionnaire reports after tasks. The control group filled out the program availability and user satisfaction questionnaire and SUS questionnaire for the First Affiliated Hospital of Nanchang University. The experimental group filled out the revised Wonderland program availability and user satisfaction questionnaire. The two groups tested the usability of two navigation applications from three segmentations of "V" (Visual Language), "B" (Behavior Interaction), and the "E" (Emotional Experience). The degrees of users' satisfaction from low to high corresponded to the scores of 1–5. The average score of each index and category were analyzed by researchers.

3.4 Data Analysis

As shown in Table 1, the comprehensive average index and the average of sub-content indicators of Wonderland and traditional programs are all positive feedback. Wonderland's composite score is higher than that of traditional application, with a difference of 0.6. Among them, the sub-content index with the largest positive gap between Wonderland and traditional application in the "Visual Language" is "Icon Element", which has great appeal to children; the sub-content index with the largest positive gap in Behavioral Interaction part is "Navigation Path", which proves that Wonderland does optimize the traditional medical navigation program; the biggest positive gap in Emotional Experience part is "Pleasant Experience", indicating that Wonderland can improve children's emotional experience in medical procedures. The analysis and evaluation provide theoretical basis and guidance for the subsequent design of the pediatric navigation program. It is still necessary to continuously test, evaluate and improve to achieve the ultimate usability goal in the following research.

Table 1. Availability and user satisfaction data. (W = Wonderland, T = Traditional Application, V = Visual Language, B = Behavior Interaction, E = Emotional Experience.)

Segmentation	Average score of W	Average score of T	D-value *(W minus T)*
V1 Color Sense	4.1	3.2	0.9
V2 Medical Style	2.6	4.3	−1.7
V3 Icon Element	4.3	3.3	1.0
V4 Interface Layout	4.3	3.5	0.8
B1 Navigation Path	4.8	3.6	1.2
B2 Access to Info	3.7	4.1	−0.4
B3 Feedback Response	4.6	3.5	1.1
E1 Humanized Care	4.7	4.0	0.7
E2 Use Accomplishment	4.7	4.3	0.4
E3 Pleasant Experience	4.8	3.2	1.6
	Total = 4.3	Total = 3.7	Total = 0.6

4 Conclusion

Wonderland has a good application effect in alleviating children's medical fear, breaking the restrictions on time, space, resources, and methods of traditional medical services, and providing users with more professional and interesting services. It guides users in efficient diagnosis and treatment to help them expand health knowledge, improve the compliance of treatment, reduce the fear of the environment, operations, and medical staff and the occurrence of corresponding adverse reactions, optimizing the work process of medical staff, saving human and financial resources. However, the current intervention of Wonderland in physical pediatric applications generally has limitations such as short intervention cycles, small sample sizes, and loose randomization, which affects the strength of evidence. In future studies, more large-sample and long-term randomized controlled studies are needed to explore the effects of interventions and provide a basis for subsequent practices. At present, the growing demand for pediatric medical navigation programs of child patients is urgent. Developing more easy-to-use, entertaining, and diversiform of pediatric navigation programs to promote the connection between application and medical institution system, and strengthen the sharing of medical information are the direction of the researchers' future efforts.

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A Parent-Child Interactive Toy Design for Rehabilitation Training of Hearing-Impaired Children

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Abstract. Hearing-impaired children suffer from hearing impairment physically, and their performance levels in cognition and behavior are different from normal children, which greatly affects their lives. Considering that the lack of home-use rehabilitation training restricts the rehabilitation progress of hearing-impaired children, this study aims to analyze the existing rehabilitation mechanism for hearing-impaired children, identify the problems which could be further improved for facilitating the effective rehabilitation training in family context, and accordingly, develop an assistive rehabilitation product for hearing-impaired children. The proposed design can achieve effective interactive process between parents and children and can effectively help with the training of the communication skills for hearing-impaired children. This study provides an insightful exploration in rehabilitation toys for hearing impaired children and could help with the rehabilitation product design practice for hearing-impaired patients.

Keywords: Hearing-impaired children · Home-use rehabilitation training · Rehabilitation products · Cognition level · Interactive process

1 Introduction

According to relevant data, hearing impairment has become one of the largest sensory organ diseases in the world. The number of people with hearing impairment is 360 million, and about 65,000 newborns have hearing impairment every year. As hearing impairment has gradually become younger and more numerous, rescue measures and related rehabilitation studies for younger hearing-impaired patients have gradually attracted international attention.

Due to the hearing impairment, these children have different levels of language barriers, which directly affect their level of education and social participation. Cochlear implantation is one of the most recognized and effective methods in the world to help patients with severe hearing problems regain hearing [1]. To acquire sound signals, rehabilitation training is necessary to hearing impaired children. In recent years, there has been a trend that the rehabilitation objects in the early intervention treatment of hearing-impaired children are becoming younger. Besides, the family is also an important part of the rehabilitation of hearing-impaired children. However, most

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 267–273, 2020.
https://doi.org/10.1007/978-3-030-50838-8_37

parents lack relevant knowledge about rehabilitation training [2]. Therefore, it is imperative to develop rehabilitation training methods suitable for the family environment and provide learning tools for hearing impaired children [3].

2 Basic Understanding of Hearing Impairment

2.1 Performance Characteristics of Hearing-Impaired Children

Based on reviewing related literatures, it can be found that that because hearing-impaired children could not obtain verbal information, they often show different characteristics from healthy children in terms of cognition, expression and memory.

Cognition. Hearing impaired children's perception of the objective world is often weaker than other children. Due to the lack of capacity in processing sound information, their understanding of things only stays on the appearance characteristics, and they cannot understand the essence and connotation of things in depth, and stay in the image thinking stage for a long time [4]. Common errors in cognition include "conceptual enlargement and reduction".

Expression. The hearing-impaired children implanted with cochlear can adapt to a world with sound, so that they can grasp some simple words under the guidance of rehabilitation therapists. Their pronunciation is characterized by abnormal articulation (addition, deletion, replacement of individual sounds, etc.), abnormal rhythm (incorrect pitch, uncontrolled rhythm, etc.), and abnormal sounds [5].

Memory. The earliest memory characteristics of hearing-impaired children are mainly unconscious memories. After returning to the sound world with the aid of assistive devices, conscious memories will be gained to a certain extent [6]. Hearing-impaired children rely on their sharper visual abilities than ordinary people, and are more accurate and faster in image memory.

2.2 General Rehabilitation for Hearing-Impaired Children

Although there are differences in the state of hearing organs between hearing-impaired and normal children, the development laws of hearing-impaired children are in line with general child development. Therefore, the learning content of rehabilitation training for hearing impaired children is similar to that of preschool education [7]. General rehabilitation training consists of five stages: listening training, pronunciation training, language development, cognitive development and communication training [8]. Due to the late exposure to the sound environment, the development in the language field is relatively immature, and children with hearing impairment should be assisted in repetitive exercises in specific areas as appropriate.

3 Pre-design Analysis

3.1 Observation Method

Based on the theoretical analysis of the pathological manifestations and behavioral characteristics of hearing-impaired children, the behavioral performance of hearing-impaired children in actual social situations is observed and summarized.

The location of the observation experiment was set at the Tianjin Disabled Persons' Federation Deaf Children Rehabilitation Center. The participants of the observation group were from mixed-age classes (aged 3 to 7 years old) with a total of 10 people. Their performance in the classroom were emphatically observed, and their common behaviors were analyzed (Table 1).

Table 1. Record of teacher's interaction with the participants

Current activities	Interactive behaviors	Key behaviors
Fruit distribution	The student whose name was called by the teacher will go to the fruit bowl to get the fruit according to the teacher's prompt	When speaking to hearing-impaired children, the teacher deliberately increased the volume of the key words such as "take", "two pieces", and "pear"
		Only a few older children nodded to the teacher
Word guessing game	The teacher described the characteristics of animals, and then the children responded	Teachers performed one-on-one repetitive exercises with students who didn't guess the answer
Group activity	The teacher divided them into four groups according to their intentions: picture book group, consonant card group, vehicle puzzle group, and fruit puzzle group	In the state of no guidance from the teacher, the members of the puzzle group simply played the puzzle game, and there was no language communication between them

Based on the interactive performance of 10 hearing-impaired children in the classroom and in the game, the target objects were analyzed and summarized. According to the interaction between the hearing-impaired children and the teacher, it can be found that their verbal expressions are lacking. Instead, their interaction is of full physical expressions. In the process of playing with teaching aid for hearing-impaired children, it can be found that the actual effectiveness of the current teaching aid is less than expected. Without the guidance of teachers and parents, they often fail to complete the puzzle.

3.2 Follow-up Survey

This survey was conducted among the families having hearing-impaired children. Particularly, two groups of families were randomly selected for investigation.

According to the performance of families with hearing-impaired children in collective activities, it is in line with the results of previous research on the characteristics of hearing-impaired children. The survey found that hearing-impaired children show strong dependence on their parents and less communication with relatively unfamiliar volunteers. When talking with hearing-impaired children, parents try to find topics and describe their children's favorite things, input sound information to the hearing-impaired children. When the hearing-impaired child's speech is unclear, parents will guess what they want to express, and the child can use the parent's prompt to answer. In this process, parental encouragement is an important part of the parent-child dialogue.

4 Design Development

Based on the pre-design analysis, an interactive toy design was proposed to assist with the parent-child communication in order to help with the rehabilitation of the hearing-impaired children. The final product design consists of three parts: the main body of the smart toy, the cognitive module, and the module for tone practice. Figure 1 shows the relationship between products and users. With toys as the medium, parents can achieve two-way interactions in rehabilitation training by guiding their children to choose proper sub-modules and setting proper cognitive training patterns.

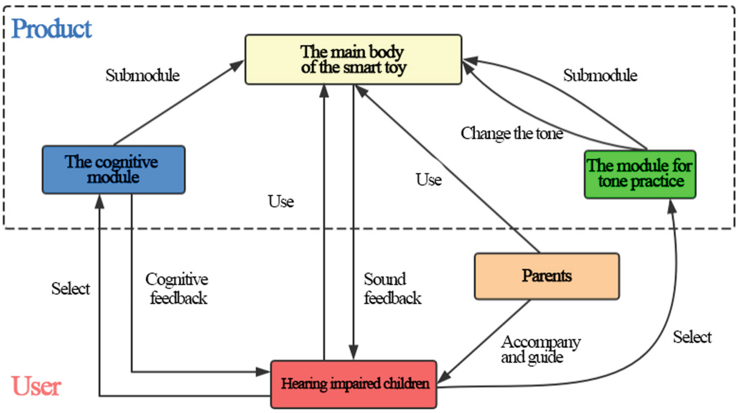

Fig. 1. The product structure and main interactions between parents and children

The product is presented in the appearance of cartoon radish. The four faces of the modules are animals, vehicles, Chinese initials and finals. Each face of different modules and stepped sound modules can be freely combined. And the main part of the product obtains the information corresponding to the module surface by identifying the pin order of the module. Hearing impaired children can imitate the pronunciation of onomatopoeia and consonant vowels, can strengthen the control of sound length, intensity, pitch and other aspects, and achieve a certain rehabilitation effect in the game.

4.1 The Main Body of the Smart Toy

The main part of the product is mainly composed of a volume control knob, a volume indicator, a sound button and a speaker hole (Fig. 2).

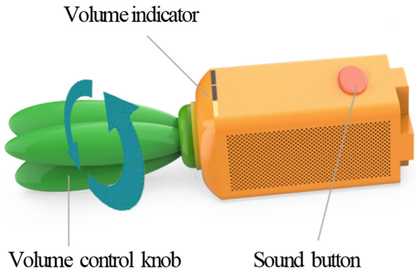

Fig. 2. The main body of the smart toy

By pressing the sound button, the patterns on the module that are inserted to the entity can be sounded in turn. This part is used to practice the children's control of the sound intensity (single-dimensional difference) by manipulating the sound volume rotation function. The product provides three levels of volume for adjustment. Parents can adjust the knob to let the child feel the change in sound intensity. Through continuous practice and imitation, hearing-impaired children can control the volume of the sound better.

4.2 The Cognitive Module

There are four types of patterns on the four planes of the cognitive module: animals, vehicles, basic vowels and initials (Fig. 3).

Fig. 3. The cognitive module with four types of patterns on it

The sounds of animals and vehicles are their onomatopoeia. Hearing-impaired children can imitate onomatopoeia to practice breathing and strengthen airflow control. The superposition of modules with the same pattern can extend the sound of the toy. Parents can guide hearing-impaired children to control the sound length (single-dimensional difference) by increasing and decreasing the number of the same modules, and improve the overall expression effect.

Hearing-impaired children can also deepen their understanding of abstract concepts through the patterns of these vehicles and animals. And the module is designed in six colors of red, orange, yellow, green, blue, and purple. Children can also use these modules to enhance their awareness of colors.

4.3 The Module for Tone Practice

The last part of the toy consists of a step sound module, see Fig. 4. This part is used to help hearing-impaired children practice pitch (three-dimensional difference). There are three types of stepped sound modules to choose from, namely, Do, Mi, and So (low, medium and high), which can emit corresponding tones when connected with the main body. The low, middle and high notes correspond to the height of the module in turn. By adding the tone module, children can experience the change of tones and try to apply it to daily conversation.

Fig. 4. The module for tone practice

4.4 Design Evaluation

The evaluation consists of user testing and expert evaluation. First, set the task flow according to the product's functional characteristics, and record the completion time, completion rate, and satisfaction score of 8 groups of test subjects (with a hearing-impaired child and a parent per group). The results showed that the product can effectively guide the hearing-impaired child in rehabilitation training. Parents' participation has made the hearing-impaired children get more enthusiasm to pronounce. The combined scores of the two rehabilitation therapists interviewed also showed the product is effective to some extent.

5 Limitations and Future Work

Based on the basic characteristics of hearing-impaired children, this study designed a parent-child interactive toy for hearing-impaired children. The research has achieved some results in design, but many details are still insufficient. In addition to the existing four series of modules, other categories of onomatopoeia can be added to enrich the cognitive world of hearing-impaired children. Apart from providing the product, some hints for parents to better use the product should also be designed and standardized, which for example can be shown in the form of a manual. When the hearing-impaired child has mastered the basic pronunciation, some advanced gameplay can be provided, such as disrupting the same series of modules to allow the hearing-impaired child to respond quickly. Moreover, the participants involved in the design evaluation are still limited, and a larger-scale user evaluation will be performed in the future.

In conclusion, this research focuses on the problem of the early rehabilitation of hearing-impaired children in the family environment, and contributes a product which can help with the training of the communication skills for hearing-impaired children in daily parent-child interaction. It is expected to provide a creative exploration in rehabilitation toys for assisting hearing impairment rehabilitation and may have some significance in improving the rehabilitation effect and experience for hearing-impaired patients.

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Identifying Persistent Usability Issues When Using an Electronic Health Record to Inform EHR Instructional Redesign

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Abstract. Ineffective training can impact the perceived ease of use of an electronic health record (EHR) system. This study aims to determine persistent usability issues experienced by primary care residents when using an EHR to inform EHR instructional overhaul. Methods: Primary care residents participated in two rounds of usability tests. Physicians completed nineteen tasks based on an Five themes emerged during analysis: (1) Inconsistencies, (2) User Interface Issues, (3) Structured Data Issues, (4) Ambiguous Terminologies, and (5) Workarounds. This study was novel in that the authors have no knowledge of any iterative EHR usability studies among primary care residents to assist in improving EHR training.

Keywords: Human-computer interaction · Usability · Electronic health record

1 Introduction

EHRs are said to reduce physician workload; however, physicians who are not appropriately trained on using an EHR in medical school may encounter a steep learning curve and experience usability issues when using the EHR in clinical practice. Ineffective training can impact the perceived ease of use of an electronic health record (EHR) system. Usability evaluation is important in the EHR adoption and implementation process [1]. Current best practices promote the use of cognitive approaches to examine human–computer interactions in the EHR system [2]. The objective of this study is to determine recurring usability issues experienced by primary care residents when using an EHR to inform EHR instructional overhaul.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 274–281, 2020.
https://doi.org/10.1007/978-3-030-50838-8_38

2 Method

Sixteen primary care residents participated in two rounds of usability tests. Physicians completed nineteen tasks based on an artificial but typical patient visit notes. The recorded sessions were examined with Morae Manager® using markers to code difficulties and errors the physicians experienced. Thematic analysis was employed to analyze our data and categorize our findings. Some themes used in this study were adopted from a study by Walji et al. [3] but were supplemented with additional themes for a more granular analysis. Three individuals iteratively reviewed the themes: a family medicine physician champion, an experienced usability engineer, and a doctoral student. All three individuals came to consensus on the themes presented. The usability issues identified were also rated on a five-point severity scale based on a National Institute of Standards and Technology report [4] and was reviewed by a physician champion. Severity ratings were: 4) Catastrophic: Potential for patient mortality, 3) Major: Potential for patient morbidity, 2) Moderate: Potential for workarounds that create patient safety risks, 1) Minor: Potential for lower quality of clinical care due to decreased efficiency, increased frustration, or increased documentation burden or workload burden, and 0) No Issue/Not applicable.

3 Results

Five themes emerged during analysis: inconsistencies, user interface issues, structured data issues, ambiguous terminologies, and workarounds (Table 1). Six common inconsistencies were identified between both resident physician groups. *Inconsistencies* are being defined in this study as a lack of uniformity among different elements, such as naming conventions, and location of buttons in the EHR. Eight common and one unique user interface issues were identified. *User interface issues* are difficulties that arise when the physician interacts with the EHR's screen menus and icons. Seven common usability issues related to ambiguous terminologies were identified. *Ambiguous terminologies* are obscure labelling of items in the EHR that makes the system difficult to understand. Six common structured data issues were identified. *Structured data issues* are complications caused by data that resides in a fixed field, such as drop down menus, within the EHR. Four common and two unique workaround usability issues were identified. *Workarounds* are processes that diverge from intended methods in order to bypass issues instead of fixing them [5].

Table 1. Usability issues identified from sub-task analysis, severity level, description of usability issue, their implications on practice and suggestions for improvement.

Inconsistencies
Inconsistent ordering of command/action buttons (2). Tasks 14 – 16 & 18: The location of buttons "Orders for Signature", "Sign", and "Done" varied depending on the window that is being used when signing for orders completed in the CPOE. *Implication*: Orders may not be completed because physicians ignore the alert warning that "some tasks are not complete. Are you sure you want to leave this chart?" *Improvement*: Conduct card sort/user mental mapping process to see what terms physicians find more natural. Provide style guide to development teams
Inconsistent labeling of action buttons (1). Tasks 7, 9, 11, & 13: Both physician groups were confused about the command button "Include Selected" vs "Include." *Implication:* Physicians may unknowingly omit items and take more time repeating the process of adding wanted items because their first attempt was unsuccessful. *Improvement*: Simplify the interface by being consistent with labeling action items. Emphasize how to add a diagnosis during EHR training
Inconsistent use of double mouse clicks (1). Task 9: In the Family History tab, there are two unlabeled columns, one for positive and one for negative, located underneath the column labeled "mother." *Implication* - Physicians may mark an item as positive or negative and not know how to clear it. *Improvement* - Make affordances visible, or allow toggling between positive and negative by double clicking
Absent Action buttons (1). Task 9: The "Include" button to add Family History to the note is only accessible through the clinic note being created but not when you try to add family history from the main menu to the left. *Implication* - Takes more clicks to enter Family History if not accessed through the note. *Improvement* - Improve the workflow for entering Family History
Illogical ordering of lists (1). Task 17: Medication list cannot be consistently sorted alphabetically when imported into a patient's visit note. *Implication* - Non-alphabetized lists frustrate physicians when they cannot figure out how to sort the medication list. *Improvement* - Import medication list to patient visit note in the order that physicians had them sorted in the CPOE, or alphabetically by default
Duplicate diagnoses (1). Task 13: The same diagnosis can be added twice because of different naming conventions for the same diagnosis. *Implication* - Causes an annoyance to physicians. *Improvement* - Teach physicians to find most accurate diagnosis in didactics classroom setting, training by chief residents, or online web based module available to the residents
User Interface Issues
Long note template list (1). Task 1: Long list of different templates to choose from when creating a note that is not department specific. *Implication* - Time consuming and increased cognitive load to search through template list. *Improvement* - Teach and assist physicians to configure template list and create their own personal template list in first training session
Meaningful title for note not required (1). Task 12: Physicians were not required to change the generic title, provided with the progress note template, to a meaningful (specific) title when saving or when creating the note. *Implication* - Unhelpful title inhibits physicians to know content of visit later. Generic title reveals no summary of visit detail. *Improvement* - Have the generic title highlighted to bring attention to the physician, suggesting to edit the title
Unexpected terms in date fields (1). Task 15: One expert physician did not create a future order for one month because the terminology used was "four weeks" and the physicians kept

(*continued*)

Table 1. (*continued*)

searching for "one month." *Implication* - It is confusing and takes doctors a little longer to complete orders. *Improvement* - Add an additional choice that says "1 month"
Misuse of textboxes (1). Task 7: Some "read only" fields appeared as editable text boxes. When adding a medication allergy, a text box is highlighted which makes physicians assume that they should type in the textbox when they cannot. *Implication* - Highlighting a field that cannot be edited fields suggests that the field accepts text entry, which is confusing and wastes time. *Improvement* - Do not add yellow highlights to fields that cannot be edited
Required fields are indistinct (1). Task 7: The status field was not highlighted to indicate that the status field needed to be changed for the allergy to be active. *Implication* – this causes mental model mismatch where physicians think a "Cancelled allergy" should not be on the list. *Improvement* - Remove cancelled allergy items or, remove data from status field and highlight the field in yellow indicating a requirement to enter a new selection
Lack of keyboard shortcuts (1). Task 13: The keyboard shortcut ctrl + A cannot be used to highlight all rows in a list of diagnosis. *Implication* - Contradicts physician expectations based on functionalities from other applications. Lack of shortcuts take more time and effort to add multiple diagnoses *Improvement* - Add keyboard shortcuts where feasible
Unclear menu options (1). Task 16: Unclear option that says "Change Medication". To change a medication you either use "Renew", "Cancel/DC", or "Cancel/Reorder". *Implication* - Physicians make the wrong choices, and take longer to complete the task because language is confusing. *Improvement* - Test the language in the menus with actual physicians to identify the best terms to use. Repeat initial training later by training by chief residents or didactics classroom setting
Hiding functionalities one layer down (1). Task 17: Physicians cannot add medication to a favorite list from the medication list in a patient's visit note. Adding a med to favorites can only be done in the order detail view, not in the main medication list view. *Implication* - Physicians are less likely to build a favorite menu therefore, they cannot take advantage of this functionality. *Improvement* - Add the option to add a favorite by right clicking the main medication list
Extra mouse clicks (2). Task 14 – 16 - To see the changes that were made in the CPOE, the "Refresh" button needs to be clicked for the changes to appear. Note: The "Refresh" button improves system performance by reducing frequent queries to the database. *Implication* - Physicians may miss new information and act without the new piece of information. Confused and frustrated because they expect the results to automatically update Automatically trigger refresh soon after sending new orders. *Improvement* - Physicians need to be trained, and reminded later, to remember to click "Refresh"
Structured Data Issues
Lack of distinction between columns (1). Task 9: To input family history, the blue or white columns (indicating negative vs. positive finding) for the family member were unlabeled. *Implication* - Physicians were unsure how to mark a family history item, such as cancer, "positive". *Improvement* - Labeling the header would help physicians understand what column to use to make a history item positive
"Indication" field not required (1). Tasks 16 & 18 - Physicians do not usually input the "Indication" when prescribing medication. Physicians were not required to provide a diagnosis to justify a medication and therefore some physicians did not feel it was important or necessary to enter a reason for prescribing the drug. *Implication* - Would not affect physicians but would

(*continued*)

Table 1. (*continued*)

affect the patient reading prescription bottle with no "reason" information. *Improvement* - Promote filling out certain unrequired fields to make EHR meet patient information needs
Structured data unutilized (1). Task 13: If physicians use free text, the diagnosis will not be available for them to select when ordering labs. *Implication* - Creates duplicate work when physicians have to add diagnosis using structured data when they already used free text to enter diagnosis. *Improvement* - Train physicians to add diagnosis using structured data when ordering labs
Time consuming to complete tasks (1). Task 13: Physicians must navigate multiple screens, go through a number of clicks, and scroll through a long list to find and select a diagnosis. *Implication* - Time consuming for physicians when inputting diagnosis in patient visit note. *Improvement* - Intelligent Medical Objects (IMO) search is available but appears inactive because the field label and input box are gray. Many physicians are unaware of this tool so IMO field label color should be changed from gray to black
Unclear import function (1). Task 13: Physicians do not know they should highlight all the diagnoses (multi-select) before clicking "Include" to get the entire list of diagnoses into the visit note. *Implication* - Takes more time when physicians have to repeat the process of adding wanted items because physicians' first attempt was unsuccessful. *Improvement* - Simplify the interface by being consistent with labeling action items. Provide in-class training provided by the EHR trainers at the beginning of R1 residency; online web based module available to the residents
Diagnoses can only be deleted one at a time (1). Task 13: Multiple diagnoses cannot be deleted altogether. *Implication* - Takes a longer time for physicians to remove multiple diagnoses. *Improvement* - Add that functionality to the primary "Problem and Diagnosis" tool. Use the more efficient, newer tools, "FamMed ViewPoint" or "IntMed ViewPoint" widget labeled "Consolidated Problems" to access multi-select functionality
Ambiguous Terminology
Multiple fields with the same functionality (2). Tasks 14 & 15 - There is no clear difference between the drop down labeled "Requested Start Date", the drop down labeled "Requested Time Frame", and the radio button labeled "Future Order." *Implication* - Future labs may not be ordered properly so labs may not be completed at the right time. Patients may have to get the test redone, which brings additional cost to the patient. *Improvement* - Make similar sounding field names more understandable with additional hints, or more descriptive names
Unclear terms (1). Task 13: Unclear difference between "Other Diagnosis" vs "Other under the Diagnosis" subsections. *Implication* - Physicians were unaware that "Other" is a free text box and "Other Diagnosis" opens tool for "Problems and Diagnosis menu item. *Improvement* - Change name of "OTHER" to "FREE TEXT" or similar term by using open card sort to get physician mental model to understand the physicians' thought process
Unclear difference between "All Results" and "Lab Results" (1). Task 11: Physicians try to find CMP results from "All Results" subsection but it is located in the "Lab Results" subsection. *Implication* - Terms are misleading to physicians. *Improvement* - Explain the difference during EHR training and alternative input methods (e.g. keyboard shortcuts) for lab results, such as, typing "..CMP" to import CMP lab results
Unclear terms (1). Task 13: There are three different sections labeled "Diagnosis" (allowing for separate "Plan" items for each diagnosis) under the "Impression and Plan" section of the note that physicians clicked on. *Implication* - Physicians are unsure of what term to select.

(*continued*)

Table 1. (*continued*)

Improvement - Simplify the interface by being consistent with labeling action items, or use Gestalt design principle of proximity to make associations more evident
Missing symptoms (1). Task 8: "Dry mouth" and "clear nasal discharge" missing from symptoms list. *Implication* - Physicians have to type in symptoms that are not included in the symptoms list. *Improvement* - Include common symptoms in the symptoms list
Search results do not match physicians' expectations (1). Task 15: A search for BMP, blood tests that provides information about patient's body's metabolism, retrieves multiple versions of same test with different order detail completion. *Implication* - Takes extra effort for physicians to complete orders. *Improvement* - Pare down menu options or simplify menu choices
Vague wording for alerts (2). Task 14: A novice physician tried to order a chest X-ray but continuously received an error: "Radiology orders should be placed following downtime procedures during 2200 and 0000." *Implication* - Physician becomes frustrated, spends time trying to decipher the meaning of the alert and may ignore (alert fatigue). *Improvement* - Create alerts that are more meaningful where the physician can clearly understand the next steps
Work Arounds
Extra steps to complete multiple orders (1). Task 15: Novice physicians did not know how to create two orders at the same time. One novice physician mentioned that there was probably a way to order them both but did not know how. *Implication* - Take more steps to complete multiple orders. *Improvement* - Train resident on how to place multiple orders. Follow-up training sessions at didactics classroom setting
Unawareness of functions (1). Task 8: Physicians were not able to add a comment to a symptom by right clicking the symptom. *Implication* - Physicians omit descriptive comments, or avoid using the discrete diagnosis tools. Add an affordance to allow physicians to "add comments", although it increases the size of the field and take up more space
Unawareness of functions (1). Task 13: Physicians were not able to move "hypertension" from the problem list to the current diagnosis list so they re-added "hypertension" as a new problem. *Implication* - Takes more time for physicians to diagnoses to the active problem list. *Improvement* - Train physicians to use the "Diagnosis" button. Repeat training periodically. Enlarge "Diagnosis" button to say, "add to diagnosis" or add a tooltip to "Diagnosis" button
Entering date in the wrong field (1). Task 15: One expert physician put the future date in a comments field to place a future lab order instead of using the structured date entry field. *Implication* - If the date is not entered properly, labs may be completed at the wrong time. *Improvement* - Educate physicians on best practices for inputting future orders. Repeat training periodically
Free text option can be used to bypass structured data entry (1). Tasks 8, 9, 10, & 13: Instead of selecting a structured term, some physicians used free text to add diagnosis, family history, review of systems, and physical exam. *Implication* - Time consuming for physicians to enter information using structured data. Also, information may not be fully captured from using structured data. *Improvement* - Use clinician terms (IMO, SNOMED) for these diagnosis items
Structured data not utilized (1). Tasks 8 & 10: Physicians rarely expanded the "short list symptoms" to access more structured codes for symptoms. They just clicked "OTHER" and type it in. *Implication* - Time consuming to expand the symptoms list and search for a specific symptom. *Improvement* - Train physicians about macro functions to make data entry easier

4 Discussion

Inconsistencies. Inconsistencies in an EHR may cause critical information, such as, a diagnosis or significant family history, to be discarded instead of being added to the patient's note. For example, non-alphabetized order of the medication list and absent action button, which slows physicians down by forcing them to read the entire medication list in order to find a specific medication. Allowing medication lists to be sorted alphabetical or by disease may reduce inefficiency in clinicians' workflow that may improve physicians' behavior and decision-making processes.

User Interface Issues. Poor interface design, such as, required fields that are indistinct, creates difficulties for physicians trying to find certain information, which may lead to unsuccessful clinical information searches that further frustrate busy physicians. Poor user interface design of EHRs may also increase the risk of medical errors if important information is not presented in an effective manner. Allowing medications to be added to a favorites list from the main medication list would increase the chances of physicians utilizing this useful feature.

Ambiguous Terminology. In our study, resident physicians were unclear of the differences among terms, such as, the drop down menu labeled 'Requested Start Date', the drop down menu labeled 'Requested Time Frame', and the radio button labeled 'Future Order', which has the same function. This may have confused resident physicians causing future labs to not be completed in a timely manner. Patients may have to get tests redone, which brings additional cost to the patient. Redundancy in structured data fields, can affect the quality of documentation by causing errors when documenting a patient's visit. Removing duplicate fields may further improve the system's usability by preventing physicians from having to choose from unclear options.

Structured Data Issues. In our study, if a data field was not highlighted in yellow, indicating that that the field is required to be filled, resident physicians left the field blank. Because the "Indication" (diagnosis) field was not required when resident physicians were completing tasks in the CPOE, they did not provide a diagnosis to justify prescribing a drug. Although the field was not required, it may lead to information gaps in the EHR. The presence of these tactics to circumvent required fields shows how significant it is for vendors to be innovative when designing data entry structure to meet the needs of the physicians.

Workarounds. If physicians find completing a task in the EHR too complex, they create workarounds [6]. In our study, novice physicians took extra steps to complete multiple orders in because they were unaware of functionality to create two orders at the same time. Developing a user-friendly interface by understanding the mental model of its users will reduce workarounds.

This study had some limitations. This study took place in a laboratory setting, which does not make room for usual distractions experienced by physicians during a clinical encounter. However, lab-based usability tests permit flexibility in questioning and enables the facilitator to conduct more in-depth probing of the participants. Although this study contains some methodological limitation, this is a well-constructed study with clear instructions, which allowed for successful completion of research goals.

Overall, this study was able to identify varying degrees of usability issues experienced by expert and novice physicians that may be impeding the use of EHRs. Although the usability issues found were ranked lower on the severity scale, these errors may accumulate to create critical ones and cause significant errors. The study suggested that higher experience levels with EHR is not equivalent to being an expert, proficient in using EHR. The study was novel in that the authors have no knowledge of any iterative EHR usability studies among primary care residents to assist in improving EHR training. Also, the categorization of usability issues has not been grouped in this way previously that addresses whether the issues identified would be solved by training or improvement of the system. While there are no widely accepted evidence based guidelines for training residents effectively [7], this study may assist in the improving the EHR education and training program by highlighting the areas of difficulty residents are currently facing.

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Estimation of Load on Lumbar Spine While Walking by Using Multiple Regression Analysis

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Abstract. In this study group, we proposed lumbar disc load as an index to quantitatively determine the load on the lumbar spine, and approached lumber disc leading using two methods. One method assumes the amount of deformation of the intervertebral disc from the body surface shape of the lumbar spine, and is useful in stationary posture and walking. The second method estimates the moment applied to the lumbar spine assuming the spine is a beam. Although this method was useful because the same tendency as the measured value in the previous research was obtained in the stationary posture, the estimation was not performed for walking.In this report, we examined whether the load estimation method based on moment can be applied to walking. The characteristics during walking appeared in the estimated values, so we believe that the proposed method can represent the tendency of the lumbar spine load during walking.

Keywords: Lumbago · Multiple regression analysis · Walking · Support system

1 Introduction

In recent years, the number of people suffering from lumbago regardless of age and gender has been increasing in Japan. According to the Ministry of Health, Labor and Welfare's announcement [1], the number of people with subjective symptoms due to illness or injury was 305.9 per 1,000 people, and looking at the percentage of people reporting symptoms by symptom, lower back pain is the most frequent problem in men and the second largest in women. One of the reasons for the increasing number of people with lumbago is that they routinely maintain a posture that places a heavy burden on the lower back, such as desk work or bending over. At present, there are chiropractic treatments and postural improvement stretching methods to improve lower back pain. However, postural improvement by chiropractic treatments is temporary, and stretches are designed for general use, and are not designed for individual differences. Therefore, this research group is developing a system that supports voluntary

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 282–288, 2020.
https://doi.org/10.1007/978-3-030-50838-8_39

posture improvement in daily life by constantly sensing a person's posture and providing feedback of poor posture to the user. We propose the use of the lumbar intervertebral disc loading as an index to judge posture deterioration. We approach lumbar intervertebral disc loading in two ways. One method estimates load ratio by assuming the movement of vertebrae from the body surface shape and predicting the shape change of the intervertebral disc [2–4], the second method assumes the spine as a beam and estimates load ratio from the moment applied to the lumbar spine [5, 6]. The estimation method based on the change in the shape of the intervertebral disc is useful because the same tendency as in the previous studies was confirmed in stationary posture and walking motions. However, although the estimation method based on the moment applied to the lumbar spine has been useful in stationary posture, it has not been applied to the estimation of walking motions. In this report, the load on lumbar spine when walking is estimated from the moment applied to the lumbar spine.

2 Overview of a Method to Estimate Lumbar Load by Multiple Regression Analysis

In previous report [6], it is thought that lumbar load is the moment applied to the fifth lumbar vertebrae, and load was estimated using multiple regression analysis. If the spine is modeled with beams and the lumbar spine and pelvis are pin-coupled, the sum of the bending stress by the moment and the axial compressive force by the vertical force of the spine represent the lumbar load. If the weight of the upper body is m, the weight of both arms is marm. the heavy objects is M, the upper body inclination angle is α, and the pelvic inclination angle is θ, the lumbar load consists of the following four elements as shown in Fig. 1: The components vertical to the spine directional vector from the weight of the upper body applied to T8(8th thoracic vertebra), which is the mass center of the upper body (m-marm)gsinα; The components vertical to the spine directional vector from the weight of both arm and the heavy objects applied to T1 (first thoracic vertebra), which is the mass center of both arm (M + marm)gsinα; Effects of pelvic rotation θ; Axial compressive force in the direction of the spine by the weight and the weight of upper body (m + M)gcosα.

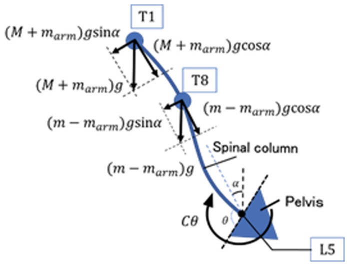

Fig. 1. The cubic curve represents the spine and the triangle represents the pelvis. The force applied to the first thoracic vertebra (T1) is due to the weight of both arms and heavy objects, and the force applied to the eighth thoracic vertebra (T8) is due to the weight of the upper body.

A regression equation was created with a lumbar load that is the sum of values that are each above factors multiplied by the partial regression coefficient. In previous report [6], since the value of the previous report [7] was the target variable, multiple regression analysis also was performed for the posture while holding heavy objects. Since results similar to previous reports [7] were obtained, it was found that it is possible to estimate the load from the moment applied to the lumbar spine in the stationary posture. In this paper, I examine whether it is possible to use this method to estimate the load when walking. In a previous report [3], although the subject is not walking but sneezing, during exercise, it has been confirmed that the acceleration changes significantly when the load increases. Therefore, it is thought that inertial forces which were not taken into account when stationary posture are affecting the load, the inertial force of the upper body is taken into account when walking. Since the user is not holding any heavy objects when walking, the influence of a heavy object, which was one element of the load when the user is stationary, is not taken into account. In this paper, the upper body was divided into the upper (head, both arm, and upper trunk) and lower part (lower trunk) when walking by referring to the report of Ae et al., [8]. Therefore, assuming that each mass center is T3 (the upper part) and T10 (the lower part), two inertial forces are taken into account. In addition, the mass of each is 31.8% of the body weight (the upper part) and 33.8% of the body weight (the lower part). In this paper, the movement on the sagittal plane in the traveling direction and the vertical direction are considered. Figure 2 shows the force applied to the spine to be considered this time. Y describes the load value (target variable). A, B, C, D, E, F, G, H, I, J, K describe the partial regression coefficients. θ describes the pelvic inclination angle. α describes the front tilt angle of the upper body. g describes gravitational acceleration. $\ddot{y}$ describes the acceleration in the direction of travel. $\ddot{z}$ describes the acceleration in the vertical direction. M describes the mass of the upper body. m_{up} describes the mass of the upper part (31.8% of body weight). m_{down} describes the mass of the lower part (33.8% of body weight). The explanatory variables used for multiple regression analysis can be represented from the above parameters as follows. The force applied to the lumbar spine by the weight of the upper body is

$$Mg\sin\alpha \tag{1}$$

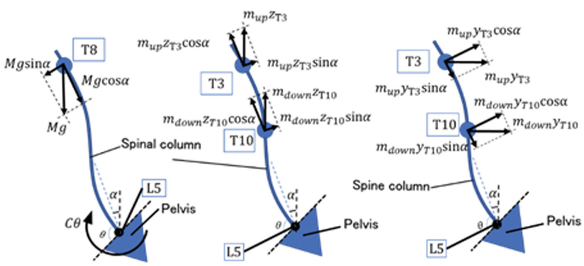

Fig. 2. The figure on the left shows the force due to its own weight, the axial force and the effect of the pelvic angle. The middle figure shows the vertical inertial force. The figure on the right shows the inertial force in the traveling direction.

The Effect by pelvic rotation is

$$\theta \tag{2}$$

The Axial compressive force by the weight of the upper body in the spinal direction

$$\mathrm{Mg}\cos\alpha \tag{3}$$

The influence of the inertial force of T3 are two forces a component force on the Spine direction and a component force perpendicular to the spine direction. The component of each Inertial forces is derived from the acceleration in two directions.

$$m_{\mathrm{up}} y_{\mathrm{T3}} \sin\alpha \tag{4}$$

$$m_{\mathrm{up}} y_{\mathrm{T3}} \cos\alpha \tag{5}$$

$$m_{\mathrm{down}} y_{\mathrm{T3}} \sin\alpha \tag{6}$$

$$m_{\mathrm{down}} y_{\mathrm{T3}} \cos\alpha \tag{7}$$

Similarly for T10,

$$m_{\mathrm{up}} y_{\mathrm{T10}} \sin\alpha \tag{8}$$

$$m_{\mathrm{up}} y_{\mathrm{T10}} \cos\alpha \tag{9}$$

$$m_{\mathrm{down}} y_{\mathrm{T10}} \sin\alpha \tag{10}$$

$$m_{\mathrm{down}} y_{\mathrm{T10}} \cos\alpha \tag{11}$$

The load Y is obtained by multiplying each of the above 12 elements by a partial regression coefficient and adding This time, the lumbar disc load ratio derived by the method of a previous report (4) is used as the objective variable.

3 Walking Experiment

In this experiment, I measured the fifth and sixth steps twice from the time the two subjects started walking (male: age 21.5 ± 0.5, height 1.7425 ± 0.0425 [m], weight 57 [kg]). A total of 24 markers were placed on the spinal processes of the 20 locations along the spine (from C6(sixth cervical vertebra) to S1(first sacrum)), on the left and right superior anterior iliac, and on the left and right superior posterior iliac. The coordinates of each marker were obtained using a total of 12 optical motion capture cameras (Manufactured by Motion Analysis Company: Kestrel Digital Camera). The sampling frequency was set to 100 Hz. Figure 2 shows the location of the MC marker. The experiment was performed with the approval of the Ethics Committee of Kochi University of Technology and with the consent of the subjects.

4 Result of Analysis

A regression equation was created from the first gait data of subject A using Eqs. (1) to (12) as explanatory variables and the load ratio Y as the objective variable. The acceleration of T3 and T10 was obtained by performing a three-point differentiation of the coordinate data of the MC marker twice, the pelvic angle θ is the angle formed by L1 and L5 and the midpoint of the two markers attached to the superior anterior iliac, and the forward inclination angle α was determined from the angle of the straight line connecting L1 and L5. The number of total data points was 125. Table 1 standardized partial regression coefficient value.

Table 1. Standardized partial regression coefficient value

A	−0.35	*D*	0.37	*G*	0.76	*J*	−0.22
B	−0.85	*E*	−0.43	*H*	−0.19	*K*	−0.03
C	−0.58	*F*	−1.14	*I*	0.2		

As results of the analysis, the value of the adjusted coefficient of determination R^2 was 0.9 or more. R^2 is an index that indicates the fitness of the regression equation created, is generally accepted that 0.8 or more is sufficient. Therefore, the regression equation created this time has high fitness. Next, focusing on the value of the standardized partial regression coefficient indicating the influence of each element. These values show the effect of each explanatory variable. The greater the absolute value of this value, the greater the effect on the response variable. F, B, and G showed particularly high values. F and G show the influence of the inertial force in the vertical direction of the upper part of the upper body, and B shows the influence of the axial compressive force by the weight of the upper body. Therefore, it can be assumed that the influence of the axial compressive force and the inertial force are important factors in the load estimation when walking.

The load ratio is estimated using the above regression equation. The result shown in Fig. 3 is a comparison between the objective variable (orange line) and the estimated value (blue line) obtained by substituting each element into the regression equation from the first walking data of subject A. The vertical axis indicates the lumbar load ratio [%], and the horizontal axis indicates the walking rate [%] normalized at the timing of heel contact. When the two values are compared, there is no large difference between the two values. The double stance phase is indicated by a black frame. The load ratio tends to decrease when the double stance phase. This tendency has been reported in a previous report [4] and can be understood as a characteristic of the load ratio in walking motions.

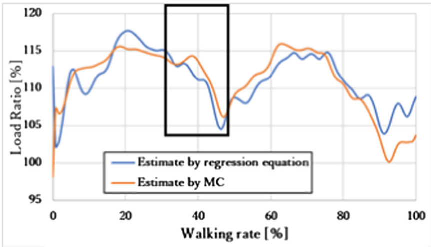

Fig. 3. The blue line is the load ratio estimated using the regression equation, and the orange line is the load ratio derived from the body surface shape. The black frame indicates the two-leg support period, we are confirmed the decrease in the load ratio.

5 Consideration

The load ratio was estimated using the partial regression coefficients derived in Sect. 4 from the walking data of subject A and subject B, which were not used in the creation of the regression equation. Figures 4 show the results of estimation. (left figure is subject A. right figure is subject B.) Comparing the estimated value with the objective variable, a difference of up to approximately 12% occurred between the two values in left figure. However, there is no significant variation in the Changing Moments of load. Comparing the estimated value with the objective variable, a difference of up to approximately 30% occurred between the two values in right figure. However, since the decrease in the load during the double stance phase can is confirmed on the regression equation estimates, and the method can is expressed the characteristics of walking. Therefore, it is not possible to obtain a highly accurate load value by the proposed method, but it is thought that load fluctuations when walking can be obtained. The remaining task is to increase the amount of data obtained for analysis by increasing the number of subjects, because the analysis was performed only on two subjects in this study.

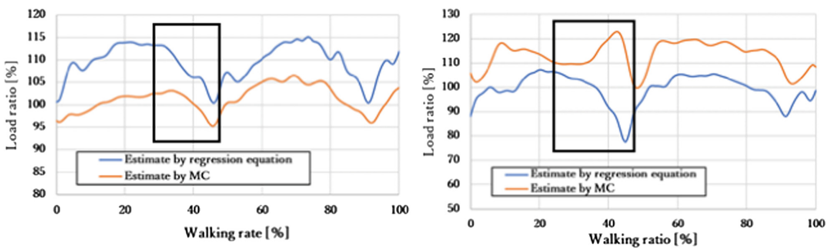

Fig. 4. The blue line is the load ratio estimated using the regression equation, and the orange line is the load ratio derived from the body surface shape. The black frame indicates the double stance phase, we are confirmed the decrease in the load ratio.

6 Conclusion

In this report, the load ratio while walking was estimated from the moment applied to the lumbar spine based on previous reports [5, 6]. At that time, since acceleration occurs when walking, the effect of the inertial force was taken into account. Since the estimated value using the data used for the regression equation creation did not show a large difference from the objective variable, it was revealed that the load could be estimated from each element of the subject's weight, pelvic angle, and inertia force. In addition, when the load was estimated from the walking data not used in the regression equation creation, the accuracy of the load value was not high, but the fluctuation of the estimated value from the regression equation showed the characteristics of walking. Hence the tendency of load during walking could be obtained by using the method proposed in this study. Therefore, it is necessary to improve the accuracy of the estimated value, but the load estimation by multiple regression analysis is sufficiently applicable to the walking motion. By constructing a mechanism that can constantly sense the three elements of the upper body acceleration, pelvic rotation angle, and forward tilt angle, it may be possible to develop a posture improvement support system to prevent lumbago.

Acknowledgments. This work was supported by JSPS KAKENHI Grant Number JP18K11106.

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An APP Design for Stroke Rehabilitation

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Abstract. Stroke has become a major threat to the health of modern people, especially for the elderly. After the stroke, it is very important to apply effective and convenient rehabilitation therapy. Based on the advanced therapies, this study presents a scientific treatment process in an interactive manner to assist the rehabilitation of stroke patients, and developed a product to realize the treatment process accordingly. Through the use of tablet computers, the rehabilitation guidance and interactions set by the APP can be presented to stroke patients. This study explores the possibility of applying advanced therapies (i.e., motor imaging therapy) for stroke rehabilitation therapy on the mobile terminal. It is driven by patient needs, provides an autonomous platform for stroke patients, and realizes the functions of stimulating exercise, recording the treatment effect and providing health management knowledge in stroke rehabilitation.

Keywords: Stroke rehabilitation · Interaction design · Motor imaging therapy · Task-oriented training · Electromyographic biofeedback

1 Design Background

1.1 Research Background and Current Situation

Stroke is an acute cerebrovascular disease, which has the characteristics of high morbidity, high mortality, high disability rate, high recurrence rate and many complications [1]. It not only reduces the quality of life of the patients, but also brings heavy burden to the family and society [2].

A large number of medical evidences show that stroke rehabilitation treatment can significantly reduce the degree of disability, improve patients' exercise capacity and their life quality [3–5]. After the rehabilitation treatment, the vast majority of stroke patients can regain the ability of exercise and self-care life, and one third of them can recover some lighter work ability [6]. If there is no rehabilitation treatment, the percentage of the above-mentioned ability recovery of patients will be significantly reduced [7].

At present, many researches and practices have been carried out on stroke rehabilitation products at home and abroad, and many research results with reliable reference value have been obtained [8].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 289–296, 2020.
https://doi.org/10.1007/978-3-030-50838-8_40

1.2 Research Purpose and Significance

The study is guided by the treatment principles of the stroke rehabilitation, to assist the rehabilitation of the physical functions of stroke patients. It is expected that the project will help the patients to achieve independent rehabilitation, emotional and scientific rehabilitation treatment, so as to achieve more accurate, vivid and high-level rehabilitation effect than traditional rehabilitation therapy.

2 Pre-design Analysis

2.1 Questionnaire Survey

Questionnaire survey was performed to generate a reference report which can be used in the design of stroke rehabilitation treatment by investigating the rehabilitation status of stroke patients and the relevant experience of stroke rehabilitation physicians [9].

Using a complete random sampling strategy, 11 respondents were involved in total, including 3 neurology patients randomly selected from the Municipal People's Hospital, 6 acupuncture patients randomly selected from the Municipal Hospital of Traditional Chinese Medicine and 2 rehabilitation doctors randomly selected.

Based on the questionnaire results, the analysis can be performed referring to the three parts of the survey.

The first part of the survey shows that most of the patients are about 50 years old, and most of them are educated in primary school or below. Among them, the participants living in urban and rural areas account for half.

The second part shows that two-thirds of the patients have received formal rehabilitation training. Particularly, the patients who have received formal rehabilitation training generally have early start time, professional rehabilitation place and good rehabilitation effect. While, the patients who have not received formal rehabilitation training are generally affected by the expense, time and place, and their rehabilitation place is mainly in rural or community clinics and at home; thus, the rehabilitation effect is not ideal.

The third part shows that the respondents all hope to get regular, timely and effective rehabilitation, and are willing to try a simpler and more intimate rehabilitation treatment product.

2.2 Existing Related Studies

Through analyzing a large number of literatures and network resources, the author learned that the existing rehabilitation treatment of stroke can be realized by diverse therapies. Among the advanced therapies that have been scientifically verified and have been clinically applied, the author selected three therapies that may be suitable for developing a new product for assisting the stroke rehabilitation at home, namely, Exercise imagination therapy, task-oriented training, and electromyographic biofeedback [10]. The following is a brief introduction of these three advanced therapies.

1. Motor Imaging Therapy
   Definition: exercise imagination therapy refers to the repeated exercise imagination for the purpose of improving the motor function, without any motor output. It helps to activate a specific area of an activity in the brain according to the motor memory, so as to achieve the purpose of improving the motor function [11, 12].
   Treatment process: ① explain to the patient what to pay attention to in sports imagination, such as controlling the body as much as possible but not need to produce real muscle movement; ② give the patient specific sports imagination instructions, such as imagining wrist movement, imagining walking on the grass; ③ guide the patient to describe the previously imagined content with detailed language as much as possible.
2. Task-Oriented Training
   Definition: aiming at the activation of the missing or abnormal functions of patients, aiming at the recovery of daily life ability, and guiding patients to complete reasonably planned sports training according to the tasks pre-designed, so that patients can improve their functional ability in the actual task practice [13].
   Treatment Process: ① relax the affected limb and place it on the table in front of you; ② rotate the affected limb to alternate the palm and the back of the hand upward; ③ lift the affected limb to touch the tip of your nose; ④ move the affected limb to grasp the water cup on the table; ⑤ relax the affected limb and wait for the next process [14].
3. Electromyographic Biofeedback
   Definition: use electromyographic equipment to record the EMG signals of the patient during the exercise, and feedback the records to the patient in the form of graph or voice to quantify the patient's control over themselves [15].
   Treatment Process: ① the instrument screen displays the actual EMG signal values of the patient with an orange horizontal line; ② the patient contracts the muscle according to the instructions, for example, the EMG signal value generated by muscle movement gradually rises, and the patient should try to make the orange horizontal line exceed the trigger limit; ③ the patient should try to relax the muscle at the affected limb in the rest stage, so as to reduce the orange horizontal line to the minimum value [16].

2.3 Market Research

At present, one of the relatively mature products in the market is the iKCare remote traction rehabilitation system, of which the function is to assist patients to complete rehabilitation training under the remote guidance of doctors, and the main form is to instruct patients to move the patient limbs according to voice and other prompts. With the help of Internet of things technology, the software can make the rehabilitation treatment more intelligent and provide more possibilities for rehabilitation doctors and patients [17].

In addition, there are "medical care", "sports and creative power" and other products, covering hospital appointment, sports, drug management and other directions.

3 Design Conceptualization

The design is developed referring to the treatment principles of the stroke rehabilitation. To help the patients to achieve scientific rehabilitation treatment simply and effectively, the design details are fully considered. The specific design content is shown in Table 1.

Table 1. Design conceptualization.

Name of product or system?	Xingjian - stroke rehabilitation treatment system
A brief description of what it is?	Rehabilitation treatment system of stroke based on three advanced therapies
Target users and stakeholders?	Stroke patients and rehabilitation physicians; stroke patients and their caregivers
Rationale for development and unique benefits of product?	Independent rehabilitation; Emotionalization; scientific
Primary product function?	Training, rehabilitation status analysis, etc.
Secondary product functions?	Health data recording, health management information, tests, settings, etc.
Key technologies?	Motor imaging therapy, task-oriented training, electromyographic biofeedback

4 Design Development

With the help of the three advanced therapies abovementioned, this study presents a scientific treatment process in an interactive manner to assist the rehabilitation of stroke patients, and developed a product to realize the treatment process accordingly. Specifically, the product consists of tablet computers and an APP. Through the use of tablet computers, the rehabilitation guidance and interactions set by the APP can be presented to stroke patients (Fig. 1).

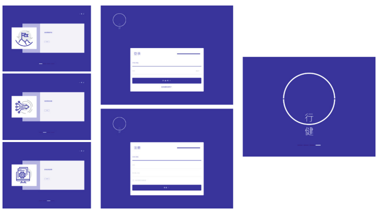

Fig. 1. Access, login and registration pages.

With the help of the APP, efficacy records and other treatment functions can be achieved. In details, the main functions of the APP are listed below:

1. Training: Gradually guide patients to complete motor imaging therapy and task-oriented training through text, voice, video, etc. This function is particularly to provide rehabilitation treatment for patients with impaired athletic ability (Fig. 2).

Fig. 2. Training pages.

2. Test: Assign patients with simple physiological and psychological tests to verify the treatment effect (Fig. 3).

Fig. 3. Test pages.

3. Analysis: Record the time and effect of patient training and display it visually, making the effect more intuitive (Fig. 4).

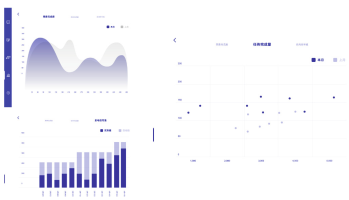

Fig. 4. Analysis pages.

4. Information: Provide functions for patients to communicate with each other and enable patients to receive treatment information posts (Fig. 5).

Fig. 5. Information pages.

5. Settings: Provide membership service, so as to provide better and advanced services for patients (Fig. 6).

Fig. 6. Settings pages.

The system design pays attention to the disease situation of different patients, making the treatment process more flexible and make the user experience better. Specifically, simple information guidance training process can make the patients more confident and motivated; accurate data collection and feedback function can provide more real-time and more scientific treatment; the treatment variance between different doctors can be avoided which leads to more standard and unified treatment.

The interaction design can be used for professional training assisted by doctors in the early stage and independent family training for patients in the later stage. It has strong adaptability and obvious rehabilitation effect, which improves the public's attention on stroke prevention and rehabilitation, and is of great benefit to doctors, patients and their caregivers.

5 Design Verification

Finally, through the use of EMG and EEG equipment, a total of 90 min of user tests were conducted among five target users. The results showed that the proposed design has positive effects on stroke patients in stimulating their motions, training their athletic ability, and suggests the effectiveness of this design in assisting the rehabilitation training of stroke patients.

6 Discussion and Conclusion

This project focuses on the current social rehabilitation treatment hot spot. Based on the strategy of Co-Design for Healthcare, it is expected to make use of the related innovation of mobile medical and interactive design to improve the rehabilitation experience of stroke patients. The promising advantages of this design are as follows:

1. This study explored the possibility of the application of advanced stroke rehabilitation therapy in the mobile terminal, provided an independent platform for the rehabilitation of stroke patients, realized many functions of stroke rehabilitation therapy, and had a good significance of expansion.
2. This study can help stroke patients who receive regular rehabilitation to correct themselves and predict the process of rehabilitation, as well as stroke patients who receive informal rehabilitation to guide the process and evaluate the effect of independent rehabilitation.
3. Compared with the existing research results, this study pays more attention to demand-oriented, and makes supplement and development in the application of advanced rehabilitation therapy for stroke.

Inevitably, limited by time and ability, the design has some defects, such as the lack of research in the hardware part of EMG biofeedback, thus it will be considered to make improvements in the technical design in the future. Moreover, the design evaluation is still rough, and a larger-scale user experiment will be organized in order to fully understand the effect of the current design.

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Safety, Integration and Interaction for Older Adults and Children

Do Perceived Stress and Coping Strategies Differ by Generation in U.S. Military Active Duty and Veterans?

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Abstract. U.S. service members move frequently and work in high-stress jobs that affect the individual, military mission, and family dynamics. A deployment situation could involve life and death decisions or encounters for themselves and fellow service members. U.S. service members must cope effectively for their own, their fellow warriors, and their family's well-being and success. This study assessed self-reported perceived stress and coping strategies of active duty U.S. service members and veterans, based on generation age groups (n = 246). Three stratified groups consisted of 1) Baby Boomers, 2) Generation X, and 3) Millennials. No significant generational age differences were seen on the Perceived Stress Scale (PSS) responses or the brief COPE (Coping subscales). This research does not support prior research findings in which age was associated with coping, possibly due to volunteers self-selecting into a study on stress-management or being averse to reporting less beneficial coping strategies.

Keywords: Coping · Stress · Age · Conditioning · U.S. Military · Performance · Conditioning · Exercise

1 Introduction

At a moment's notice, active-duty military personnel are subject to frequent deployments. Conflicts overseas have exposed both U.S. military and civilian personnel to high occurrences of bodily harm or even death [1, 2]. In many instances, service members are required to engage and destroy enemy objectives or make the best course of action decisions that could affect personal and team survivability. In fact, as recent as 2020, U.S. service members were called upon to deploy in response to threating and provocative actions overseas [3]. These situations and similar circumstances are mentally challenging and can subsequently lead to increased stress.

An important consideration during times of military conflict is the evaluation of service members' physical and mental health. Similarly, during peacetime, the same

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 299–306, 2020.
https://doi.org/10.1007/978-3-030-50838-8_41

strategy is prudent for maintaining a healthy military workforce. Reactions to stress and individual coping abilities differ among military personnel [4]. Two potential assessment measures are perceived stress and coping.

1.1 Coping

Coping is "the use of cognitive and behavioral strategies to manage the demands of a situation when these are appraised as taxing or exceeding one's resources or to reduce the negative emotions and conflict caused by stress" [5]. Wright and Hamilton (1978) proposed a "job change mechanism," suggesting older workers have better jobs and skills that enable them to cope more effectively with job demands [6]. Aldwin and colleagues (1991; 1996) further suggest a greater range of experience requires the development of more coping resources, and therefore older persons will assess their problems as less stressful and their coping as more successful [7, 8]. The lifestyle of those serving in the U.S. military is not the same as a civilian [9]. Regardless of age, military deployments, coupled with separation from family and friends, can have a compounding effect on a service member's psychological and emotional well-being – as well as negatively affecting their life partner and children [10, 11]. Rice and Liu (2016) reported that coping strategies among active-duty service members and veterans differ with age [12] and Kugel and colleagues (2017) suggested that developing effective coping strategies and skills can mitigate the harmful effects of moderate to high stress [13].

1.2 Perceived Stress

Perceived stress refers to the self-appraisal of ones' current life as being stressful, including the unpredictability, lack of control, and overload encountered. Research shows that stressors can emanate and manifest from daily life environments [14], again emphasizing the potential for high stress among military service members and veterans. Although evidence supports the efficacy of acute stress as a physical and cognitive performance enhancer [15, 16], it is well documented that prolonged stress negatively affected service members of all ages during armed conflicts – often with injurious outcomes [17, 18]. Yet, during basic military training, and subsequently, service members receive training on how to respond appropriately during stressful and challenging conditions [19]. Determining the best approach to prevent or manage and reduce post-conflict stress lacks a one-technique fit all concept. In an effort to regain balance during or after a stressful situation, service members could instinctively revert to their military mental stress or survival training [20, 21]. Service members may also choose to use self-centered relaxation practices or advanced specialized remediation strategies, to include seeking the assistance of a licensed mental health professional. While previous research suggests stress reduction occurs with age [7], Osmanovic-Thunström and colleagues suggest the opposite is true – as they reported older people have higher levels of perceived stress than younger people [22].

1.3 Purpose

In light of the age-related differences in coping and stress seen in the literature, this study explores generational differences in perceived stress and coping among active-duty service members and veterans. We hypothesized both perceived stress and coping strategies would differ between generations of U.S. military active-duty and veterans.

2 Methods

2.1 Participants

U.S. active-duty service members and veterans of varying ages volunteered to participate in the study.

2.2 Procedures

This study is part of a larger study examining the impact of mindfulness-based stress reduction training on perceptions and functioning of U.S. military active duty and veteran service members. This study examined the data prior to MBSR intervention, that is, baseline data. Volunteers signed an Institutional Review Board approved consent document. Volunteers were assigned to a generational group: Baby Boomer, Generation X, Millennials, and Post Millennials, according to their age (Table 1). Using electronic self-report instruments, volunteers completed demographic, perceived stress, and coping assessments. See (Table 2) for a description of the self-report surveys.

Table 1. Description of generational categories

Category	Year range	Age range
Baby Boomer	1946–1964	54–72 years old
Generation X	1965–1980	38–53 years old
Millennials	1981–1996	22–37 years old
Post Millennials	1997–Present	Birth - 21 years old

2.3 Instrumentation

Table 2. Instruments

Survey	Survey summary
Demographics	Demographics included general information on age, gender, active-duty status, marital status, and education level
Perceived Stress Scale (PSS) self-ratings	The PSS is a 10-item instrument that uses a four-point Likert response scale (0 = Never, 1 = Almost Always, 2 = Sometimes, 3 = Fairly Often 4 = Very Often) to quantify stress levels [23]
Coping (COPE)	The COPE Inventory is a self-report measure used to assess a variety of coping responses [24]. Volunteers rate how often they have been using dysfunctional and functional coping methods, on a four-point response scale (1 = Not at all, to 4 = A lot)

2.4 Statistics

IBM SPSS software (version 24) was used for analysis. Nonparametric Kruskal-Wallis tests were used to compare baseline values from 3 age groups for ordinal scale scores from the Perceived Stress Scale and 14 subscales of the (COPE) coping scale.

3 Results

3.1 Demographics

Two hundred and forty-six (n = 246) volunteers participated in the study. As shown in Table 1, volunteers were stratified into four generational age groups. There were no subjects < 24 years old, therefore the Post-Millennials category was removed. Similarly, three volunteers older than 72 years were excluded from these analyses (Table 3).

The population was comprised of more males than females (Table 4), and over half of the sample were Caucasian (53%) and married (58%). A higher percentage of veterans (65%) volunteered than active-duty service members. Finally, over 90% of the volunteers had received education beyond the high school level.

Table 3. Perceived stress scale scores by generational categories

Group	Year range	N	Median	Interquartile range
Millennials	(1981–1996)	57	21.0	14.0–25.3
Generation X	(1965–1980)	97	21.0	14.0–26.0
Baby Boomers	(1946–1964)	85	18.0	12.5–24.5
Total		239	20.0	13.0–25.0

Table 4. Perceived stress scale scores by gender

Gender	N	Median	Interquartile range
Male	130	20.0	13.0–25.0
Female	111	20.0	13.5–26.0

3.2 Coping and Stress

See Table 5.

Table 5. Kruskal-Wallis test results for PSS and coping comparing 3 age groups

Perceived stress and COPE subscale	Millennials	Generation X	Baby boomers	*p-value*
PSS	21 (14 -25)	21 (14-26)	18 (13-25)	*p = .411*
Self-distraction	5 (4-6)	5 (4-6)	5 (3-6)	*p = .092*
Emotional support	5 (4-6)	4 (4-6)	5 (3-6)	*p = .298*
Instrumental support	5 (4-6)	5 (4-6)	5 (3-6)	*p = .497*
Religion	5 (3-6)	5 (3-7)	6 (4-8)	*p = .180*
Active	6 (4-7)	5 (4-7)	5 (4-7)	*p = .965*
Reframing	5 (4-7)	5 (4-6)	5 (4-7)	*p = .627*
Planning	6 (5-7)	5 (4-6)	6 (4-7)	*p = .396*
Humor	4 (2-5)	4 (2-6)	4 (2-5)	*p = .324*
Acceptance	6 (4-6)	5 (4-7)	6 (5-7)	*p = .167*
Denial	2 (2-4)	2 (2-3)	2 (2-3)	*p = .081*
Substance abuse	2 (2-4)	2 (2-3)	2 (2-3)	*p = .461*
Behavioral disengagement	3 (2-4)	2 (2-4)	2 (2-4)	*p = .423*
Venting	4 (3-5)	4 (3-6)	4 (3-5)	*p = .623*
Self-blame	5 (4-6)	4 (3-6)	4 (2-6)	*p = .213*

4 Discussion

The study hypothesis that generational age would differentially impact perceived stress and coping strategies among U.S. military active-duty and veterans was rejected. No significant differences were seen among volunteers who were categorized as Millennials, GenX, or Baby Boomers on the PSS or any of the fourteen coping strategies identified in the brief COPE.

This research does not support prior research findings suggesting a greater range of experiences will yield greater coping skills, and therefore older individuals will perceive less stress and more successful coping. These findings also do not corroborate other findings in which age was associated with more effective coping [25] among managers [26] and women [27]. Neither do our research results support Osmanovic-Thunström and colleagues (2015) results of older people having higher levels of perceived stress than younger people [22].

The lack of differences in perceived stress and coping strategies according to age may be the result of the population self-selecting into the larger study focusing on a training program designed to reduce personal stress. It may be that volunteers for the study had high levels of perceived stress and poor coping skills and therefore, sought out assistance for reducing stress and improving their coping abilities. In addition, military training includes resilience training (including coping) occurring at various times during a military career. Finally, military professionals are proud of their military service and their decision to serve the country, as well as being aware of how their responses impact the military and possibly their career aspirations. In these cases, research volunteers may have been averse to reporting information they felt was not positive and advantageous.

5 Conclusion

Generational age differences did not impact scores on self-reported perceived stress or coping strategies among 246 U.S. military service members and veterans, thus not supporting the existing literature with civilian populations. This phenomenon warrants further attention to ascertain whether coping strategies (and training needs) differ situationally, according to vocation, current assignments, or deployments rather than age. The described results may serve as a dialogue catalyst for military leaders and the military healthcare community.

6 Limitations

The primary limitation of this study is the rather homogenous sample of U.S. military active duty, reserves, and veterans at one military installation. Caution should be taken in generalizing these results to other populations.

Acknowledgements. Special thanks to the U.S. military service members and veterans who participated in this study. Support for this research is in part by the U.S. Army Study Program Management Office (ASPMO).

Disclaimer. The views expressed in this article are those of the authors and do not reflect the official policy or position of the Department of the Army, Department of Defense, or the U.S. Government.

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A System Supporting Intergenerational Storytelling for Older Adults

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Abstract. This paper reports the implementation of the Story-me system, consisting of a slots-machine-like device used by older adults, and a cellphone application used by their children, which aims to facilitate intergenerational life story and family memento story sharing. In the field study, seven pairs of participants (each pair consisting of an elderly adult and his/her child) were recruited to use the system. Semi-structured interviews were conducted both with both the senior and young participants. The stories collected were transcribed and analyzed, and the findings. Conclusion and future work are in the final part.

Keywords: Elderly · Memento · Storytelling · Tangible interface · Story sharing

1 Introduction

The globe is graying. Among the most significant achievements and challenges that the society is facing today, is that human beings are living to unprecedented ages [1]. The worldwide population over age 65 is expected to more than double from 357 million in 1990 to 761 million in 2025 [2]. There are two major causes for global aging: Life expectancy increases and fertility rates decline [3]. EU will face more severe situation: the old-age dependency ratio (people aged 65 and above relative to those aged 15 to 64) in the EU is projected to increase by 21.6 percentage points, from 29.6% in 2016 to 51.2% in 2070 [4]. Across the world, family members are the most important providers of support, especially psychological support, for the older adults [1]. Since one feature of older adults is their memory of events, persons, and locations, they have the potential to be story content producers [5]. The story sharing could be a method to make connections with others.

Within this context, this paper briefly introduces the field study of the system named Story-me, which consists of a tangible device used by the older adults, and a mobile phone application used by their children. It is trying to elevate the intergenerational story sharing between older residents in the nursing home and their children. A detailed description of the system is reported first, follows up the field study process.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 307–312, 2020.
https://doi.org/10.1007/978-3-030-50838-8_42

2 Research Prototype

The research prototype in field study comes from our previous work [6]. Its basic idea is that older adults are storyteller, while their children are memory trigger (including trigger questions and memento photos) providers. The initial prototype was improved based on feedback from the users, during preliminary evaluation. The final prototype (Fig. 1) consists of a tangible device used by older adults, and a cellphone application used by their children. The tangible device utilizes the metaphor of slots machine. Its tangible interface employing metaphor and intuitive interaction aims at enhancing familiarity and simplicity for the senior users. It includes two interfaces: the “Photo interface” and “Question interface”, which are both in vintage style. Considering the loss of vision of the older adults, it uses bold fonts. The interaction is similar to slots-machine: Pulling down/pushing up the right handle to switch to the next/previous trigger question or photo. The left button is to switch between the “Photo interface” and “Question interface”, while the right button is to record. The cellphone application is used by the young, which is composed of four pages. “Camera”, which is used to take photos of mementos. “Photo”, which displays the photo gallery, tap the photo and get to the corresponding audios. “Question”, which displays the trigger question and corresponding audios. “Setting”, including often-used setting options.

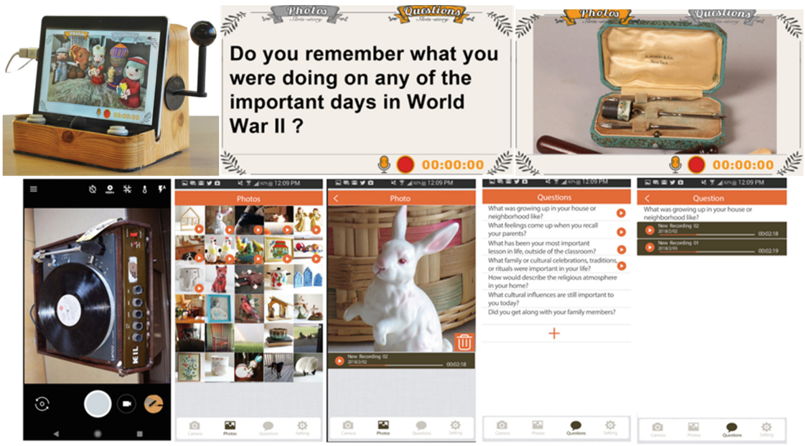

Fig. 1. The tangible device (above) and cellphone App (below)

Trigger questions in the this study came from The Life Story Interview [7], covering the following aspects: “Birth and family of origin”, “Cultural setting and traditions”, “Social factors”, “Education”, “Love and work”, “Historical events and periods”, “Retirement”, “Inner life and spiritual awareness”, “Major life themes”, “Vision of the future”, and “Closure questions”. Young participants could directly choose questions, and add personized questions.

3 Field Study

3.1 Procedure and Method

Seven pairs of participants were recruited for the field study, and each pair was composed of an old adult and his/her child. The recruitment criteria were (A) Older residents had no severe physical disorders (cognitive impairments, such as dementia and Alzheimer's disease). (B) Older adults that would like to share stories and mementoes with children, on the premise of anonymity. The education background, previous occupations, and gender were considered as random variables. During the field trial, there were no real hard requirements for the number of trigger questions and mementos. Names and data in this article are anonymous, and the access to the data was restricted to our research team only. After using the prototype, they were interviewed to reflect on their use of the system.

3.2 Trigger Questions and Memento Photos

Figure 2 shows the overall results of the categories of trigger questions chosen by the young participants. The top three trigger question categories the young chose most were "Birth and family origin", "Cultural setting and traditions", and "Social factors". While the last three categories were "Closure questions", "Vision of the future", and "Major life themes".

Regarding the mementos, the categorization of mementoes in this paper follows our previous study [8], which was classified into three categories: object, paper document, and photo. Example memento photos are shown in Fig. 3.

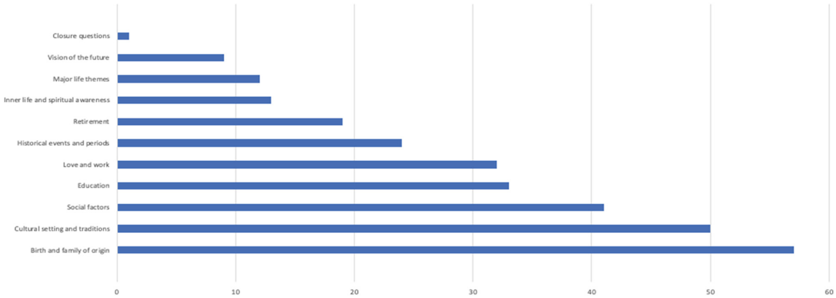

Fig. 2. Categories of trigger questions chosen by the young participants

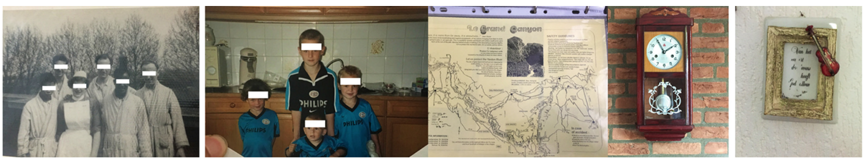

Fig. 3. Mementos of different types

3.3 Findings of Interview

Their Feelings and Opinions on the Prototype. For the senior participants, first, the senior participants appreciated it that provided an opportunity for them to tell what they did not have the opportunity to tell. One said: "The project builds a bridge for us two generations. This allows me to talk about what I usually never get a chance to say, and what I can't remember." Another said: "When I was little, I dreamed of being a writer. I have never talked about my dreams to my children, until this project." Second, the project helped enhance intergenerational mutual understanding. One said: "The cause of generation gap, is lack of mutual understanding. I think talking about the past things contributes to it." Third, the project also contributed to family history preservation. As one said: "My children maybe not interested now, but they could listen in the future." Finally, while for the reminiscence process, they enjoyed and felt happy. Another said: "I feel as if back to the past, and suddenly, I realize I am old."

For the young participants, first, despite that they knew most of the stories, they still learned something they did not know before. As one said: "*We didn't talk much about stories when I was an infant. It is a blank to me. I had just known that it was snowing when I was born."* Even for the stories the young had known, they re-learned their parents in a more detailed way. Another said: *"I realize that she experienced the ups and downs of life, after listening to her stories."* Or from a deep level. As one said: *"Without the storytelling in person, I couldn't have such a deeper understanding."* Second, the young were moved by the stories. One said: *"I can feel that my father was very happy when he was recalling his youth, and I feel happy for him."* This emotion stems from the great contrast between their parents' youth and now. Another said: *"He tells stories of his happy childhood, while now he is more than 80. This contract touches me a lot."* Therefore, they signed time flew and re-thought the importance of staying with parents. Another said: *"Time is flying. I feel I have more to lose than gain. I didn't treasure the family time."* The young were also touched by their parents' love for them. One said: "*I remember for the question What experience has given you the greatest joy? She said it was my birth, and I was really moved when hearing this."* Third, the stories raised their empathy and increased their understanding of their parents. Especially for the second-generation immigrants. One said: "*I realize that their living conditions are so different from us."*

Some of the audios were concrete stories with plots, for example, audios related to trigger questions *"What are your best memories of school?",* while some were subjective feelings, for example, audios related to trigger question *"What do you hope to pass on to your grandchildren?"*. We were interested in their preferences for these two types of audios. We found that most participants had preferences for the concrete stories, reasons included. First, audios with concrete plots were not tedious but absorbing. One said*: "Stories are more interesting, and it brings me back to childhood's story times."* Second, they were relatively more real and objective than subjective feelings. One said: *"Stories are vivid, and let me understand things that happened to her more clearly."* Third, they were more impressive. One said: *"Stories could leave me a deeper impression, because they are concrete people, events and things."*

Regarding preferences for using prototype separately or face-to-face, the participants felt each way had its advantages and disadvantages. When using it alone, they could be free to concentrate on the storytelling, without being disturb. However, since talking to a device seems to be more formal, which brought a little pressure on them. One said: *"It is not as casual and comfortable as face-to-face talking."*

Communication During and After the Field Study. As expected, most of the young contacted their parents after listening. The first motivation was that they wanted to know more details of the story. One said*: "I ask her a lot about her childhood life, after listening to her recordings."* Second, the project made the young realize the importance of staying with parents. One said: *"I realize I spent little time with my mother, let alone heart-to-heart talk with her."* Beyond that, surprisingly, some young participants did not want to contact their parents specifically. One said: *"I won't deliberately make a phone call to ask my mother. But next time when I visit her, I will talk about that naturally."*

Comments for Improvements. For the older adults, usability aspects, most found it easy to learn and operate. One said: *It is not hard to use. Press the button before talking, and press it again after talking.* Some participants mentioned they got help from their children: One said: *At first I don't quite understand how to use it, and my daughter teaches me.* Two senior participants appreciated the recording repeatedly for one question/photo One said*: If I need to add after recording, I just need to push the recording button again. That's why I have several recordings for each question.* One said*: "Once I remember, I could add by simply pressing the button. It is like writing a diary."* While for the improvements, most older adults complained about the lack of delete function. One said: *I don't know how to delete the useless recordings, So I need to make drafts in my mind before speaking. It makes me a bit stressed.* There was one older participant had an iPad and had related using experiences, and he used the android pad directly.

For the young participants, all the young participants reported that the App was generally satisfying. In the aspect of usability, since currently there was no delete function in the App for the young, not surprisingly, they hoped to add that function. Second, the young suggested adding more functions to the current over-simple App. One said*: "The interface and functions of this App are too simple. Apps we use every day, like WhatsApp, Facebook, are far more complicated than it. After all."* Specifically, the App could also record the young's voice. One said: *"I have lots of feelings when listening. The App should help me to record them, and they could be sent to my mother, or kept by myself."* Second, improving the curation of digital content. Third, some trigger questions were too closed. One said: "For the question Did you enjoy being alone, or was that too boring?, his answer is "I enjoy being alone. That's all." The "Photo Interface" could also include trigger questions. One said mentioned that: "For example, his watch, he talked about the date, the price, etc. But I want to know why he bought the watch." Therefore, to make the memento storytelling more concrete, related trigger questions could be provided, such as *Who was involved? What happened? Where did it take place? When did it take place? Why did that happen? And How did it happen?* Usability aspects, one mentioned the sensitivity of touch need to be enhanced,

4 Conclusion

In this paper, we report the implementation of the Story-me system. The interview results indicate that the system could facilitate intergenerational story sharing. Due to space constraints, this paper reports only part of the study's findings. Therefore, the future work will present all the field study results in a comprehensive and deep manner.

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Driver Persistence, Safety and Older Adult Self-efficacy: Addressing Driving Challenges Using Innovative Multimodal Communication Concepts

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Abstract. New assisted driving technology provides a solution to enabling driver persistence while also addressing older adult fitness to drive issues. The proposed driver assistance system follows a detailed literature review, an analysis of secondary data, and the specification of a solution using human machine interaction (HMI) design methods. Overall, the assisted driving concept follows from a principled/ethical perspective in relation to promoting self-efficacy and enablement for older adults. The system is conceptualized as a supportive friend or 'co-pilot'. It is argued that the use of new car-based sensors, along with machine learning intelligence and novel multimodal HMI communication methods will enable driver persistence while also promoting older adult self-efficacy and positive ageing.

Keywords: Human factors · Active ageing · Older adult · Driver task · Automated driving · Adaption · Self-efficacy · Ethics · User acceptability

1 Introduction

Living longer poses many challenges including maintaining independence and mobility. Changes in the physical and cognitive abilities of adults as they age presents a safety challenge [1]. Health deterioration is a key contributory factor to driving cessation among older adults. Mobility in the form of driving is very important for older adults. Mobility constraints and/or loss of mobility impacts on older adult independence

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 313–319, 2020.
https://doi.org/10.1007/978-3-030-50838-8_43

and opportunities for social participation [2] Nondrivers rely on their family, friends and/or transport services, to enable them to travel to social and recreational activities [3].

Driverless cars are being introduced by several car manufacturers. Automated cars draw upon diverse sensors, cameras, radar and artificial intelligence (AI) and machine learning technology to travel between locations without requiring a human driver. The available automation technologies follow the guidance of National Highway Traffic Administration in terms of 'six levels of automation' [4].

Events, obstacles and potential collisions external to the vehicle are by the very nature of the environment, omnidirectional. The potential to exploit spatial audio within the vehicle as part of an advanced driver assistance system (ADAS) offers scope to present localized and detailed information to the driver about the type, direction and proximity of the hazard, using a less invasive modality that reduces driver distraction. In addition, there is a considerable body of evidence in the literature on the fatiguing effects of vibratory stimuli to the human musculoskeletal complex. Novel research has advanced the understanding of how vibrations or mechanical stimuli in general are processed by the human body, how muscles react to these stimuli and how muscle stimulation can trigger muscle activation [5]. This could help the driver to maintain optimum driving performance for longer periods of time.

Driver assistance solutions need to be carefully thought out in relation to promoting successful ageing, driver persistence and self-efficacy for older adults. Further, issues pertaining to ethics and user acceptability must be considered. This paper reports on research pertaining to the development of a novel and ethically responsible assisted driving solution for older adults. Specifically, it provides a summary overview of the methodologies adopted and the emerging driving assistance concept.

2 Objective and Method

The purpose of this research is to identity the framework and preliminary needs for a novel assisted driving system which would enable safe driving for older adults with different cognitive and physical abilities.

This research has been structured in two phases. The first phase of research has involved the specification of a preliminary concept using a combination of analyses. This research has been mostly theoretical. A multidisciplinary analysis of relevant literature pertaining to (1) older adults and models of successful ageing, (2) the driving task, (3) the classification of older adult drivers, (4) medical and age-related conditions that effect safe driving, (5) the detection and analysis of driver physical, cognitive and emotional state using sensors and machine learning procedures, (6) novel driver communication methods and (7) new driver monitoring, task support and feedback systems was undertaken. A secondary analysis of data from the Longitudinal Study on ageing in Ireland (TILDA) was also undertaken [6]. User profiles were decomposed into specific persona and scenarios. The combined outputs were further analyzed, using the 'Human Factors and Ethics Canvas' [7]. This resulted in the specification of an overall system concept and underlying ethical principles.

The driver interface solution was further specified using personae-based design [8] and scenario-based design [9] approaches. Nine driver profiles were identified, based on a segmentation of older adult drivers from the perspective of driver persistence, health and physical and cognitive ability [10].

These proposed nine profiles reflect ‘ideal classes or types and are derived from the project goals – to promote driver persistence, while also supporting road safety and ensuring an enjoyable driving experience. A series of personae corresponding to the nine user profiles was then advanced. The persona defined the older adult’s goals, health, cognitive and physical ability, medications, driving habits and behaviors, and specific challenges [10].

In parallel, several scenarios were defined. Scenario definition involved a mix of a top down and bottom up approach. That is, it reflected the project goals and older adult driver behaviors and issues, as defined in the literature review [10]. These are defined in Table 1 below.

Table 1. Scenarios

#	Scenario description
1	Driver is enjoying drive
2	Driver is distracted by call on their mobile phone
3	Traffic delays is causing driver stress
4	Driver has taken pain medications and is drowsy
5	Driver is fatigued after a long day with grandchildren
6	Driver is having difficulty parking
7	Sudden advent of acute medical event
8	Driver is having difficulty remembering the correct route home
9	Driver has taken alcohol and is over the legal limit for safe driving

The different scenarios were classified in terms of six specific interpretation challenges (IC’s). These include activation/flow, distraction, fatigue and drowsiness, intoxication, medical event (e.g. heart attack/stroke) and task support. Lastly, the scenarios were further elaborated in terms of a text narrative which provided information about the events as they elapsed in time and the allied behavior of car sensors and driver communication system [10].

To date, a preliminary workflow and driver communications concept has been defined in terms of the above scenarios. Subsequent phases of research will further validate the multimodal solution. This will involve mixed methods including participatory design/evaluation and testing in a driving simulator.

3 Results

The design problem is conceptualized from the perspective of positive ageing and promoting older adult ability and enablement. The system logic is underpinned by concepts of driver capability and adaption and not full automation. A collaborative system underpinned by a partnership concept and personalization is recommended. To achieve this, the system provides different levels of assistance, as is appropriate to the drivers (1) health, (2) physical and cognitive ability, (3) sensory function and (4) the real-time psychological/emotional state [10]. The three levels of assistance are: (1) no response, (2) task support and (3) safety critical intervention (i.e. entailing automation of either some or all of the driving task). The 'co-pilot' is conceptualized a supportive and vigilant friend, who works with the driver to ensure a safe drive. The co-pilot is constantly monitoring the driver state, the driver's behavior, the car state and the driving the environment/road context. The proposed sensing system enables the co-pilot to gather evidence about the above. Using data fusion, the available evidence is integrated to form a coherent and predictive picture of the combined team state. The co-pilot then assesses the overall situation using artificial intelligence (AI) and deep learning techniques. This overview is structured in relation to the six interpretation challenges. Having interpreted the situation, the co-pilot determines the best course of action. In line with the proposed partnership approach, the co-pilot provides feedback to the driver about this decision (and associated driving assistance and automation levels), using the multi-modal HMI.

The older adult driver is in charge and chooses the appropriate assistance. Further, the system proposes different levels of assistance based on the driver's ability and real time situation. Although the driver is in charge, the system authority moves to the co-pilot in certain predefined situations. This includes situations where the system detects that the driver is in impaired state (i.e. alcohol or medications), that there is a potential for a safety event or if the driver is incapacitated.

Data-gathering and interpretation is, of course, only part of the co-pilot's task. The other part is to enable driver interaction with the system (i.e. multimodal driver input and output), considering the co-pilots interpretation of the current driver factors, driver task, vehicle state and driving environment/context. The co-pilot is typically silent – if (1) the driver state is normal, (2) driver behavior is normal, (3) the car state is normal. As such, the driver is making decisions and not obtaining alerts/warnings from the co-pilot via the multi-modal HMI. Depending on (1), (2), (3) and the associated risk rating (major/minor), the co-pilot provides task support/feedback via the multi-modal HMI in manner that is tailored to the driver's profile and ability. As such, this feedback considers the driver's functional ability (i.e. reach, strength), sensory ability (sight, hearing), cognitive ability, emotional/psychological health (i.e. if anxious or stressed), and associated preferences. Critically, the co-pilot is continuously assessing the state of the joint system.

In relation to HMI communication methods, innovation is defined in relation to the use of haptic interaction (steering wheel and seat vibrations), earcons and advanced spatial audio, and combining different modalities.

New haptic technologies (for example, seat vibrations and steering wheel vibrations) can be deployed to enhance co-pilot and driver communications, particularly in situations where the driving task is already using visual and auditory resources.

New auditory technologies provide huge opportunities in relation to optimizing communication between the co-pilot and the driver (for example, earcons that are spatially located). An advanced feedback system could use spatially located earcons to convey external object location, including rising intervals to communicate proximity and haptic feedback, potentially from the seat, to indicate the magnitude/type of object (e.g. car, cyclist, pedestrian, bollard etc.), which also associates with urgency.

There are many opportunities in relation to advancing new auditory and visual technology in the context of older drivers, where the driver communication system (i.e. design of the visual and auditory information) is optimized according to the person's sensory ability. The integration of different feedback modalities when done correctly will deliver a positive and safe driving experience. Combining advanced audio alerts (including spatial information), with other feedback modalities such as visual cues (visual display/augmented reality) and haptics (i.e. vibrations in car seat and/or steering wheel), will provide a less distracting and more context-rich feedback system for the driver. Also, making use of the latest advances in touch, gesture and voice interaction (i.e. driver input) will yield a more enjoyable driving experience.

The proposed multimodal logic has been worked out in relation to addressing the six IC's while considering concepts of older driver efficacy, assistance and adaptive automation. Several high-level user profiles and associated personae have been advanced and associated with the given IC's and scenarios. Figure 1 provides an example of the multimodal solution in relation to a specific IC, personae and scenario. Further research will address the detailed design of the driver communication system.

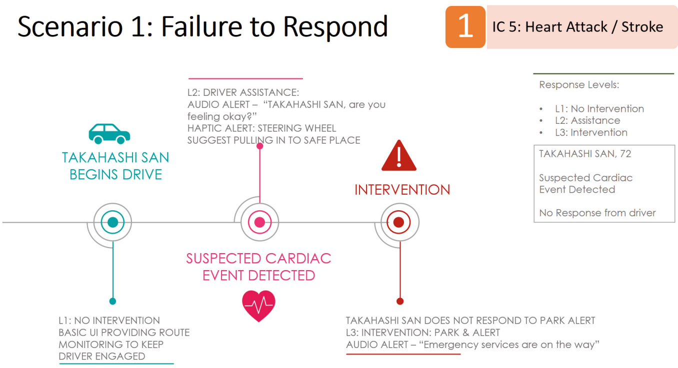

Fig. 1. Example scenario: IC5, heart attack/stroke (failure to respond)

4 Discussion

In general, drivers are very diverse in terms of size, strength and driving competency [10]. Older drivers present even greater diversity when sensory, physical and cognitive abilities are concerned. The focus on the older driver is important as they are a growing market segment internationally with a wider range of medical and psychological challenges for driving. In addition, if a system is designed to address the range of challenges facing older drivers, is should also encompass those faced by other drivers.

The driving assistance system reconciles the ostensible conflict between (1) ensuring road safety and (2) promoting driver persistence. The purpose of the driving assistance system is to interpret the implications of the driver's state in terms of their ability to drive the car safely. Most of the relevant medical events (i.e. heart attack, stroke, etc.) can be detected by a combination of just six symptoms (for example, dizziness, drowsiness, syncope/cardiovascular disturbances, attention deficit/distraction, reaction time and muscle strength). By sensing these six symptoms a system should be able to determine if the driver is conscious and capable of driving, and how the vehicle should respond.

An intelligent co-pilot affords possibilities of personalization not previously feasible since it can recognize the driver and configure the vehicle for the stored driver profile. In tailoring the assistance level and multimodal communications to the driver's ability and state, personalization enables a more positive driver experience.

Several crucial human factors issues need to be effectively addressed in the design of the multi-modal driver/system. Transitions are a critical safety issue with semi-autonomous systems. Both the driver and the intelligent co-pilot need to be clear which functions are being handed over and when. Transitions are part of the broader issue of situational awareness – the interface needs to support the driver in maintaining a clear picture of whom is in control of which functions but also of the external and internal driving context, other road users and vehicle state. Workload is also a critical issue. The HMI needs to provide information in a format that aids the driving task without overloading the driver with information that interferes with the driving task. Societal acceptability of this novel driving assistance system depends upon how it treats issues pertaining to driver rights – including driver autonomy and protection of personal information [10].

5 Conclusions

Supporting driver persistence is a societal issue, and not just an issue for older adults. It is important that older adults continue to drive safety while they age and that this is an enjoyable experience. The use of novel car-based sensors, supported by AI and machine learning processes, along with new driver communications systems, fosters driver persistence and safety, while also promoting positive ageing. New multi-modal driver input and feedback technologies can enable successful communications between the driver and the co-pilot system while at the same time enriching the driver experience. In relation to HMI communication methods, innovation is defined in relation to the use of (1) haptic interaction (steering wheel and seat vibrations), (2) earcons and advanced spatial audio, and (3) combining different modalities. The driving assistance technology, logic and communications system will be further validated using co-design techniques and testing in a driving simulator.

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Design of the Public Travel Reservation System for the Elderly Based on Empathy Research Map

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Abstract. With the development of the urban public transport system, the choice of public transport has become an important lifestyle for the elderly. Conducting empathy research on the travel of the elderly and designing a public travel service system that meets the needs of the elderly. The empathy and state empathy two different empathy designs form the empathy research map of the elderly travel, and use the information of the empathy map to complete the design scheme of the public transport system for the elderly. Conclusion, the public travel reservation service system for the elderly through the empathy map will raise the design of the elderly from product design to system design. By perfecting various links in the system, the design quality will be effectively improved and the urban elderly will be satisfied. Take the initiative to travel for social activities, social and fitness needs.

Keywords: Empathy research map · Trait empathy · State empathy · Old people · Public transport system

1 Introduction

As is known to all, the world has stepped into the aging society and the state of life of the elderly has play an important role in the harmonious society. Take China as an example. Experts predict that by 2025, China will have about 280 million elderly people, accounting for 19.7% of the total population. By 2040, the total number of elderly people in China will increase to 376 million, accounting for 24.4% of the total population [1].

With the acceleration of the process of urban aging, the travel situation of the elderly is also in urgent need of social attention. Compared with the young people, the elderly's ability to act and think decrease. Elderly people have a strong desire to travel in transportation, but they tend to hesitate when considering objective physical reasons and other concerns. The survey found out that the inconsistent line, bad service attitude of drivers and the frequency of the bus were the main reason weakening the willingness of them to take the public transportation.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 320–326, 2020.
https://doi.org/10.1007/978-3-030-50838-8_44

As for public travel, there are many design studies on spatial optimization, movement orientation and other aspects [2] also put forward relevant design constraints to guide designers to complete the design of relevant vehicles in combination with the physiological and psychological characteristics of the elderly [3]. However, the study on the bus travel system combined with the elderly is of more practical significance. This paper uses the method of empathy research to conduct an in-depth study on the elderly's travel, and proposes a travel system plan based on the elderly's physical and psychological characteristics of public transport reservation seats.

2 Method

The term empathy stems from Titchener, who derived it from the Greek empatheia [4]. Empathy generally refers to psychological transposition. This is the cognitive awareness, grasp and understanding of other people's emotions and feelings. Emotional intelligence is associated with emotional self-control, empathy, listening skills, and expressing respect. In product design, the research map of empathy can be used to guide the direction of design. Existing researchers usually divide the empathy into qualitative empathy and state empathy. Among them, the trait empathy is a stable personality trait, while the state empathy is an emotional response to the situation [5].

As shown in Fig. 1, Johnson D G presents the designing process of empathetic research map. Step 1: tasks – – what tasks are users trying to accomplish? Step 2: feelings – what is the user's experience? What affects their user experience? Step 3: Environment/influence/pain spot – which person, object or place will influence the user's behavior? What is the ultimate goal of the user? Step 4: solutions (plan) – brainstorming, designing concept visual presentation, and the acknowledgement of the effectiveness of the design.

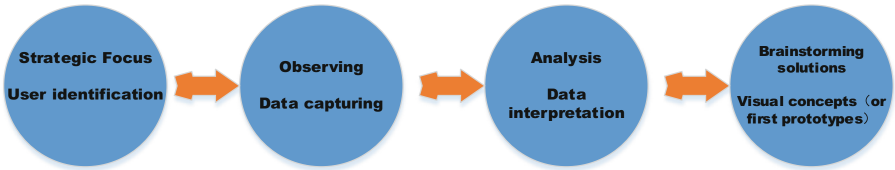

Fig. 1. Empathic design process based on [6]

Empathy is the ability to experience and be influenced by the emotional state of others. The researchers' definition of empathy can be roughly divided into two dimensions: one-way and multi-dimensional. One-way dimension: Hoffman believes that the empathy research can not only correctly perceive the feelings of others, but also have appropriate empathic responses to others' situations. Other scholars believe that empathy is the care for people in need of help, which is an important factor influencing pro-social behaviors.

As for “multi-dimensional empathy”, some scholars believe that there are four most representative aspects of empathy respectively: (1) Perspective-taking: the tendency to spontaneously understand the inner feelings of others. (2) Fantasy: the thoughts and actions of imagining oneself as a fictional character. (3) Empathic Concern: it refers to the person who sympathizes with and cares for the pain. (4) Personal Distress: refers to the anxiety and Distress experienced by an individual in a state of tension.

3 Elderly People’s Public Travel Research

3.1 The Study on the Elders’ Trait Empathy

The physiological functions of the elderly are mainly reflected in the average resolution of vision and audio, the resolution of static objects, the average response of strength and speed, as well as the ability of memory and the flexibility of feeling. It is difficult to acquire complex thinking skills, so the relevant operations need targeted simplification. For the elderly population, due to the rapid deterioration of vision, its sensitivity and adaptability are not as good as that of the young people. Therefore, the visual expression of information in the public transport system needs targeted design. Due to the decline of the elderly’s reaction ability and the easily disturbed characteristics, their ability to adapt to the traffic environment is weakened. In the process of adaptation, they need a safe and suitable walking environment to enable them to pass the road. And their characteristics of getting tired also need comfortable rest places.

In terms of psychology, most of the elderly gradually lose their labor force and normal movement due to their age. Besides, their children are generally married. Therefore, they often feel emotional loss, loneliness and other adverse psychological reactions due to their children’s absence all year round. In addition to special care for the elderly from the society, their self-esteem should also be taken care of. According to the interview, most elderly people prefer to complete all kinds of behavioral activities independently through the facilities provided by the environment. The elderly hope to have the same rights as ordinary people to participate in social activities and share the fruits of society [7].

In terms of travel characteristics of the elderly, Burkhardt JE found that the elderly tend to learn traffic information through some simple means, such as telephone, easily recognized maps, symbols and so on. The analysis of the data of the American aging survey found that the travel accessibility of the elderly would decrease with the increase of age, and it also found that the degree of decrease was faster for women than for men. The elderly encounter a series of problems in bus travel: the bus travel safety problems due to the decline in physical ability, the difficulties of traveling in morning rush hour and the difficulty in accessing information about bus stops. Therefore, humanized design is particularly important, because it can help the elderly to complete the trip independently, which is a recognition of their own value for the elderly, and bring a sense of security to comfort the elderly.

3.2 The Study on the State Empathy Characteristics of the Elder

A survey was conducted between September and November 2018 among retired elderly people over the age of 55 in four counties and districts in Shanghai, who were able to drive their own cars, ride with family, friends or neighbors, and need public transportation services [8] (Table 1).

Table 1. The statistics of travel condition among the elders in part of Shanghai area from Sept to Nov in 2018

Investigation area	Subjects	Frequency every week and purpose	The way of going out
Jiading District	40 elder people from 55 to 70 years old	More than 7 times per person, shopping, exercise and medical treatment	Mainly bus, occasionally walking
Hongkou District	33 elder people from 55 to 67 years old	More than 9 times per person, shopping, exercise and medical treatment	40% of them have walk,15% of them take a bus
Baoshan District	32 elder people from 55 to 69 years old	More than 11 times per person, 20.18% of them shop and 19.16% of them go to hospital	Over 20% of them take public transportation
Putuo District	21 elder people from 55 to 71 years old	More than 12 times per person, mainly shopping, exercise and medical treatment	Over 30% of them take bus

According to the survey in Shanghai area, the proportion of the elderly going out by bus is more than 20%, and the elderly are more willing to go out, mainly manifested in shopping (33%), social activities (22%) and medical treatment (16%). In order to better understand the bus travel status of the elderly, the bus travel process of 21 elderly people was tracked and observed. Before going out, the elderly will make careful preparations and pay more attention to the time of the bus.

The elderly will choose to walk to the nearest bus stop. During the waiting process, the elderly will confirm the arrival time of the bus through the information provided on the platform. And the arrival of the car will be identified for fear of missing the vehicle.

When the vehicle arrives at the station, the elderly may be slow in getting on the bus and worry about falling down. In the process of swiping the card on the bus, they may worry about being criticized by the driver or other passengers because of the slow action. After entering the compartment, if there is no vacant seat, there will be no passengers willing to give up their seats. Therefore, they often choose not to seek help, which increases the risk of injury.

Before arriving at the destination, the elderly will prepare to get off in advance, fearing that they have missed the stop. If the car is crowded, they will worry that the driver will not pay attention to their need to get off, and they will also worry about falling down in the process of getting off.

3.3 Map of Empathy for the Elderly

Combined with the research contents of the elderly's trait empathy and state empathy, the related contents were sorted out and completed the empathy research map. For the related tasks aimed to the elderly to take public transport travel, the completion of empathy map emotion, impact and other related content was listed.

On the empathy map, the following pain spots are proposed for the elderly to travel: 1. Design to provide timely information (or equipment) for the elderly; 2. Be able to have a service system for the elderly; 3. In case of any accident, timely rescue and auxiliary treatment can be provided (Fig. 2).

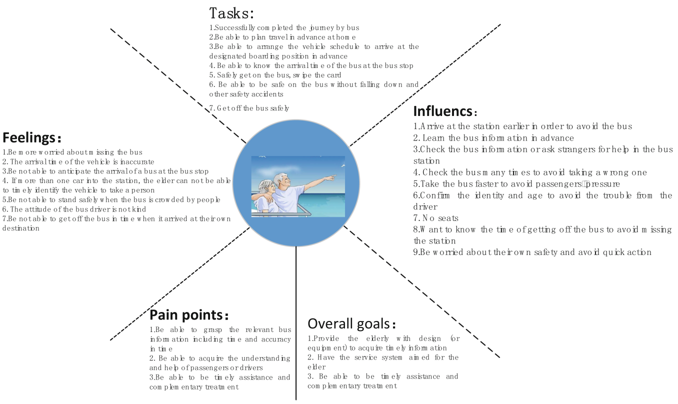

Fig. 2. An empathic map of senior citizen travel

4 Design Presentation

Combined with the travel empathy map of the elderly, the pain points of the design were analyzed, and the bus reservation system based on the mobile phone system was completed. Before going out, the elderly can clearly know the location of the bus, the number of passengers on the bus and the degree of crowding, and determine the travel time. To solve the problem of elderly people's bus seats, a bus seat reservation system for elderly people is developed, which can use the voice recognition function to complete seat reservation (as shown in Fig. 3).

The construction of bus station can provide some clear traffic information for passengers to read. Especially for the elderly. In the aspect of face recognition and fingerprint identification, the bus stop can use big data analysis to locate the location of the elderly, further lock the traffic information needs of the elderly, correlate the vehicle information, and relieve the pressure of identifying vehicles.

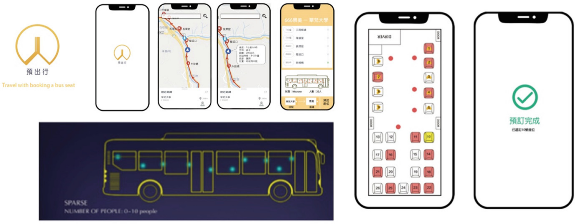

Fig. 3. The mobile APP displays information and completes the reservation of seats

Bus seat design combined with the elderly travel safety needs, remote agreement after the location, can prompt reservation status through color recognition, seat design includes simple drugs and related monitoring functions. At the same time, it can remind the elder of the arrival information (Fig. 4).

Fig. 4. Bus station design and intelligent elderly seat design scheme

5 Conclusion

Likert 7-point scale was used to rate the participants from 1 to 7 according to their degree of approval of the topic in three aspects. The first was “whether the information confirmation before the trip is useful”, and the average score of the participants was 5.65. Second, “whether seat reservation before travel will increase your willingness to travel”, with an average score of 6.43; The third was “how much you like the design of the bus stops”, with an average score of 5.13. From the subjective feedback of the elderly who participated in the survey, we can see that the elderly are quite willing to accept the design scheme based on empathy design research.

As a stable personality trait, trait empathy is difficult to change in a short period of time. It can be combined with the state of empathy under specific circumstances and stimulation conditions. Related research methods were used to guide the elderly design, and the research results showed that the design results brought very effective improvement for the elderly travel.

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Aging-People Accessibility to Urban Garden: A Case Study in Turin

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Abstract. Contemporary European society is characterized by the aging population and, simultaneously, by an increasing of the average retirement age, by the improvement in average health conditions, even in old age. Active elderly is a relatively new user in our society, to which the service offer must look carefully. In urban contexts characterized by high density and medium-small sized dwellings, green areas as parks, small urban gardens but also residual spaces, constitute an important resource as recreational and meeting spaces, especially for elderly users who live a state of isolation. The level of safety, maintenance, accessibility and availability of equipment in those green public spaces has an important influence on the average quality of urban life. The paper presents the case study of the city of Turin (Italy), in which the municipality is involved in a project to improve accessibility and services in the so-called "urban gardens".

Keywords: Active ageing · Outdoor spaces · Field surveys · User satisfaction

1 Introduction

The world's population is growing rapidly: in 2050, 21% of the population will be over 60, with a total of 2.4 billion elderly people, compared to today's total of 739 million. Italy is the European country with the third highest elderly population [1]. Extended life expectancy requires a general rethink and adaptation of "housing models", to meet the needs of the elderly and satisfy primary requirements such as physical and psychological wellbeing, social interaction, safety and accessibility. It is necessary to encourage active ageing, a term introduced by the World Health Organization [2], overcoming the concept of the elderly as reliant on a caregiver, increasing the possibility of leading an active life by means of a social, economic, physical and cultural contribution to society. At international level, the phenomenon of active ageing has been studied extensively, focusing attention not only on domestic private spaces but also on the role of the city and of open spaces in terms of mobility and safety [3]. Some studies in particular have identified the main characteristics that a city has to have to be age-friendly in order to adequately support the elderly population [4]. In addition to easy access to mobility, examples of these characteristics include the presence of

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 327–334, 2020.
https://doi.org/10.1007/978-3-030-50838-8_45

furnished rest areas in open spaces and the possibility to participate more and more actively in social activities in the cities [5]. Consequently, attention towards the design of age-friendly cities is the challenge facing us for decades to come: the design of an inclusive city, capable of hosting people of all ages.

2 Materials and Methods

Outdoor spaces fit for active ageing is part of a cultural and operational contribution within the scope of international studies related to the design of age-friendly outdoor spaces. The aim of the research is to develop tools to support the design of particular kinds of green area: urban gardens, which are smaller than urban parks and can be reached on foot in just a few minutes and used every day by the elderly population. A checklist has been developed for use in a survey on the subject of urban gardens, aimed at:

- measuring the main physical, environmental characteristics that play a role in determining usability, particularly by the elderly;
- critically assessing the general conditions of accessibility, highlighting strengths, weakness, problems and opportunities, in relation to the development of a plan for improvement.

Thanks to a partnership with the Green Areas Department of Torino three case studies have been selected to provide a basis on which to build test instruments for application to the city's urban gardens. Research phases can be summarized as:

- selection of Turin urban gardens as study areas;
- development of direct surveys (checklists and interviews) and indirect surveys (based on international scientific literature on active ageing);
- assessment of the results of direct and indirect surveys to identify the weaknesses of the study areas and the needs of elderly users;
- definition of guidelines for design and related intervention strategies.

Generally-speaking, the method refers to the need-performance approach which, based on the characteristics of users and the activities they perform in the urban gardens, leads to the expression of their needs and consequently to the definition of design guidelines.

This paper intends to present part of the ongoing research with reference to one of the direct survey tools, the checklist to measure the characteristics of the area. The methodological reference of the checklist consists of tools developed at European level, adapting them to the local situations (environmental, economic and social aspects). This allows whoever has been appointed by the public administration to measure the qualitative and quantitative data, as described later.

3 The Case Study of Turin

In agreement with the Green Areas Department of Comune di Torino, some urban gardens have been selected to provide a basis on which to apply and test the research instruments. Starting with the classification of green areas within the Municipality (urban parks, river parks, hill parks, gardens), the decision was made to focus attention particularly on urban gardens, considered as green “inserts” at neighborhood level. These areas are already equipped with play areas for children of different ages or a scheduled to be refurbished with play areas in forthcoming projects. The aim is to create an integration among users, with a view to inclusion, encouraging age-friendly use. The urban garden selected also share the same type of urban context (residential neighborhoods), each the size of a single block, with green areas (trees and grass) and seating (Fig. 1). They are all characterized by the presence of shops and represent as “green” resource within the neighborhood of pertinence, for the residents, who have no other easily reachable green areas. It is interesting to note the percentage of elderly residents in the areas subject to study: in District 3, there are 32,754 elderly residents, accounting for 26% of the resident population, in District 4, there are 23,834 elderly inhabitants, accounting for 25% of the total, and this is a trend that is destined to increase in the next few years.

Fig. 1. Urban gardens chosen (from left: P. Benefica, P. Peyron, P. Risorgimento).

Urban garden 1: Piazza Benefica. Situated in the Cit Turin area, District 3, the residential neighborhood of Piazza Benefica (Giardino Luigi Martini) occupies a surface area of 9,987 m^2, and comprises Via Susa, Via Palmieri, Via Duchessa Jolanda and Via Principi D’Acaja. The area is characterized by the market, which is held in the roadway and in part of the streets that cross the square, until 4.00 p.m. The Municipal Council has plans to refurbish the square and create a play area for children, implementing an interactive design process.

Urban garden 2: Giardino di Piazza Peyron. Situated in the San Donato neighbourhood, District 4, the square occupies a surface area of 9,791 m^2, 3900 m^2 of which are covered by a green area. It is surrounded entirely by roads open to traffic and parking places. There is a play area at one end of the square and this is fenced off. The rest of the space is characterized by trees and small patches of grass.

Urban garden 3: Giardino di Piazza Risorgimento. Piazza Risorgimento, located in the San Donato neighborhood, District 4, occupies a surface area of 12,377 m^2 with a green area of 5000 m^2. The play area is fenced off and positioned at one end of the square. The area is equipped with furnishings to encourage socializing and there is a bowls ground and a kiosk. The square is surrounded by roads that are open to traffic and by parking spaces, with little vegetation or other natural elements.

4 On Site Surveys

Direct observation is a highly effective technique to investigate the “real” use of outdoor spaces by specific users, to understand any problems they may have and consequently identify strategies for intervention. As far as the analysis of age-friendly outdoor urban spaces are concerned, the aim of the research is to identify some survey tools developed and tested in other international contexts, to ensure their applicability inn Turin. Two significant examples of checklist have been selected from the analysis of international scientific literature on the relationship between the needs of the elderly and the design of outdoor spaces. The *Checklist of Essential Features of Age-friendly Cities* is based on the results of a WHO project entitled Global Age-Friendly Cities [6], a tool for the self-assessment of a city. The assessment of outdoor spaces represents a specific category of assessment, which comprises the other aspects linked to transport, housing, social inclusion and participation, occupation, etc. This checklist is structured in consideration of qualitative parameters, focusing on elderly users and their needs. Another interesting survey tool for the assessment of parks has been developed by a work team called Age Friendly London Network - Outdoor Spaces & Buildings - in collaboration with the students of the Western University: *Age Friendly Parks Checklist* [7]. This tool, adapted and altered in relation to the results of research carried out in the city of Philadelphia [8], aims to assess the content of services and the characteristics of the paths, accessibility and the safety of parks in London (Ontario), in order to be able to formulate recommendations and guidelines to make green areas age-friendly. This tool identifies pedestrian paths, seating, toilets, signposts and access to the area, also from a quantitative point of view, as essential aspects on which to intervene to improve the inclusion of the elderly. These tools have been applied to the analysis of three case studios, accompanied by direct, unstructured surveys, which have led to interesting observations specific to the reference context. The surveys were carried out on different days of the week, with two inspections a day (10.00–12.00 and then 3.00–5.00 p.m.). In addition to the completion of the checklist, a photographic survey of the area was carried out along with an assessment of the percentage of users present (children, adults and the elderly), a series of qualitative and quantitative observations which have helped with the understanding of the three case studies and with the construction of the new checklist.

5 USUAAL: A Checklist for Urban Gardens

Beginning with the international experiences analyzed, the research team developed a specific checklist for the urban gardens of the City of Turin: USUAAL (Upgrade Social and Untemporal Activities for ALl ages). The following additional conditions were defined in the construction of the checklist:

- the subject to which it is addressed is the city administration, to gain a picture of the conditions of maintenance and use of the city's green areas (specifically urban gardens) to plan a strategy of intervention;
- after an inspection, the checklist is filled in by an "expert" with specific knowledge of the built-up environment, the town planning arrangements, outdoor comfort, the elimination of architectural barriers and urban safety. The profile corresponds to that of a Bachelor of Architecture, capable not only of "measuring" data, but also of interpreting them for specific purposes;
- maintenance of outdoor spaces and, in our case, of urban gardens, and their conservation in optimum conditions can be guaranteed only through use and the feeling, on the part of users, that they belong, which is why the critical assessment by the person filling in the checklist of the satisfaction of user needs and of the unexpressed potential in the use of spaces is essential;
- attention to "elderly" users is essential and falls within the principles of accessibility and inclusion for all.
- the main data and information, measured objectively, along with certain assessments, expressed on scales of satisfaction, are indicated for each section into which the checklist proposal is divided, and this required critical interpretation by the person filling in the checklist.

The checklist proposal presents a "scalar" arrangement spanning from the relationship between the garden and the city to the registration of the individual furnishing items. The structure is divided in four main section: general information, relation with the city, boundaries and urban accessibility, urban garden. The first section concerns information on the inspection and the data of the person filling in the checklist.

For the correct interpretation of the subsequent parts, it is necessary to register the conditions that can most influence user behavior: day of the year, time of day, climatic conditions. If we assume the implementation of the checklist, we can imagine repeating the inspection on different days and at different times, highlighting the fact that determined records – belonging to the subsequent sections – can change in relation to objective variables. The tests on the case studies chosen showed how the scenarios can change radically, not only on the basis of the seasons, but also of time bands, on the basis of the time profiles of other organizations within the neighborhood, such as schools and nursery schools. The next section analyses the urban scale in the section entitled *Relationship with the city*. In addition to general information such as the dimensions of the area, it is necessary to take into consideration the characteristics of the built-up area around it: its central or outlying position, the main destinations within the neighborhood, the presence of specific functions and the relative scale of influence (such as nursery schools at very local level and primary and secondary schools with bigger catchment areas), the demographic breakdown of users into age groups and income brackets, the proximity of other urban gardens or other green areas to establish the potential user catchment area. This section, for example, can highlight both the presence of the market in Piazza Benefica, which has a considerable influence on the times at which the urban garden can be used, but also the presence of the underground air-raid shelter under Piazza Risorgimento. This shelter does not influence the ordinary activities of the square but is a well-known site of urban interest capable of attracting a certain number of visitors to its occasional openings. The *Boundaries and urban accessibility* section looks exclusively at the urban garden and the permeability of its boundary. The aim is to measure the physical accessibility of the accesses, starting with the secondary roads and pedestrian crossings, and the system of cycle paths, the modal interchange points of the transport system (bus stops, carparks with electric car sharing charge points, bike-sharing stations, simple bike racks). The survey of the businesses that overlook the perimeter of the area and which can somehow influence the use of the public space, such as cafés with pavement seating and tables and ice-cream parlours, which, in determined conditions, can catalyse a large number of users and establish a synergistic relationship with the presence of the urban garden, is of particular interest. The last section, Urban garden, focuses on what happens inside the garden, taking into consideration users, equipment and furniture, the green system and the activities performed thanks to the effective interaction between the two. With reference to the first point, it is necessary to record the number of users that belong to different categories, possibly building up a timing profile for each one (reiterating the inspections and calculations. The categories can be built up taking into consideration variables such as age (children, adults, the elderly), gender, reason for visiting the urban garden (relaxation, playing, sport, activities with pets, but also as a living space for the homeless or activities such as drug dealing and prostitution), and disability. In some cases, it is possible to identify specific groups in addition to ordinary users. These recognized groups can be the students of a school or association and can be more or less organized. Pets who make use of the garden are to be considered to all intents and purposes as "users" who generate specific needs, such as the presence of enclosed areas or of equipment for cleaning. While elderly users have greater needs in terms of accessibility and utilisation this is also the group that is best able to integrate with other groups, such as children, also providing active surveillance. The survey of the facilities present then follows. These can be small buildings (kiosks, newsagents-stands, public toilets, other small buildings with specific functions - such as the entrance to the aforementioned air-raid shelter or furnishing elements. The latter can be classified, for our case study but also for others too, partly in compliance with the Manuale d'Arredo Urbano della Città di Torino (the Urban Furnishings Handbook of the City of Turin), in which the elements are registered and divided into functional groups: waste collection, traffic bollards, communication systems, transport network facilities, the elements of technology networks, seating, drinking fountains, items such as flower pots and rising gardens, public street lighting and other things (for protective grids around trees to clocks, public weighbridges, letterboxes); safety devices (such as SOS points and defibrillators). A specific system must be reserved for paving, to be described and classified on the basis of specific functions (such as playgrounds) and water permeability. Green systems are essential and are the most attractive feature of urban gardens and they can be classified into trees, grassy areas, flowerbeds, flowerpots, rising gardens and vertical gardens. The section dedicated to activities requires a capacity for synthesis and critical assessment of the levels of user satisfaction and problems on the part of the person filling in the checklist. Here is where all the elements necessary for the subsequent development of a need-performance study are recorded, listing the needs of every homogenous group of users, expressing them in terms of needs and associating the performances supplied by the elements included in the equipment and furniture section. The general perceptive aspects related to the urban garden (attractive, welcoming, unsafe, degraded, abandoned, …) fall within this section, as do those linked with microclimatic comfort (the control of solar radiation, shelter from atmospheric agents, …) and with the integration of occasional functions. In our case studies, we observed numerous conditions of discomfort due, for example, to choices of position of the functions or a lack of attention to integration between urban furnishing components. All the activities carried out in urban gardens are of interest in this section, from the most common to those that are more innovative and experimental, for which it is appropriate to assess the effectiveness and continuity in time.

6 Outlook and Conclusions

The results of the surveys carried out show the centrality of urban gardens in neighborhood social life and are an important outdoor space in densely built up areas. However, their design does not always take into account the complex framework of user needs, particularly those of the elderly. The tests of the checklists chosen at international level on the case studies and the elaboration of the new checklist proposal, have revealed certain general observations:

- some gardens present a wide variety of facilities but they are poorly integrated with one another. An example is the fragmentation of enclosed functional spaces in Piazza Risorgimento to which access is poor, or the lack of integration between urban furnishings, with interference between the elements of technological networks and seating;
- some urban gardens present unexpressed potential: they are used but often fail to adequately meet the needs of users, who are increasingly sensitive to the possibility to perform sports or recreational activities outdoors;
- the elderly are a constant presence, spending greater time in urban gardens and, consequently, there is greater potential for their involvement in the surveillance, care and "keeping" of these gardens and greater attention to the satisfying of their needs;
- the checklist is an essential tool to reveal problems and in preparation for a strategic plan for the enhancement of urban gardens, with the involvement of users.

The aim of the paper is to identify the unexpressed potential and implement aware and effective planning for accessible and inclusive outdoor spaces, in response to a specific interest by the municipality. Regardless of the specific case studies, the tools identified and the method adopted can be extended beyond the local scale. Appropriate integrations and adaptations of the checklist allow its use on a broader scale and in different contexts.

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Research on the Design of Medical Self-service Terminal for the Elderly

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Abstract. As an effective tool to alleviate the phenomenon of hospital queuing, the medical self-service terminal is used by the majority of hospitals. Due to the decline of physical function and learning ability, the elderly people have the psychological exclusion of new technology, and generally have difficulties in the use of medical self-service terminals. To raise the utilization rate of medical self-service terminals among elderly patients, this study analyzed the obstacles of elderly people using medical self-service terminals through field observation of elderly people's operation behaviors in different hospitals. This paper discusses the design of the medical self-service terminal for the elderly from four aspects: humanized design of hardware, interface visibility, operation process, and operation feedback. This paper proposes an improved method to make the operation process of medical self-service terminal more convenient, ameliorate the fault tolerance rate, and make the interface conform to the cognitive characteristics of the elderly. At the same time, humanistic care should be added to meet the emotional needs of the elderly. The research results can ameliorate the design of the medical self-service terminal, raise the utilization rate of the elderly so that the elderly can also enjoy the convenience of self-service.

Keywords: Medical self-service · Terminal · Design for the elderly · Operation process · Interface design

1 Introduction

With the increase in the number of elderly patients in hospitals, a large number of elderly patients are stranded in hospitals because they are waiting for registration, treatment, and payment, resulting in dense staffing in outpatient halls, waiting for areas and other medical places. The phenomenon of "three long and one short" (Long waiting time, long queuing time and short medical treatment time) in hospitals is widespread in China [1]. As an effective tool to alleviate the phenomenon of hospital queuing, the medical self-service terminal is used by the majority of hospitals. Medical self-service terminals can provide self-service registration, self-service payment, self-service inquiry, self-service receipt, and other functions, reduce the queuing of patients

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 335–349, 2020.
https://doi.org/10.1007/978-3-030-50838-8_46

in the process of medical treatment, minimize the process and time to see a doctor and provide better quality and convenient services for patients [2].

However, the users of medical self-service terminals are often positioned as people with higher knowledge levels and Internet skills. The elderly have low contact with intelligent products and physical function decline. There are many obstacles in the operation of self-service terminals, such as being unable to see legibly, not familiar with the operation process, not clicking the buttons on the screen, etc. The elderly often can't complete the whole operation process independently, and there is a certain psychological rejection of the new technology. Many elderly people prefer to queue for hours for staff service rather than use the medical self-service terminal. The existing medical self-service terminal cannot satisfy the operation and emotional needs of the elderly. To raise its utilization rate in the elderly, we need to optimize it for elderly people.

This study selected three first-class public hospitals in Shanghai, namely Huashan Hospital affiliated to Fudan University, Shanghai Sixth People's Hospital affiliated to Shanghai Jiao Tong University, and Zhongshan Hospital affiliated to Fudan University. Starting from the actual operation of the aging, this study focuses on the registration link and analyzes the problems when using self-service terminals. On four aspects of hardware design, interface visibility, operation process, and operational feedback, this paper discuss the design strategy for the elderly people of medical self-service terminals. The improved method proposed in this paper is conducive to the operation process of the medical self-service terminal to be simpler, the fault tolerance rate to be raised, the interface to meet the cognitive characteristics of the elderly, and the appropriate addition of humanistic care to meet the emotional needs of the elderly. The research results can ameliorate the design of the medical self-service terminal, raise the utilization rate of the elderly so that the elderly can as well enjoy the convenience of self-service.

2 Research Background and Literature Review

According to the prediction of Analysis of China's Population Aging Development (2019), China's population aging will accompany the whole first half of the 21st century [3]. From 2010 to 2050, China is in the stage of rapid aging, with a high level of aging and a rapid growth rate of the elderly population, whose proportion of the total population is on the rise. With the increase of age and the increase in chronic diseases, the illness of the elderly has become a problem for many families. Many elderly people are physically inconvenient and lack of relevant medical knowledge. In the process of seeing a doctor in a hospital, they often need to be accompanied by their children, which increases the burden of seeing a doctor. Given the complexity of the hospital's medical process and a large number of people queuing up, the major hospitals have introduced medical self-service terminals to facilitate patients' medical treatment. However, for the elderly who have low contact with intelligent products and lack of relevant knowledge, the utilization rate of these self-service terminals has not reached the expected value, and the elderly are more willing to achieve the goal through staff services. At present, the commonality of the medical self-service terminal is not enough, and it has not become the main tool for the elderly to registration and payment.

In the research of therapeutic products for the elderly and web page design for the elderly, the established literature has been dedicated to exploring how to design medical products for the elderly and web pages for the elderly from the perspective of psychology and physiology. Based on digging out the perceptual factors of the elderly population, Yang Jingjing (2019) penetrated the perceptual factors into the design of the medical products for the elderly, making the products better serve the elderly population while being widely accepted [4]. Xu Xiaoxia et al. (2017) based on the concept of emotional experience design, analyzed the elderly's emotional experience design needs in-home medical products and adopted corresponding design strategies to explore the design path of the elderly home medical products [5]. Li Yongfeng et al. (2015) proposed an emotive design method for the elderly from three levels of emotionalization so that the elderly can get a better emotional experience in the process of using the website [6]. According to the physiological characteristics of the elderly, such as sight distance and retina, Yang Zhi (2012) made suggestions on the size, color, and layout of the elderly [7]. Zhang Ming (2012) proposed and analyzed three obstacles in the use of medical products by the elderly: motor dysfunction, perceptual dysfunction, cognitive dysfunction, and summarized the gap in product design opportunities for the elderly [8]. Li Wei et al. (2013) analyzed the degradation characteristics of cognitive ability such as perception, memory, thinking ability of the elderly, and proposed accessibility design methods for the website [9]. Bruder et al. (2014) proposed an adaptive training interface to guide the elderly to improve the usability of the first-time user interface [10]. Kuo et al. (2012) conducted a behavioral analysis on shopping websites for the elderly, and used SIDS (Supporting Interface Design System) to test the behavioral performance of the elderly when using the website, and found that the system greatly reduced the time for the elderly to purchase items, while also reducing their psychological load [11].

In the research of medical self-service terminals, scholars have proposed solutions to optimize medical self-service terminals from the perspectives of interaction design and service design. Yu Feifei (2014) discussed the design method of the self-service registration device user interface of general hospitals and concluded that the design of the user-oriented self-service registration interface can meet the self-service registration needs of the elderly [12]. To ameliorate the utilization rate of self-service payment terminals among people with disabilities, Xu Xiaohan (2019) proposed that from the perspective of universal ease of use, it can be enhanced from three aspects: hardware, software, and guidance and promotion [13]. Based on in-depth analysis of the "human-machine-environment" system of medical self-service terminals, Xu Fengqin (2011) analyzed the dimensions, functions, overall layout, and interaction methods of medical self-service terminals based on the design content of the human-machine theory to study self-service. The interface design of the service terminal in the medical system environment forms a set of medical self-service terminal interface design patterns [14]. To ensure the rationality of the usability design of the interactive interface, Li Xiaoying (2018) constructed an evaluation model based on eye-tracking and usability questionnaire to improve the design of the interactive interface of the self-service registration machine in a hospital [15]. Based on the analysis of the operation log of the medical self-service terminal system, David et al. studied the information search behavior of users on the self-service terminal interface and established the evaluation index of the touch screen self-service terminal interface according to the analysis results of the system operation log of 70 medical self-service terminals in the UK. And this paper classifies users according to their interaction patterns and proposes a self-service terminal interface evaluation method [16]. Jennifer et al. analyzed the tasks of users under 38 years old to understand the obstacles that users may encounter in the process of utilizing, which led to users' rejection of self-service terminals [17]. The study found that there are three main reasons why users do not use self-service terminals: self-service terminals do not have a friendly feeling of manual service. They doubt their operational capabilities, and they lack a sense of security. The research objective of this article is young users. Elderly people are more insecure about self-service terminals than young people. Simeon used the elderly as a research object and applied the universal design method, pointing out the obstacles for the elderly in using the self-service terminal [18].

3 Field Survey Analysis

In this study, three top tertiary hospitals in Shanghai were selected as survey objects: Huashan Hospital affiliated to Fudan University, Shanghai Sixth People's Hospital affiliated to Shanghai Jiaotong University, and Zhongshan Hospital affiliated to Fudan University. All three hospitals are large-scale public first-class comprehensive hospitals, with a wide range of departments, patients of all ages, and similar general conditions. In addition, the staff is arranged to assist in the use of self-service terminals for comparative study. A total of 150 elderly patients were actually recorded in this survey, of which 46 were from Huashan Hospital, with male and female ratios of 52% and 48%; there were 50 people from the Sixth People's Hospital, with male and female ratios of 54% and 46%; and 54 from Huashan Hospital, with male and female ratios of 45% and 55%. The focus of this study is placed on the use of self-service registration by patients using medical self-service terminals. Through field surveys, it has been observed that the average registration time of elderly people using self-service terminals varies greatly (Fig. 1). Shanghai Sixth People's Hospital has the shortest average registration time, of which the average registration time for elderly patients who have been booked is 39.4 s, and that patients who have not booked is 48 s. Secondly, the average registered duration of elderly patients who have been booked in Zhongshan Hospital is 46.1 s, and those who have not booked are 64.7 s. Huashan Hospital takes the longest time. The average registration time for elderly patients who have made an appointment is 50.8 s, and 72 s for patients who have not made an appointment.

Aiming at the operation of medical self-service terminals in three hospitals, this study makes a comparative analysis from four aspects:

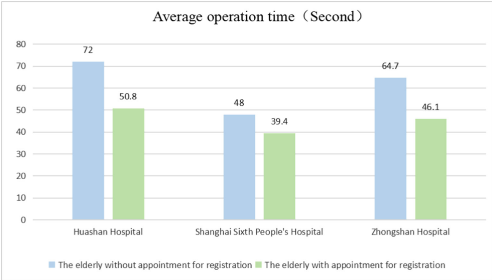

Fig. 1. Comparison of the average length of registration of the three hospitals

3.1 Registration Process

According to the research of Schaie [19], with the gradual increase of age, the reasoning ability of the elderly weakens, and the energy required in reasoning is more than that of the young, and it takes longer to think about the impact and consequences of the same thing. In terms of operational behavior, the cognitive ability of elderly users has

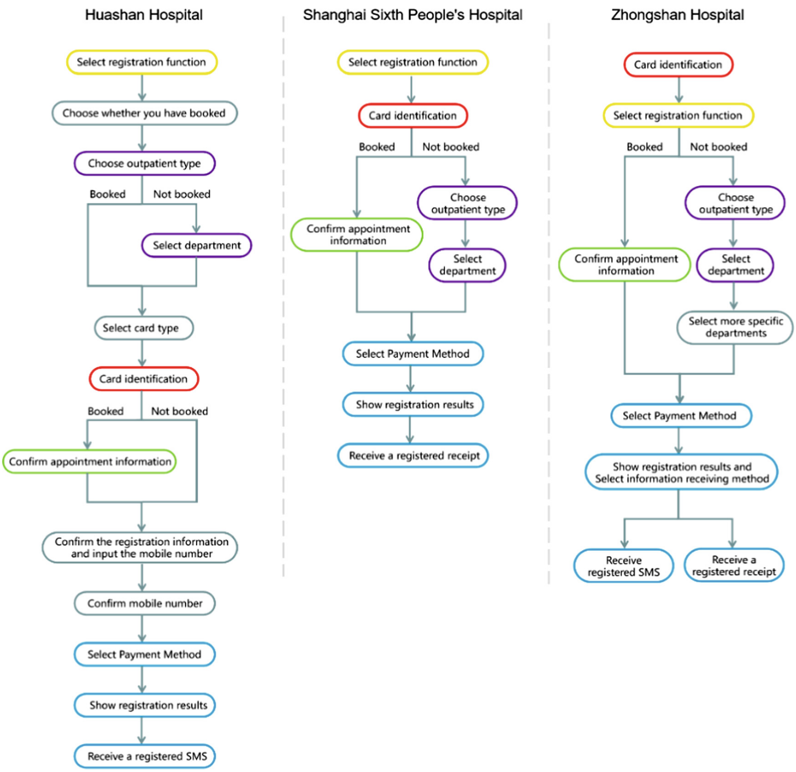

Fig. 2. Registered flowchart of three hospitals

decreased significantly, and the level of information reception, processing, and memory and thinking is far lower than that of young people. As a tool for quickly fulfilling user registration requirements, medical self-service terminals need simple and obvious operating procedures to adapt to the cognitive abilities of the elderly, so that tasks can be completed more smoothly and quickly. In this study, by comparing the operating steps of the elderly using different medical self-service terminals, it is found that there is a large difference in the registration process (Fig. 2) (Table 1).

Table 1. Comparison of registering processes.

Hospital name	Huashan Hospital	Shanghai Sixth People's Hospital	Zhongshan Hospital
Number of steps required for a successful operation	12 steps	7 steps	8 steps
Number of steps to be selected	6 steps	4 steps	5 steps
Number of steps to be confirmed	4 steps	1 steps	1 steps
Whether need to enter information manually	Enter mobile number manually	N/A	N/A
Card identification position in the operation process	Step 6	Step 2	Step 1
Operation duration	Longest	Shortest	Secondary

In summary (Fig. 2, Table 2), the registration process of the Shanghai Sixth People's Hospital is the most concise, without the need for the elderly to make too many choices and confirmations, and the operation task is simpler. The card identification process is in front of the overall process, which is convenient to remind the elderly who do not carry the medical card to handle it in time. The registration process of Huashan Hospital is the most complicated, which requires the elderly to select and confirm the information for numerous times. The location of the card identification process is behind, and it cannot be distinguished according to the reception card information in the initial stage of operation, which does not bring the corresponding convenience to the patients who have already made an appointment.

3.2 Card Identification Operation

The registration operation requires the elderly to perform card insertion verification according to the interface prompts, and complete the system's information extraction for users. There are two types of medical card: chip card and magnetic stripe card. Medical self-service terminals usually install two kinds of card readers. The elderly need to select the right card reader according to the interface prompt information and the card type to identify. Legible information and simple steps can help the elderly quickly understand and respond. In the face of card identification, the elderly often encounter problems such as disordered card slot location, unclear card inserting method, unclear information, which lead to blocking operation (Fig. 3).

Table 2. Comparison of card identification operations.

Hospital name	Huashan Hospital	Shanghai Sixth People's Hospital	Zhongshan Hospital
Whether the information prompt is obvious	N/A. Click the medical card type to pop up the corresponding prompt message	YES	YES
Information prompt mode	Text	Text and video	Text and video
Whether need to click the interface button	YES	Magnetic stripe cards do not need to be clicked, chip cards need to click the "read medical insurance card" button	N/A

Huashan Hospital Shanghai Sixth People's Hospital Zhongshan Hospital

Fig. 3. Card identification interface

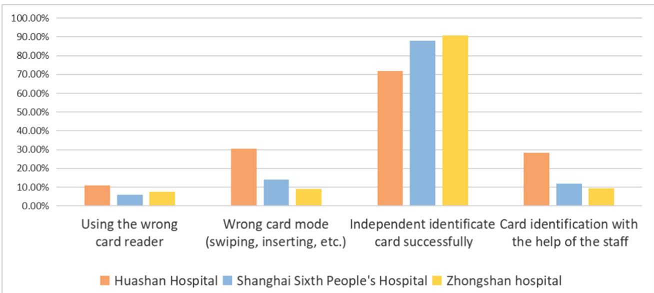

Fig. 4. Statistics of patients' card identification operation and frequency in three hospitals

To sum up (Fig. 4, Fig. 5, Table 2), Zhongshan Hospital has the most convenient operation of self-service terminals with the lowest error rate, followed by Shanghai Sixth People's Hospital.

Huashan Hospital Shanghai Sixth People's Hospital Zhongshan Hospital

Fig. 5. Function selection interfaces

3.3 Interface Design

Interface design is a complex project involving different disciplines such as cognitive psychology, design, and linguistics. The interface of a medical self-service terminal needs to quickly and directly convey information so that the elderly can use it efficiently. Owing to the decrease of photoreceptor cells and retinal degradation, the ability to discriminate and analyze colors is reduced, and the decline in perception ability also affects the recognition accuracy of interface graphics and text. Therefore, the elderly have higher requirements for interface design. The existing medical self-service terminal interface has problems such as messy color, too much information, and small fonts for the elderly.

The following is an analysis for the function selection interface and department selection interface of the medical self-service terminal for the aging.

Huashan Hospital Shanghai Sixth People's Hospital Zhongshan Hospital

Fig. 6. Department selection interface

3.4 Comparative Analysis of Function Selection Interface

To sum up (Fig. 6, Table 3), Zhongshan Hospital's function selection interface design is simple and obvious, without using too many elements to cause visual disorder, with large size and strong guidance, which is most convenient for the elderly.

Table 3. Comparison of function selection interfaces

Hospital name	Huashan Hospital	Shanghai Sixth People's Hospital	Zhongshan Hospital
Design features of option buttons	Color modularity	Icon text combination	Icon text combination
Color features of option buttons	High saturation, small color difference, strong contrast with the background	High saturation, complex colors and weak contrast with the background	Low saturation, strong contrast with background
Registration button's location	In the upper right corner of functional area	In the upper left corner of the functional area	At the top of the ribbon
Existing problems	Small size of registration button difficult to find	The meaning of the icon is unclear, which is too complicated visually	The meaning of the icon is unclear

3.5 Comparison of Department Selection Interface Design

There is a major amount of information in the Department selection interface, and there are some problems such as confusion of departmental classification and department names are too professional. Too much text information majors and page options will lead to obstacles when the elderly search for the target. Clicking the page-turning button many times to search will test their eyesight and increase their memory burden. In the actual investigation, it is found that not only the elderly but also the young users are confused about the professional name of the department. They may hang up the wrong department because they fail to understand the disease, so they need help from the medical director (Table 4).

Table 4. Comparison of department selection interface design

Hospital name	Huashan Hospital	Shanghai Sixth People's Hospital	Zhongshan Hospital
Department layout	Grid layout	Grid layout	Grid layout
Page turning method	Press the button or slide	Press the button	Press the button
Color characteristics	Black characters on white background Low saturation	Blue words on white background High saturation	Green characters on light green background Low saturation
Department search method	Page search	Page search	Page search and keyword search

Zhongshan Hospital Department selection interface design is the most simple and uncomplicated to identify, the font size is large and the color is beautiful and elegant. Nevertheless, after the selection, patients are obliged to make a secondary selection from more professional and specific department categories, which are easy to burden the judgment of the elderly.

3.6 Registration Voucher

Zhongshan Hospital self-service terminal can choose the way to receive vouchers independently, which is more convenient to patients. Huashan Hospital directly sends text messages to patients. This requires the elderly to input a mobile phone number and confirm it before the registration operation, which wastes time (Table 5).

Table 5. Comparison of registering vouchers

Hospital name	Huashan Hospital	Shanghai Sixth People's Hospital	Zhongshan Hospital
Registration voucher	SMS	A receipt	SMS/A receipt
Existing problems	Time-lag in SMS receiving Does not meet the operating habits of the elderly	Risk of loss	Need to choose how to receive information

4 The Strategy of Design for the Elderly

According to the above comparative analysis, the self-service terminals of the three hospitals have similar pain points in the process of going through four main steps (Fig. 7). In the function selection interface, there exists the problem that the icon of the registration function is not obvious and the font is too small to recognize; In the identification of the medical card, there are some problems such as the scattered position of the card slot, unclear card insertion method, and unclear information. In the process of department selection, there are some problems such as too professional medical vocabulary, too many department options and difficulty in the inquiry department; there are some problems in the process of receiving registration certificates, such as the disunity of information receiving mode and the delay of message receiving. Based on the above pain points, this study proposes appropriate aging design strategies for medical self-service terminals.

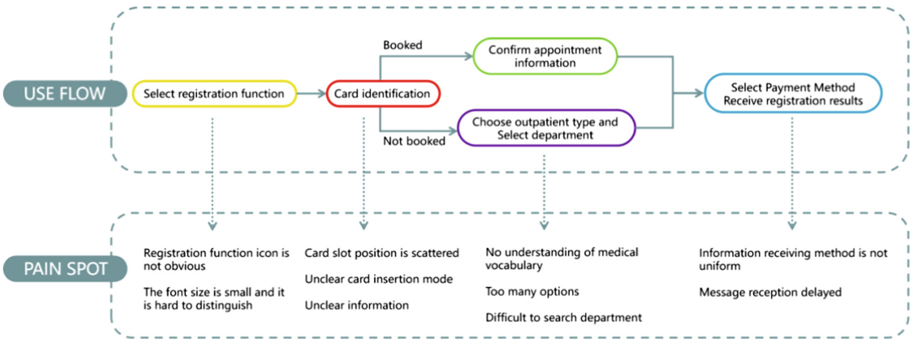

Fig. 7. Main steps and pain points of registration

4.1 Optimize Operation Process

There is still no uniform standard for self-service terminals in different hospitals, and the operation process is dissimilar. The elderly do not usually familiar with the operation process, so it is not difficult to give up registration after the operation is blocked. The optimization design of the operation process of the medical self-service terminal be supposed to meet the principles of rational and compact overall operation process, clear hierarchical relationship and simplified operation steps. Avoid making the elderly think too much, and let the elderly do the least and simplest operation to complete the task in the shortest time.

(1) In the function selection interface, the frequently-used option buttons ought to be set in a conspicuous position, and the uncommon operations should be placed back to create a reasonable hierarchy. Besides, reasonably deleted the function of low frequency. Lessen the interference of functional accumulation on the elderly, not just minimize the decision time of the elderly and improve the controllability of the operation. (2) Depending on the concept of "Intelligent Service", the automatic jump function is designed for the operating system. For example, the system judges whether an appointment has been made in identifying the patient's card information automatically jumps to the next step, simplifies the operation process by patient-centered. (3) The department selection interface has the most page information, and its design should be user-oriented, placing specialties such as gynecology, internal medicine, pediatrics and surgery in tiled positions, to facilitate the positioning and search of the elderly. (4) The progress bar can be added to the interface of the medical self-service terminal so that the patient can identify which steps are being taken and how many steps have been completed. This is particularly significant for the elderly with impaired memory, which upgrades the visibility of the operation and reduces the anxiety of the patient.

4.2 Universal Design of Hardware

The hardware of the medical self-service terminal needs more universal design to improve its usability so that the elderly can get a positive emotional experience during the operation and establish a good human-computer relationship.

(1) Reasonably optimize the human-machine scale of medical self-service terminals to lighten the burden on the elderly's body. The reasonable scale is supposed to meet the physical characteristics of the elderly, and improve the versatility of the device. (2) The medical self-service terminal requires the elderly to perform auxiliary operations on a series of physical devices, including numeric keyboards, card readers, barcode reading, receipt printing, and bill printing. Proper layout of tangible equipment can make the elderly more comfortable to use and reduce misuse. (3) Existing medical self-service terminals are often equipped with one or two card slots for diverse types of medical cards. Seniors need to select the corresponding card slot and perform the correct card insertion operation according to their card type to successfully identify the card. To lessen the burden and ameliorate the use efficiency, the medical self-service terminal can be installed with a card slot that can be adapted to different medical cards. The card slot should be installed in the place where the elderly can see and should be marked with a conspicuous sign for easy searching. (4) Field research found that the elderly often hold a variety of medical records and checklists when operating self-service terminals, occasionally resulting in the drop of medical cards or mobile phones. To solve this problem, the medical self-service terminal can also design a platform for the temporary storage of items to facilitate operation.

4.3 Improve Interface Visibility

Due to the decrease of perceptual ability and memory ability of the elderly, the top-down information guide is affected, so that they cannot quickly scan the page to filter information. [20] The medical self-service terminal needs to improve the visibility of interface information, make the interface more consistent with the elderly's cognition and reduce their memory load. The interface should be consistent, visible and color coordinated.

(1) The layout of the interface should be as simple and reasonable as possible so that the elderly can understand the functions of the self-service terminal at a glance. For more frequently used functions or buttons, they should occupy a larger size in the interface or use more saturated colors for rendering to make it easier to locate. (2) In the design of icons, metaphorical information should be correctly expressed and the icons should be avoided to be too abstract. Icons that have been generally accepted by the public can be referred to continue their general information. (3) It is preferable to choose a larger font size to meet the reading needs of the elderly while adapting to the overall page. (4) In terms of interface color, due to the visual sensitivity of the elderly and the attenuation of color resolution, it is recommended to use simple and lively colors as far as possible to reduce the use of low-contrast colors.

4.4 Specific and Quick Operation Feedback

Feedback refers to the response or instruction to the operation that the user has performed. It is a valued mechanism for users to recognize whether the operation is correct and effective [21]. Medical self-service terminals should give timely and specific feedback on the results of operations. Insufficient feedback will not only cause repeated operation problems but also increase the use of time and reduce the use efficiency of the terminal. Due to the perceived barriers of the elderly, it is impossible to judge how their operating behavior has affected the system. Although current medical self-service terminals have basic operation feedback and error feedback, they still need to be further improved.

(1) In terms of the content of the feedback, we should avoid only giving back the "error" information, instead of telling the elderly the error points and solutions. In the process of card identification, if the information reading fails, also to the failure information, the interface should be besides the correct operation prompt, to avoid repeated operations. (2) In the form of feedback, the feedback information such as text and icon should be legible. When the elderly encounter negative feedback and can't solve the problem by themselves, they can find the help-seeking method on the interface, or "call" the staff to help by ringing the bell and lighting the light. This will be help to build the confidence of the elderly in using. (3) The feedback time should be more rapid, and the registration certificate, as a sign of the end of the registration operation, should be delivered to the patient in time after the payment is successful. Owed to the time lag of message transmission, the self-service terminal should print the registration voucher and send the message to the patient at the same time, provide multiple information receiving methods. (4) The feedback system can be combined with "Intelligent Service", and the negative feedback can automatically jump to the correct step or page to guide the elderly to correct after displaying the error information.

5 Conclusion

Facing the increasingly serious aging phenomenon, designers pay more and more attention to the needs of the elderly, a special group. The elderly's demand for medical treatment is increasing, the large-scale comprehensive hospital's medical process is complex, the medical self-service terminal does not conform to the elderly users' cognition and use habits, and there are great difficulties in the elderly's operation process. The research focus of this topic is on how to improve the use of medical self-service terminals for the elderly. According to the physical and mental characteristics of the elderly, this paper found problems in the actual registration operation and made a comparative study. It is proposed that the medical self-service terminal should simplify the operation process, design the universal hardware, improve the visibility of the interface, and provide specific and timely operational feedback. The research results will help to improve the design of medical self-service terminals, improve the utilization rate of the elderly, and enable the elderly to enjoy the benefits of science and technology in the context of the rapid development of the Internet.

Acknowledgements. This paper was supported by the research project Systematic Construction of Comprehensive Medical Space under the Environmental Requirements of the Big Medical and Big Healthcare.

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Postural Analysis in Older Females from an Indigenous Community of Ecuador that Uses a Chumbi as Part of Their Traditional Outfit

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Abstract. In Ecuador, indigenous communities are a significant percentage of the population, mainly dedicated to agriculture. Observations show that elderly women of these communities suffer severe spine deformations associated with pain and instability, that could be related to the use of a traditional lumbar girdle called chumbi, their manual daily activities and/or to poor medical care. Forty women, that used chumbi since infancy, were photographed in the sagittal and frontal planes to perform a qualitative static postural analysis to assess back musculoskeletal alterations, shoulders position and their relationship with scapulae. The results show a high prevalence of hypertonicity in back muscles (80%), hypercifosis in more than 50%, scoliosis in 46% and more than 80% of rolled shoulders and winged scapulae. The musculoskeletal disorders found aim to a muscular imbalance, that could be associated to the frequency and magnitude of the carried loads, the lifting and mooring techniques and the use of the chumbi.

Keywords: Postural analysis · Indigenous women · Chumbi

1 Introduction

Musculoskeletal injuries have become one of the main factors causing pain and disability in industrial environments, mainly promoted by the inadequate postures and incorrect loads manipulation [1]. Body posture refers to the positioning of a person's body parts, different positions imply changing the relative position of body parts and are assigned different names (standing, sitting, kneeling). Tasks that require to assume and maintain any awkward posture can result in injuries, early fatigue, musculoskeletal disorders, among others. Several factors can cause poor body posture such as social environment, personality, occupation, postural habit, genetics, clothing, age, nutrition and physical activity [2].

Early, frequent and adequate postural evaluations can be a valuable tool to detect musculoskeletal alterations due to inappropriate postures [3], as maintaining an adequate posture contributes to a good health state and improves efficiency and

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 350–356, 2020.
https://doi.org/10.1007/978-3-030-50838-8_47

effectiveness in the developed tasks, since it generates functional harmony between the subject and his environment [4].

The postural evaluation can be static or dynamic, the first allows to establish structural asymmetries, the pelvic position and contracted or weakened musculature [4, 5].

Aging causes physical deterioration, gait and posture alterations; added to that, over time the human body loses some faculties such as joints mobility, which causes a deterioration of the bipedal position. In elderly people, the most common musculoskeletal disorders manifest in the spine (scoliosis, lordosis, dorsal kyphosis), the severity of these deformations depends on several factors, among which stands out the lifestyle. Other common ailments, of the musculoskeletal system in old age, are the decrease in height, displacement of the gravity center, decrease of the distance between the shoulders [6], bone mass deterioration, muscle aging and stiffness of ligaments and tendons [7].

Studies show that patients with spine deformations in the sagittal plane develop compensatory responses that improve their alignment while standing; if the deformation is located in the trunk, the compensations are reflected in the adjacent areas, including changes in the lower extremities and pelvic retroversion, which is considered to be the most common compensation mechanisms among elderly [8].

This study presents a static qualitative postural analysis to 40 indigenous women, that have used since infancy a traditional lumbar girdle, in order to establish the magnitude and prevalence of musculoskeletal disorders in their back.

2 Materials and Methods

The sample consists of 40 indigenous women between 58 and 87 years old, that uses a lumbar girdle called chumbi as part of their typical outfit. The women were randomly selected from the elderly group who is attended by the Ministry of Economic and Social Inclusion - zone 3 in the highland's communities of Quisapincha in the province of Tungurahua, Ecuador. Women were excluded from the sample if they presented any of the following conditions: an illness related to the neuromuscular system, a traumatic and/or respiratory pathology, or if they were unable to undress and dress for themselves. The indigenous women were notified about the project using a consent form endorsed by the bioethics committee of the Technical University of Ambato, the form was in Spanish and translated to Kichwa which is the mother language of the participants.

The postural assessment was carried out using photos of the women in orthostatic posture, in rear corona and sagittal planes with the least amount of clothing possible (see Fig. 1) [9].

The postural evaluation is carried out by body segments: head, neck, shoulders, cervical, dorsal and lumbar spine and pelvis, to establish possible musculoskeletal alterations. The alterations assessed included: pelvis (aligned, lateral inclination,

(a) (b)

Fig. 1. Photos of an indigenous woman in orthostatic posture, (a) rear coronal plane, (b) sagittal plane for postural analysis.

anteversion, retroversion); scoliosis (severe, moderate, mild); scapula (aligned, winged); shoulder (aligned, imbalance, rounded); trunk (antepulsion, retropulsion, rectification, hyperkyphosis, hyperlordosis) and head (aligned, tilt, protraction) [10, 11]. The work of the muscle chains is also established, observing when they are in excessive tension. Additionally, a physiotherapeutic clinical history is taken from each woman, where all the basic anamnesis data is collected, including the number, length and thickness of the chumbis they wear.

The back painful areas were mapped, and the pain intensity was quantified using the Visual Analog Pain Scale (VAS), which is one of the most used to measure the pain level, among other reasons for its simplicity for the person who applies it and for the one who reports the pain. The pain VAS is completed by the respondent, who is asked to place a mark in the 10-cm line at the level that best represents their pain intensity. Then the score is determined as the distance in millimeters, on the 10-cm line, between the beginning of the line and the patient mark, scaling from 0–100. The result of the pain VAS application is reported in an 11-point numeric scale with 0 representing "no pain" and 10 meaning "worst pain imaginable" (Fig. 2) [12].

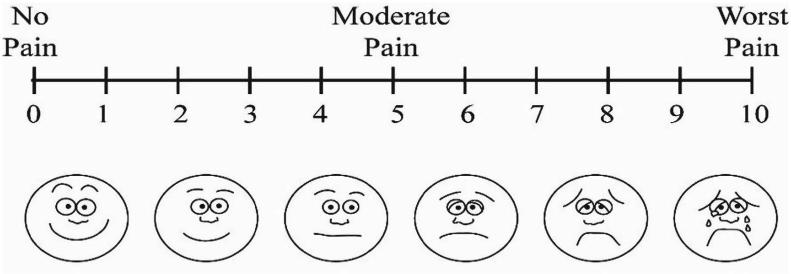

Fig. 2. Visual Analog Pain Scale. Correlation between Visual and verbal scale: 1–3 = mild pain; 4–6 = moderate pain; 7–10 = severe pain [13].

Fig. 3. Waist deformations in 3 women of Quisapincha, and the chumbis that each one was wearing on the day of their postural evaluation.

3 Results

One of the most relevant observations is the significant deformation of the women´s waist due to the prolonged and tight use of the chumbi, as well as a noticeable deterioration of the skin in this area (see Fig. 3). The average number of chumbis used is 2.1 with an average length and width of 5.23 m and 7.3 cm respectively. In the interviews, the women indicated that they increase the number of chumbis they use as the back pain worsen during their duties. Regarding the musculoskeletal alterations, scoliosis stands out, with 42.8% in the mild and moderate levels and 14.4% in the severe level; the rounded shoulders are present in 97.1% of the population, the winged scapula in the 77.5% and the right inclination of the pelvis in the 22.8%.

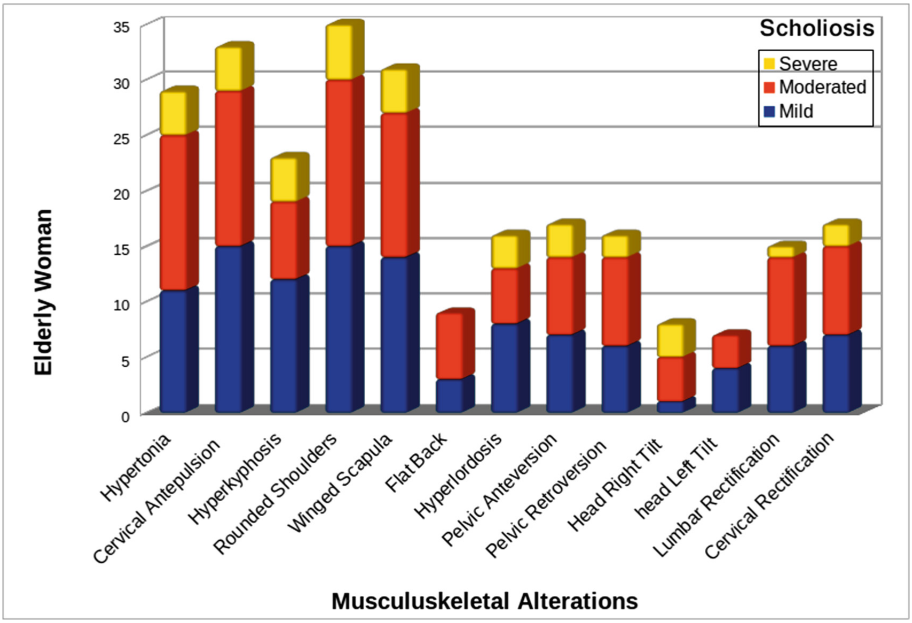

Fig. 4. Musculoskeletal alterations detected in the studied group, classified according to the scoliosis type.

The graph in Fig. 4 shows that among the women who present scoliosis in its three levels, the most frequent affections are in the upper trunk consisting of head, neck and rib cage up to the thoracoabdominal limit in the dorsal spinous apophysis in the twelfth vertebra, presenting rolled shoulders, cervical antepulsion, winged scapulae and a hypertonia of the upper body musculature. Although in older adults the deterioration of the spine is a common affection in the study group, they are more pronounced than in the general population [7, 8], which could be related to both the use of chumbi and the hard work that these women perform from an early age [14, 15].

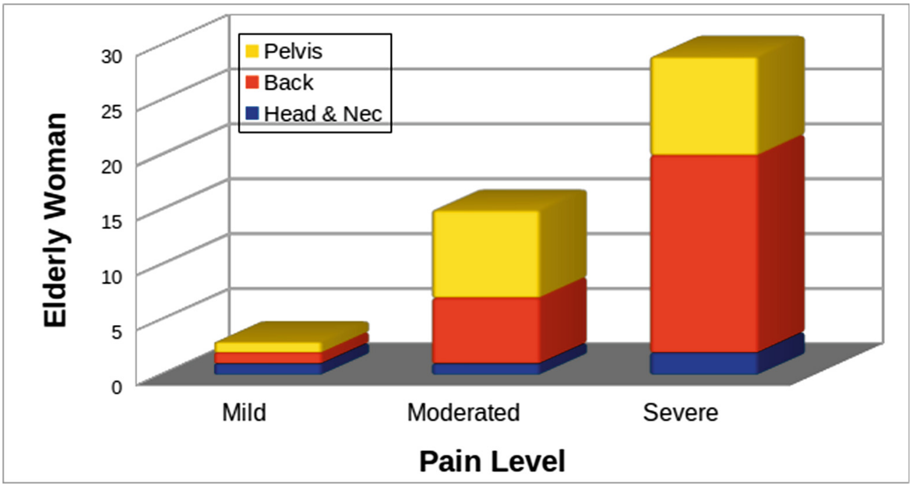

Fig. 5. Pain level using VAS in three parts of the body mid-section.

The graph in Fig. 5 shows that 62.5% of women have back pain and of these 72% have severe pain, which is consistent with the high incidence of musculoskeletal disorders of this part of the body. It can also be observed that 45% of the women report pain in the pelvis area and 94% of these have moderate to severe pain, this can because do to the compensatory processes of back deformations that impact on the position of the hip [10].

4 Conclusions

Although the use of chumbi as a lumbar girdle generates a certain degree of lumbar and pelvic stability and, as reported by the evaluated women, it lowers their lumbar pain, the fact that it is used permanently, and with variable covered areas and tightening could be the reason of the high prevalence of musculoskeletal disorders detected in this study. However, it should be considered that indigenous women carry out very demanding agricultural activities [15] which could also contribute significantly to the found alterations.

Therefore, it is suggested to continue with studies related to postural alterations and their possible relationship with the use of chumbi, as well as the evaluations of the indigenous women daily tasks in order to have the technical back ground that allows to propose interventions that are not culturally invasive and that protect their health.

Acknowledgments. This work is being funded by (1) Dirección de Investigación y Desarrollo (DIDE), of Universidad Técnica de Ambato under the project: "*Influence of the traditional use of chumbi in musculoskeletal disorders associated with the manipulation of loads in women of the Ecuadorian highlands*" and (2) Corporación Ecuatoriana para el Desarrollo de la Investigación y la Academia (CEDIA) under the project: CEPRA XIII-2019-14, *Llankak Warmikunata Kamachikkuna (Protec the working woman).*

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Research on the Interactive System of Long-Distance Relationship for Elderly Users

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Abstract. Long-distance family members can communicate with each other through communication media, the Internet and other media. Due to the constraints at elderly users physical, psychological and cognitive,which leads them to feel more difficulties in the using process. This research analyzes the advantages and disadvantages of current communication methods between family members in different places, as well as the characteristics and needs of elderly user groups. It focuses on changes in physical functions, cognitive differences, and psychological appeals of elderly users, and summarizes user needs analysis. Reasonable use technology, following the principles of safety, ease of use, and practicality, designing the long-distance relationship interactive system that base on the elderly user's interaction habits, helping the children in the long-distance families solve difficulties encountered by parents in life, and meeting the emotional needs of family members. Improve the communication satisfaction between modern long-distance families.

Keywords: Long-distance families · Elderly users · Interactive system

1 Research Background

The rapid development of science and technology and the wave of economic globalization have changed all aspects of human society. The uneven economic development between regions and the diversification of travel modes have led to greater international and inter-city population flows. Many families are facing the reality of separation. Emotional communication and communication methods are also changing [1]. At the same time, the advancement of medical technology and the improvement of living standards have gradually extended the life expectancy of individuals; changes in fertility concepts or economic conditions, the number of newborns has gradually decreased, and the size of families has continued to shrink. The birth of the family phenomenon. Under the limitation of time and space, the communication methods through mobile phones, the Internet and other media are the main communication methods for remote families at this stage. Although they can solve the daily communication problems, they have the disadvantages of lack of realism and high learning costs. Many factors such as changes in physiological conditions and cognitive differences have exacerbated the difficulties in the use process.

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 357–360, 2020.
https://doi.org/10.1007/978-3-030-50838-8_48

2 The Mode of Long-Distance Family Communication

Since the 1980s, the Internet has really entered the field of social life. By July 2019, according to the data released by the ITU (Internation Telecommunications Union), the number of Internet users worldwide has reached 3.9 billion, more than half of the global population for the first time. Internet services have brought a whole new social experience to modern life. The communication through telephone and Internet has become the link to maintain the relationship between these family members, in order to achieve the purpose of information transmission and emotional maintenance [2]. The main forms are as follows:

1. Text interaction (such as email, SMS, instant messaging chat software, etc.)
2. Voice calls (such as real-time voice communication through Lynch, etc.)
3. Video call (such as real-time audio and video communication via Skype, etc.)

These methods greatly increase the convenience and timeliness of communication, and with the progress and popularization of science and technology, the cost of consumption is gradually reduced, providing great convenience for communication and getting along among members of dispersed families in different places [3]. But there are also some problems and defects, such as text messages to understand the cost on the high side, the sense of reality in the process of communication is not strong, not face to face communication for a long time easily fatigue problems. This study to provide 60 questionnaires, participate in the research of users aged between 60 to 70, including 39 men, 21 women, which owns more than two years experience in smartphone use, recycling 49 valid questionnaire responses received after research, in the sample survey, 76% of older users said in the process of intelligent equipment and intelligent applications use met difficulties.

3 Characteristics and Needs of Elderly User Groups

Jonathan Cagan of Carnegie Mellon university has made it clear that ageing is a key area to explore and focus on in the future, and that the 21st century will provide plenty of products for people aged 50–100. For this special group, this paper will discuss the physical function, cognitive status and psychological needs of the elderly users.

Degradation of body function: with the growth of the age, people in all kinds of sensory function such as vision, hearing, touch are weakening gradually, physical size also on muscle atrophy, bones, all have great changes, and then power level and reflect speed will decline, restrictions on the physical condition can affect older users in the use of intelligent equipment and intelligent system in the process of add many difficulties, such as can't see the screen, listen to not clear voice, easy to accidentally touch and so on.

Differences in cognition: mobile phones, Internet and smart devices have been gradually introduced into People's Daily life in the past 30 years, and are also undergoing rapid updates due to the development of technology. Older users because of the differences of knowledge reserves, in the process of learning new knowledge, new technology will take a long time, and formed in the long life of the inherent knowledge framework and ideas also affect older users's ability to accept new things, hard to use and adapt to the modern science and technology products, and meet many difficulties in the process of use.

Psychological needs: after the aging stage, psychological change is accompanied by physiological functions of recession and at the same time, the physiological function of the recession will to a certain extent, limit the scope of social activities, combined with the present stage the change of family structure, especially the elderly in different family, unable to meet their children dependent demand, under long-term backlog of easy to negative emotions, adverse psychological reactions, adverse reaction can affect the body and psychology health, serious still can cause some diseases.

Therefore, in the selection of equipment and the construction of platform, the changes of physiological signs of the elderly should be fully taken into account, and the ways and means to reasonably make up for physiological limitations should be considered. When designing the communication system for families in different places, we should also pay attention to the logic of the interaction level to reduce the difficulty of operation. In the overall long-distance interaction system, convenient functional operation and friendly interaction experience should be used to provide good interaction experience and positive psychological suggestion to elderly users, promote communication between long-distance families, develop a new social platform for elderly users, and improve their psychological status from the side.

4 Design of Long-Distance Relationship Interactive System Based on Interactive Projectors

For older users group characteristics and requirements, as well as the defects of existing different family communication way, interactive projector is chosen as the initial long-distance family interaction system in this study bearing equipment, projector has certain flexibility, its size can be adjusted according to the distance, and the interface from the fixed display area is limited, under normal circumstances, projector display image range larger, older users under the condition of the degraded eyesight can be convenient to watch, the operating area is bigger, can reduce the error of operation [4].

According to Maslow's hierarchy of needs theory, physiological needs and safety needs are primary stage, belonging needs and respect needs are intermediate stage, and self-realization is advanced stage. This study also meet the demand of Maslow's hierarchy theory of three phases, the first stage is to satisfy the physiological needs and security needs, older users in life will meet many difficulties, such as intelligent electronic devices use problem, through the system, to help other children more easily to help older users to solve the difficulties in the daily life, meet the basic needs of daily life. The second stage is to meet the needs of belonging and respect. It is expected that the system can make up for the lack of authenticity and interactivity in the existing communication modes of long-distance families, so as to provide an easy way for long-distance family members, especially elderly users, to understand and feel the interaction. The third stage is to help elderly users overcome their fear of smart electronic devices through this study, to promote their willingness to communicate with the outside world, to improve their bad psychological state, so as to increase social activities and promote physical and mental health.

5 Research Defects

This research has initially proposed a way for elderly users in long-distance family to solve remote communication. Due to the short research time, some implementation details have not yet been finalized, and the physical system design is being gradually constructed and improved. At present, relevant patent protection has been applied. Gradually improve and perfect in future research.

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Study on the Influence of Schoolbags with Different Design and Working Conditions on Children's Back Pressure

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Abstract. In this study, 16 children aged 7–18 years were taken as the research objects. The air bag contact pressure tester was used to test the pressure and its peak change of 8 pressure points on the back of children when they were carrying the same weight bag and carrying different types of bags. The results show that there are significant differences in the interaction among different bag design, working condition type, pressure point location, bag design and working condition type, bag design and position interaction, bag design, working condition type and pressure point location. The results of post-test show that the design of bag 1 is more conducive to reducing the load, and 3 bags are more conducive to reducing the load in the case of tie than in the case of no tie. The research results show that the design and working condition of schoolbag play an important role in children's load reduction and spine development.

Keywords: Children's schoolbag design · Working condition · Pressure

1 Introduction

Schoolbag is a necessary tool for children of different ages to go to and from school, but at present, the design of schoolbag is not consistent with the physical development of children, the weight design of schoolbag itself is unreasonable, the division of storage space is chaotic, the pressure of students' own study, the distance from home to school, the restriction of school resources and other reasons seriously affect the use of schoolbag, and the problem of schoolbag load exists Some foreign experts have also studied it from physiology, human physiological structure, epidemiology and other aspects, and recommended different weight-bearing standards with BW as the reference standard. Although the standards are different, most of them think that the weight of schoolbag should account for 10%–15% of children's weight [1–5]. If children carry too much schoolbag, it is not conducive to their growth and development, which will make the nerve muscles on both sides of the spine in a state of high tension. Thus, the posture defects of scoliosis, lordosis, kyphosis and anteversion of spine occur, resulting in back pain, muscle ache and other diseases [6]. There are relatively few such studies

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 361–366, 2020.
https://doi.org/10.1007/978-3-030-50838-8_49

in China, mainly in foreign countries. However, due to the differences of social resources and education methods in China and foreign countries, some studies abroad are not suitable for the selection of schoolbags for Chinese social children. In this case, it is particularly important to study the design of schoolbag for Chinese children and the protection of spine function. The conclusion of this study will provide suggestions for the design of schoolbag.

Through the previous research [7–11], we found the type of schoolbag (single shoulder bag, double shoulder bag, pull rod bag) and the way of endorsement bag(one shoulder, two shoulders), the design of schoolbag (back plate, shoulder belt) and working condition (lace up or not) all affect the physical development of children. On the basis of previous studies, this study researched the influence of different bag design (shoulder belt and back plate design) and working conditions (lace up and no lace up) on the pressure of different positions of children's back through experimental research.

2 Method

2.1 Experimental Design

In order to evaluate the impact of schoolbag's biomechanical properties on children body in children's daily use, three kinds of schoolbags with different designs are selected (Design 1: schoolbag design with shoulder cushion and back cushion thickening; design 2: schoolbag design with only thickened shoulder cushion; design 3: schoolbag without thickened shoulder cushion and back cushion). The three kinds of schoolbags with different designs are shown in Fig. 1. Each bag includes two working conditions: lace up and no lace up. So,it is a 3*2 within-subject factorial design.

And the pressure values of 8 positions were collected in the experiment. Pressure point 1 (left shoulder), pressure point 2 (scapula), pressure point 3 (left waist), pressure point 4 (thoracic spine), pressure point 5 (lumbar spine), pressure point 6 (right shoulder), pressure point 7 (right scapula), pressure point 8 (right waist) (Fig. 2).

Fig. 1. Three kinds of schoolbags with different designs

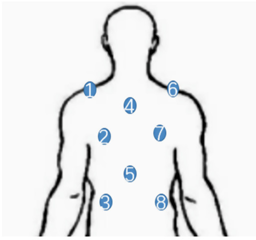

Fig. 2. The distribution map of children's back pressure points

2.2 Participants

16 children aged from 7 to 18 years old with height of 130 cm–165 cm were randomly recruited, who can express their feelings clearly, including 8 boys and 8 girls. The distribution proportion of high BMI, middle BMI and low BMI is 5:7:4.

2.3 Experimental Apparatus

The contact pressure of the bag on the skin was measured with the Japanese AMI 3037-10 air bag pressure tester. The minimum measurement interval was 100 ms and the accuracy was ±0.1 kPa.

2.4 Procedure

All the subjects had signed the informed consent before the experiment beginning. At the beginning of the experiment, the height, weight and basic demographic information of the subjects were collected. All the subjects were required to carry a bag of 6.5 kg which was separately in the three different designs (shoulder back cushion is thickened, shoulder cushion is thickened, shoulder back is not thickened). The test time of each condition is 15 min, and the pressure value is recorded six times. At the end of the experiment, there would be an interview on the design of schoolbag and the comfort of its pressure. And, all the subjects would get a certain reward for the experiment.

2.5 Statistical Analysis

SPSS 25.0 statistical software was used to analyze the influence of different bag designs and working conditions on children's back pressure.

3 Results

3.1 Comparison Results of the Pressure Values of Different Three Schoolbag Designs and Two Working Conditions

The larger the pressure value in the pressure equipment, the heavier the pressure felt by the subjects at this pressure point. The results show that the pressure values of the left and right shoulders are biggest among the pressure values of all the eight points, those of the vertebras are the lowest,whether strapping or not. The pressure points of both design 1 and design 2 bags with strapping are obviously reduced, which proves that design 1 and design 2 can effectively relieve the back pressure with strapping, but design 3 aggravates the pressure of shoulders in the case of lace up.

With regard to the pressure, a repeated-measure ANOVA was applied to the pressure of the different conditions, a significant main effect of different bag designs was found, there was significant difference among the three bags($F(2,16) = 11.17$, $P < 0.001$), the main effect of strapping and non-strapping was significant ($F(1,16) = 43.14$, $P < 0.001$), the main effect of the pressure position was significant ($F(1,7) = 1266.60$, $P < 0.001$), and there were significant interactions between the bag design and the working condition, bag design and position, work condition and position ($Ps < 0.001$). The interaction among bag design, working condition and pressure position was significant ($F(14,48) = 20.04$, $P < 0.001$). The pos-hoc test shows that the difference between design 1 and design 2 was significant ($P < 0.001$), and the difference between design 2 and design 3 was significant ($P < 0.01$). The simple effect shows that the pressure without strapping was heavier than that of strapping condition ($P < 0.05$) in the design 1 and design 2, and the pressure with strapping was heavier than that of non-strapping condition ($P < 0.05$) in the design 3.

Table 1. The analytical results of different schoolbag designs under the different working condition

	SS	*Df*	*MS*	*F*	*Sig.*
Left shoulder	60.175	2	30.088	19.156	**.000**
Left scapula	10.819	2	5.409	28.368	**.000**
Left waist	11.720	2	5.860	14.495	**.000**
Thoracic vertebra	7.143	2	3.572	5.495	**.004**
Lumbar vertebra	1.123	2	.561	5.742	**.003**
Right shoulder	16.107	2	8.053	3.968	**.020**
Right scapula	2.896	2	1.448	10.452	**.000**
Right waist	3.758	2	1.879	2.322	.099

3.2 The Results of Pressure on Each Position of Three Kinds of Schoolbag Design Without Strapping

The results showed that there were significant differences among the three bag designs in each position ($Ps < 0.05$). The pressure of design 1 is significantly lower than that of design 2 and 3. The results show that design 1 can effectively reduce the pressure on shoulder, waist, scapula and thoracic vertebrae without strapping.

3.3 The Results of Pressure on Each Position of Three Kinds of Schoolbag Design Without Strapping

We compared eight pressure positions of three different design schoolbags between the conditions of strapping and without strapping. The results of repeated ANOV analysis showed that there were significant differences in left shoulder, left scapula, left waist, thoracic spine, lumbar spine, right shoulder and right scapula under the condition of strapping ($Ps < 0.05$), but there was no significant difference in right waist.

4 Discussion and Conclusion

Through the research, it is found that under the same working condition, the design 1 of the schoolbag is obviously superior to the other two. The reason may be that design 1 is to increase sponge pads on both sides of the spine, reduce the load on the spine position, thicken sponge pads on the shoulder belt position, and increase the air permeability of schoolbag, while the advantage of design 2 is to increase the middle back Sponge pad makes the position of left and right scapula light. Although there is no thickened sponge pad on the back and shoulder in design 3, its flat back design also makes the pressure distribution on the back more even. However, in the process of interviewing the subjects, the subjects all said that the design of adding sponge pad makes the backpack more breathable and comfortable. The research results are consistent with the research results of Zhao Fengyu [11]. The use of hollow fabric can increase the air permeability of the bag, avoid the slip of the shoulder belt, increase the buffer space between the bag and the human body, make the bag more fit to the human body, and reduce the pressure peak generated by the local area of the shoulder belt contacting the human body. Increase the contact area between shoulder belt and shoulder to make the force distribution more uniform. Based on the previous research on the backpack system and the healthy design principle for children's schoolbag, it is found that widening the shoulder belt and each pressure point of the backpack system can make the back-stress uniform. Reduce the pressure on the part, and transfer more pressure to the waist at the same time. The use of three-dimensional cutting and integrated design can make the schoolbag more fit the body trunk, so that the gravity is evenly distributed in the whole trunk, and prevent the compression on a certain point. At the same time, through this kind of experiment to change the posture of children's endorsement bag, it can effectively prevent the bag from shaking left and right, and make the shoulder stress even.

The research on the pressure value of the same schoolbag under different working conditions (strapping and without strapping) shows that the pressure points of the three schoolbags are obviously reduced under the condition of tether, which proves that the tether can effectively relieve the pressure on shoulder and back, The reason is that in the process of carrying the bag, the center of gravity of the body rises, which reduces the stability of the body and easily causes falls. The use of a belt to fix the bag on the body can make children carry the bag safely and comfortably. The research results are also consistent with those of Southard et al. [9], using waistband to transfer the vertical pressure to pelvis can reduce the pressure of schoolbag on shoulder and trunk muscles.

Acknowledge. This work is supported by China National Institute of Standardization's President Fund Program (522018Y-5984, 522020Y-7176).

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Cognition Framework

Correlation Between Hearing Aid Use and Cognitive Impairment in the Elderly

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Abstract. Presbycusis is the most prevalent age-related, non-reversible, sensorineural hearing loss. Evidence supporting the relationship between auditory dysfunction and cognitive degeneration has grown over the years. Because of the aging of the world population, an early identification of the disease and an audiological recovery could mitigate the rate of cognitive decline with positive consequences for quality of elderly' social life. A group of 50 patient (70–92 years) underwent audiometric tonal examination to evaluate hearing ability. Only 50% (active group) were equipped with a bilateral hearing aid. After three years, all patients were retested. Among the active group, the Mini-Mental State Examination was administered to 7 pathological patients to assess cognitive status at the begin and at the end of the research. The results show that the active group has achieved a significantly higher minimum audibility threshold than the control group ($p < 0.01$) and a cognitive benefit.

Keywords: Presbycusis · Hearing aid · Hearing loss · Cognitive impairment

1 Introduction

World Health Organization (WHO) in 2012 quantified disabling hearing loss for people around the world, based on current data of 42 population-based studies [1]. In particular, disabling hearing loss, defined as hearing loss greater than 40 dB in the better hearing ear in adults, is the fourth highest cause of disability globally. Disabling hearing disorders affect over 5% of the world's population, or 466 million people (432 million adults and 34 million children) [1] and are very common in older age: at least one-third of persons above 65 years presents Presbycusis, the most prevalent age-related, non-reversible, sensorineural hearing loss [2]. During the next few decades, the share of global population aged 60 or more is likely to grow significantly. According to World Population Prospects 2019 [3], by 2050, 1 in 6 people in the world will be aged 65 years or over. Consequently, the number of persons with hearing loss will grow proportionately, due to population growth and ageing.

Presbycusis is more common in men than women [4] and represents the third most prevalent chronic condition, after hypertension and arthritis among elderly [5]. Usually

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 369–375, 2020.
https://doi.org/10.1007/978-3-030-50838-8_50

bilateral, it affects the high frequencies of hearing [2] and is characterized by reduced hearing thresholds and speech understanding and discriminating, which cause a tremendous impact on life quality of older individuals. Unfortunately, Presbycusis remains an often undetected, underestimated and neglected condition in the geriatric population. If untreated, its impact on patients and the society as a whole would be significant [5]. Frequently, the first symptoms occur in conversation with background noise, in echoing rooms, when there is a large distance from the speaker, in directional hearing. When advanced, the hearing impairment affects the person's ability to follow and understand one-to-one conversation also in a quiet environment and in daily living (watching television, listening to the radio, speaking on the telephone) [2]. The inability to hear prevents the elderly from communicating efficiently with family members and maintaining links to the world, reduces cognitive abilities, contributing to their isolation, causing social withdrawal, depression and possibly dementia [6].

Evidence supporting the relationship between auditory dysfunctions and subsequent cognitive degeneration has grown over the years [7]. Patients with mild, moderate, and severe hearing loss very often show high risk of developing dementia and increased hazard ratios of accelerated volumetric declines in the whole brain and Alzheimer's disease [8].

An early diagnosis and identification of the disease and an audiological recovery with hearing aid (HA) is then important to mitigate the rate of cognitive decline with positive consequences for quality of elderly social life.

According to Eurostat data, the period from the diagnosis of hearing loss to the first application of a HA is 7 years [9]. During this time, an incorrect perception of sound stimuli could lead even to a regression of the acoustic nerve, accelerating the aging process and experiencing an altered cognitive sensitivity. Even mild hearing loss can cause significant changes in the brain and a reorganization of the auditory cortex. If the brain does not receive sounds well, mechanisms are set up to compensate for hearing loss, such as greater involvement of the sight (reading of the lips) in order to obtain the same information that was previously conveyed only by hearing. If areas of the auditory cortex are recruited from vision, this slowly results in functional changes in the cerebral cortex. The more the loss increases, the greater the effort the brain makes to feel. The use of HA, even for mild hearing loss, slows down these cortical changes, with a better perception of speech and less effort in listening.

The purpose of this study is to evaluate hearing ability and the cognitive benefit in a group of elderly patients using HA respect to a control group. Through a retrospective observational study, the research wants to demonstrate that the application of HA could slow down the aging of the hearing organ, maintaining the minimum audibility threshold.

2 Materials and Methods

A group of 50 patient aged 70–92 years, where the median age is 77, 6 y, affected by Presbycusis, was recruited through the otorhinolaryngology ambulatory of the Sapienza University Rome. In the group, 7 patients were affected by Alzheimer's disease. All patients underwent audiometric tonal test.

Only 50% of patients was equipped with a bilateral behind-the-ear technology HA (active group: 44% female and 56% male), while the remaining 50% (control group: female: 48%, male 52%) did not accept HA. After three years, all patients were retested by diagnostic audiometer (Medsen Itera II, Otometrics) [10].

Audiometric tonal examinations of the two groups (the active and the control group) were studied. Two tests have been performed for each patient of both groups, pre (T0) and post (T1) application of the HA for the active group, three years apart. Center frequencies from 500 Hz to 4000 Hz were considered.

Among the active group, the Mini-Mental State Examination (MMSE test, Table 1) was administered to the seven pathological patients to assess cognitive status at the begin and at the end of the research.

Table 1. Mini-Mental State Examination test

N.	Questions	Maximum score
	Orientation	
1	What is the year? Season? Date? Day? Month?	5
2	Where are we? State? County? City? Hospital? Floor?	5
	Registration	
3	Name three objects. Ask patient to name the items Repeat the answers until the patient learns all three	3
	Attention and calculation	
4	Ask the patient to begin with 100 and count backward by 7 s, stopping after 5 subtractions: 93, 86, 79, 72, 65	5
	Or	
	Spell “world” backward	
	Recall	
5	Ask the patient to name the three objects learned under “registration” above	3
	Language	
6	Point to a pencil and watch, asking the patient to name them	2
7	Have the patient repeat “no ifs, ands, or buts”	1
8	Have the patient follow a three-stage command (e.g., “Take a paper in your right hand. Fold the paper in half. Put the paper on the floor”)	3
9	Have the patient read and obey the following sentence, written in large letters: “Close your eyes”	1
10	Have the patient write a sentence	1
11	Have the patient copy a picture of two intersecting pentagons	1

The MMSE is an 11-item test which provide a brief quantitative measure to screen for cognitive impairment, to estimate the severity of cognitive impairment at a given point in time, to follow the course of cognitive changes in an individual over time, and to document an individual’s response to treatment [11]. MMSE consists of tests of

Orientation (spatial and temporal), Registration, Attention and calculation, Recall, Language, Language-repetition, Language-understanding, Reading and written comprehension, Generation of written sentence and visual-spatial skills. The MMSE is scored on a scale of 0–30. Severe cognitive impairment: 0–17, mild cognitive impairment: 18–23, no cognitive impairment: 24–30. The score of this test is recalculated by means of corrective coefficients that take into account the age and years of schooling of each subject examined. The results collected have been statistically analysed (t test, p < 0,01).

3 Results

The results show that in the active group, the variability for T0 ranges from a minimum equal to 25, to a maximum equal to 65. After three years, among the same group, the minimum value for T0 was 33,75 while the maximum 66,25, with a statistically significant difference between the T0 and T1 data collected in the two surveys three years apart ($p < 0.01$). Globally, in the active group, the mean value for T0 was 44,9 while 49,9 for T1. The results show that in the active group, the difference between T0 and T1 highlights a hearing loss of 5 dB.

In the control group, the variability for T0 ranges from a minimum equal to 11,25, to a maximum equal to 55. After three years, among the same group, the minimum value for T0 was 22,5 while the maximum 75, with a statistically significant difference between the T0 and T1 data collected in the two surveys three years apart ($p < 0.01$). Globally, in the control group, the mean value for T0 was 34 while 49,2 for T1 (Fig. 1). The results show that in the control group, the difference between T0 and T1 highlights a hearing loss of 15,19 dB.

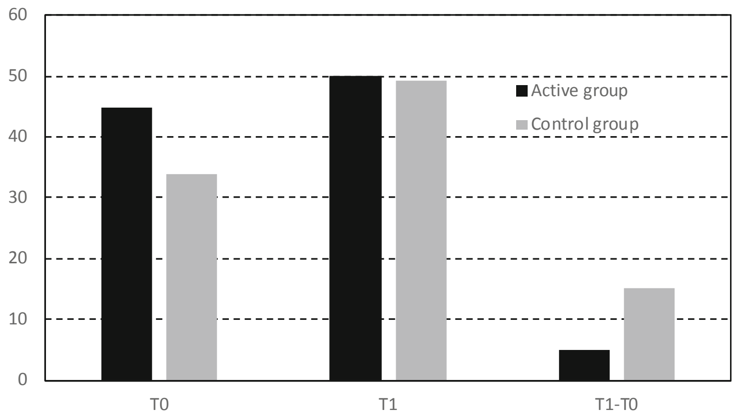

Fig. 1. Mean values for T0 and T1 among the active and the control group three years apart

The collection of audiological data shows that the active group has a significantly higher minimum audibility threshold in the three years than the control group. The average variation in hearing loss in the group of prosthesis is 5 dB, in the control group the value is 15,19 dB, a hearing loss coefficient about three times greater ($p < 0{,}01$).

The box plots of mean hearing losses on the two groups show that although the control group at T0 had lower mean hearing losses, at T1 relative auditory deterioration is greater than the active group (Fig. 2). In addition, the control group highlights a greater dispersion of data.

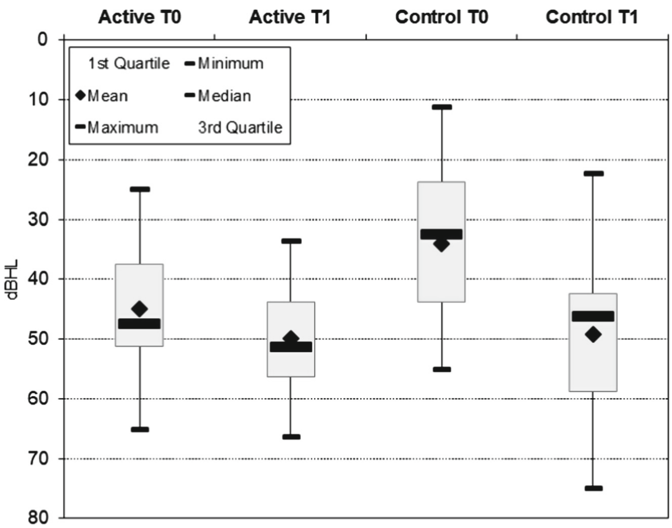

Fig. 2. Box plot of mean dBHL for the active and the control groups

Figure 3 shows the average of hearing loss for frequency by age group: auditory deterioration is greater for control group (without HA), where the greatest losses are in the frequencies range up 1000 Hz and emphasized for the age group >80 years. For the active group, a much more contained auditory deterioration can be detected; wearing HA preserve the auditory function, especially in the frequencies from 500 to 2000 Hz.

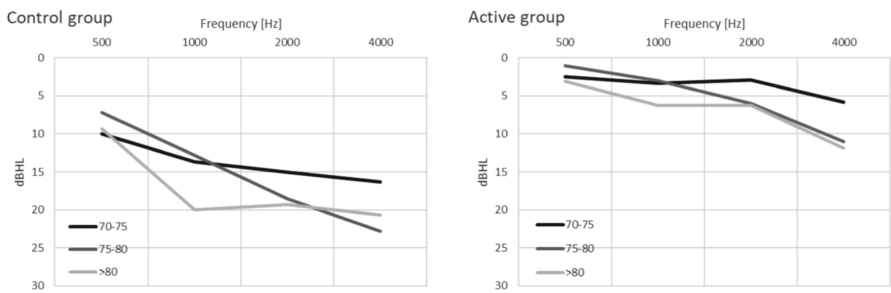

Fig. 3. Average in hearing loss per frequencies by age groups

In conclusion, the use of HA seems to protect and preserve the decay of the auditory function, also due to aging.

Among the seven pathological patients in the active group, the results of the MMSE test administration show that only one patient presents a mild cognitive impairment (22,3) with a severe sensorineural hearing loss, while the others showed a severe cognitive impairment (minimum value for MMSE 12,2, maximum 17,8) with a medium-grade sensorineural hearing loss. Among the patients, 43% were binaurally prosthesized with retro-auricular base-band technology, 43% with a mid-range retroauricular technology, 14% with a medium-high end retroauricular technology. At the end of the research, the results of the MMSE test administration show for 71,4% of the pathological patients examined, an improvement in cognitive performance: 43% of patients passed from severe cognitive impairment (MMSE test score 0–17), to mild cognitive impairment (MMSE test score 18–23). This improvement was particularly relevant for a patient with mild cognitive impairment (22,3) to no cognitive impairment (26,3) at the end of the research. Significant improvements in mnemonic abilities were also found in 57,1% of patients.

The results show that these pathological subjects found a more or less marked improvement in cognitive performance probably thanks to the continuous use of HA. The best results have been obtained for item 2 (Orientation) and item 5 (Recall). This improvement, especially in terms of social interactions, could be associated with a reduction in cognitive effort. The proper functioning of the auditory system is in fact essential for the purpose of an active participation in conversations and interpersonal relationships in general.

4 Conclusions

The results show that an approach to acoustic rehabilitation is fundamental for the improvement of sound perception, for the maintenance of hearing loss and for the slowdown of the auditory decay. In fact, in patients with sensorineural hearing loss belonging to the control group, the decay of the minimum hearing threshold is much more pronounced than in the active group. The auditory deprivation over time of certain sound stimuli could make discrimination more difficult; a lack of signal afferent to the cerebral cortex could have contributed to a lower efficiency of the acoustic nerve and of the acoustic pathways.

Then, an adequate and prompt hearing aid application can lead to a maintenance of minimum auditory threshold over time and to an improvement in cognitive performance, certainly associated with a reduction in the cognitive effort of the patient. The benefits for the patient mainly affect social interactions. The proper functioning of the auditory system is essential for the elderly to increase their relational skills. Long-term benefits are obtained for society in the whole. In the face of a constant increase in average life expectancy and a reduction in the birth rate, especially in western countries, reduction of the cognitive decline of the older population becomes a topic with social and economic implications no longer negligible.

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Characterization and Socio-Cognitive Needs of People with Intellectual Disabilities

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Abstract. The following article presents the characterization of the Integral Foundation for the Special Child - FINE (Pomasqui, Ecuador) users and the selection of pedagogical models to guide the design, monitoring, evaluation, and formulation of training plans for the development of socio-cognitive skills in people with intellectual disabilities. To define the socio-cognitive characteristics and needs of users, their records and the cards issued by the Ministry of Public Health - MSP was reviewed by the foundation. Among the most relevant results, it was determined that the study population requires extensive support systems considering the various dimensions of human functioning. The use of an educational model based on multiple intelligences accompanied by a socio-ecological disability model that emphasizes the fit between the person and the environment, with a multidimensional approach, is recommended according to the new disability paradigm.

Keywords: Characterization · Intellectual disability · Pedagogical model

1 Introduction

In recent years, a new code of values, attitudes, and social practices that directly affect school culture has been established. Recognition of the diversity that we find within each classroom starts by guaranteeing the right of each one to be educated and to attend school undisturbed by ensuring real equality with equal opportunities.

Delors [1] states that "education can be a factor of cohesion if it seeks to take into account the diversity of individuals and human groups and, at the same time, avoid being a factor of social exclusion." Therefore, "education must seek to consolidate systems based on respect for human diversity in ways that strengthen the development of more equitable and just forms of social coexistence" [2].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 376–381, 2020.
https://doi.org/10.1007/978-3-030-50838-8_51

In this sense, the paradigm of disability has completely changed over the last decade of the twentieth century, since then it aims to promote the idea of diversity as an expression of the characteristics that every one of us have when we interact in the world with others and with other things" [3]. This new way of thinking about disability means that this construct must be seen as the adjustment between the capabilities of the individual and the context in which the person lives. In short, according to Schalock [3] the new concept of disability means "a transformed vision that constitutes the life chances of people with disabilities, this view assumes an emphasis in autonomy (self-determination), integration, equality, and capabilities" it is not determined by a clinical analysis which assesses the level of intelligence of a person but by the conditions offered by the environment in which they live. Consequently, it is the responsibility of society to provide the necessary support services to eliminate barriers and reduce existing gaps.

2 Theoretical Proposal of the Pedagogical Model

As part of the research project, conceptualization is presented from an ecological and multidimensional perspective. To work with FINE users, the following pedagogical models have been selected:

Multiple intelligences model, raised by Gardner, has as a principle the new concept of disability; that is, each person has different capabilities that allow them to solve problems, create new components for society, or for itself, in different ways.

The *multidimensional model* mainly includes the revision of human performance. The American Association of Intellectual Disabilities and Development -AAIDD (formerly known as Association on Mental Retardation) proposes a conceptual framework of said performance consisting of two components [4]. The first, consisting of five dimensions: intellectual skills, adaptive behavior, health, participation and interaction, and environmental and cultural context. The second considers the representation of the role that support has on human performance: needs and their intensity.

The *socio-ecological model* allows a comprehensive assessment of the person with intellectual disabilities, namely the assessment of adaptive behavior and support needs. These two concepts must be clarified: adaptive behavior scales assess conceptual, social and practical skills that a person has learned, allowing them to respond to the circumstances of everyday's life [4]; while assessment of support needs scales determines the frequency, time and type of help, human, material or technique, a person requires to acquire a higher grade of independence, participation and well-being.

3 Methodology

In the research, 47 people with intellectual disabilities beneficiaries of the FINE Foundation participated after their signing of informed consent endorsed by the Ethics Committee of the Pontifical Catholic University of Ecuador.

To obtain information, we proceeded with the document review of the FINE users records, and because the research was qualitative, semi-structured interviews were conducted to professionals and authorities working on the foundation to reach a closer approach and increase the degree of familiarity with the dynamics of the population, aim which is relatively unknown since it involves some associated factors that are not always considered in studies and researches. Information that enables a deeper understanding of the context was sought from the understanding that any individual, group or social system has a unique way of seeing the world and understand situations [5]. The methodology used is an exploratory case study that intended to give an approximate general overview regarding the reality of FINE users. For characterization of the target population, five phases were considered:

a) Review of FINE users' records.
b) Non-participatory observation of everyday activities of FINE users.
c) Semi-structured and open interviews with [5] FINE staff.
d) Data tabulation and systematization of obtained information.
e) Analysis, conclusions and recommendations.

4 Results

The definition of the disabled person is stipulated in Article 6 of the Organic Law on Disabilities – LOD as:

> (…) Is considered disabled a person who, as a result of one or many physical, mental, intellectual or sensory impairments, regardless of the cause that originated them, is *permanently* restricted [emphasis added] in his biological, psychological and associative ability to perform one or more essential activities of daily life, in the proportion established by the bylaw [6].

The qualification process of disability is the responsibility of the MSP through first-class health facilities[1] certifying such condition by delivering a credential card after a perceptual assessment of the severity of sequels or limitations, from 30%, both organic and functional in accordance to article 1 of the bylaws to the Organic Disabilities Act [7]. The following types of disabilities are acknowledged: auditory, physical, intellectual, psychological and visual: Percentages and degrees of disability are outlined in the following ranges: 30–49%, 50–74%, 75–84% and 85–100%, which is inferred to correspond to moderate, serious, very serious and severe, respectively. This generic scale of severity of the disability, registered in the ID cards of FINE users, has been modified in the Manual of Qualifying Disability, published by the MSP in 2018 [8] and changes will be incorporated according to the requalification in 2020 [9]. For the development of the research project, a valuation is recorded in their current ID cards.

According to the percentage and degree of disability, about half of the target population (42.55%) has a serious condition; the near fifth (17.02%), very serious; and 12.77%, severe. Lesser percentages, mild conditions (2.13%), and moderate (8.51%). 17.02% of card users have therefore recorded no rating.

[1] Consolidated matrix grading centers (MSP, 2017). https://www.salud.gob.ec/wp-content/uploads/2017/04/Establecimientos-de-Salud-de-Primer-Nivel-autorizados_Calificadores-1.pdf.

4.1 Socio-Cognitive Characterization

In line with evolutionary changes on the notion of intellectual development disorder, the definition of intellectual disability is assumed from a socio-ecological perspective and in the context of a multidimensional model of human performance, as noted by Schalock (2009) to which ascribes the MSP as set out in the 2018 Qualification Guide of Disabilities.

The multidimensional nature of the intellectual disabilities forces to consider: health, context (family, community, institutional), linguistic and cultural diversity, differences and interaction between various factors (communication, sensory, motor and behavioral) to move towards the definition of personalized support appropriate during a continuous period that enables improved vital performance involving body structures and functions. [10].

From the review of the records that are part of the archive of the foundation [11] taken from Non-participant observation and information obtained through interviews, FINE users constitute a population with multiple disabilities involving not only "adding" types of disabilities but to understand the interaction (hearing, physical, psychological or visual) considering a variable range according to age, combination, and severity.

4.2 The Overall Level of Support Needs of FINE Users

The Scale Supports Intensity-SIS[2] [12] Spanish version was applied, An instrument designed solely to assess the support needs of people with intellectual disabilities or development and to help professionals working on the planning of individualized supports [13].

Evaluation proceeded with 47 users, all in adulthood. The semi-structured interviews, version for adults age 16 and over [14] was answered by educators and family members who know the person with intellectual disabilities from at least three months and have had the opportunity to observe a minimum of two hours in different contexts. The average time to complete the survey was 60 min.

The SIS evaluates the support required in 57 activities of daily living related to seven areas: home life, community life, learning throughout life, employment, health and safety, social, and security and defense. As well as, 16 medical support needs and 13 exceptional behavioral support, generally related to intellectual disabilities and conditioning their overall performance. The SIS uses as measurement parameters the frequency in terms of the regularity with which the support for each activity, daily support time, the type or nature of support is needed. The overall score or "Support Needs Index" identifies the areas that need more or less support [15] in four levels: I, 84 or fewer points; II, 85 to 99; III, 100–115; and level IV, 116 or more.

The total score obtained from the support needs index indicates that this population has an average overall level of 106 correspondings to level III. According to the type of support demanded: a user requires intermittent support (supervision), 12 users require limited support (verbal incitement or gestural), about half of users (22 users) require

[2] For its acronym in English: Supports Intensity Scale.

extensive support (support partial physical) and 11 require widespread support (total physical support).

For the analysis of the results, three SIS assessment parameters were considered: frequency of the need for support, time and type of support required and type of support demanded.

5 Discussion and Conclusions

Data on the type of disability, percentage, and level outlined in the ID card issued by the MSP, is insufficient to identify the needs of people with intellectual disabilities associated with other disabilities and factors. The application of SIS allowed us to detect that the FINE population requires extensive support both continuous and regular, they need help to perform various necessary activities of daily living, and accurate monitoring and frequent accompaniment.

The vast majority (85%) need support in the area of social skills, being essential to work on activities that allow greater independence and autonomy. In the area of learning, they require considerable time and frequency support for activities involving essential intellectual functions. Only 17% do not require cognitive learning support, a percentage that matches the need to support learning through technology. This result generates a need to create resources that promote autonomy and independence.

From the perspective of labor inclusion, 89% of the target population requires sustained support. The best option to ensure the right to work is protected employment when, in the typical labor market, execution speed is critical and support systems are generally not present.

According to the characterization of the target population, models of multiple intelligences and socio-ecological processes for learning and job training are recommended, considering a multidimensional approach to support the needs identified during the research

Acknowledgements. The research work is supported by Senescyt - National Program for Research Funding (UNPUBLISHED).

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Analysis of Tactile Display Designs on Philippine Money for the Blind and Visually Impaired

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Abstract. According to the World Health Organization, at least 2.2 billion people have a vision impairment or blindness. In the Philippines, the number of people who are bilaterally blind was estimated at 332,150 from a report of the Department of Health in 2017. These number of people face a lot of challenges when living independently, one of which is handling money. The aim of the study is to analyze the effectiveness in aiding the blind and visually impaired of the current Philippine banknote together with four other tactile designs. A tactile test with the goal of identifying a specific banknote and discriminating between banknotes was conducted with twenty blindfolded participants. Metrics of the test include: (1) number of banknotes incorrectly identified and discriminated, and (2) average time of correctly identifying and discriminating banknotes, for each tactile design. Two-way Analysis of Variance and the Fisher's LSD tests were used to analyze the results of the test.

Keywords: Money · Special population · Tactile display

1 Background of the Study

Money is defined as something that is generally accepted as a medium of exchange, a measure of value, or a means of payment [1]. It is a key for survival in our world today. Unfortunately, even when people have money, money becomes a problem when it cannot be handled properly. This is the case for the blind and visually impaired. According to the World Health Organization, at least 2.2 billion people have a vision impairment or blindness. In the Philippines, the number of people who are bilaterally blind was estimated at 332,150 from a report of the Department of Health in 2017. These number of people face a lot of challenges when living independently, one of which is handling money.

Blind people are those who are sightless [2] while visually impaired people are those who are unable to see well [3] and cannot be treated with eyeglasses or contact lenses. Blind and visually impaired people are forced to depend on their other four senses, mostly their sense of hearing and touching, to go about their everyday lives [4].

J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 382–388, 2020.
https://doi.org/10.1007/978-3-030-50838-8_52

They use their sense of touch as a substitute for their lack of eyesight in a lot of their daily routines (e.g. walking, reading). Because of their reliance to the sense of touch, tactile displays are essential.

Different countries have integrated tactile displays in their paper money. In India, Malaysia, and Australia, each of paper money denominations have different lengths. In Canada, braille dots are incorporated in the design of the banknotes. According to the *Bangko Sentral ng Pilipinas*, the central bank of the Philippines [5], the tactile display that the current Philippine banknotes have is the embossed numerical value on the upper left-hand and lower right-hand corner of the banknote.

Difficulty in distinguishing banknotes poses a large disadvantage for the blind and visually impaired in handling money on their own, thus, tactile displays in these banknotes should be effectively designed.

2 Objectives of the Study

The aim of the study is to analyze the effectiveness in aiding the blind and visually impaired of the current Philippine banknote as well as four other tactile designs.

3 Methodology

Bills currently in circulation in the Philippines are the 50-peso bill, the 100-peso bill, the 200-peso bill, the 500-peso bill, and the 1000-peso bill. Five tactile designs for banknotes were evaluated in the study: (1) current Philippines banknotes called New Generation Currency (NGC) with embossed prints; (2) increasing size. As the value increases, the size of banknote increases (50 – 142 mm × 66 mm; 100 – 150 mm × 72 mm; 200 – 158 mm × 78 mm; 500 – 166 mm × 84 mm; 1000 – 174 mm × 90 mm); (3) deeply-embossed numerical values with larger font in two of the corners; (4) punched holes. As the value increases, the number of holes on two corners increases. The holes are horizontally placed on the top left and bottom right of the banknote. The lowest denomination, 50, has one hole and the highest denomination, 1000, has 5 holes. The diameter of the holes was set at 3 mm and the distance of each hole from each other was also set at 3 mm. This design is based on Braille marks [6]; (5) number of vertical strips of tape on two corners increases as the value increases. This design is based on the Israeli banknote which has very small engraved strips on its banknotes. 25 mm by 5 mm vertical strips of tape placed on both sides of the banknote were used and were 3 mm away from each succeeding strip. The lowest denomination, 50, has one strip and the highest denomination, 1000, has 5 strips.

Makeshift banknotes with the enumerated tactile designs were created. A pile of five bills, one bill of each denomination of the same tactile design, were placed in separate test stations. A tactile test was conducted with participants, while blindfolded, identifies a specific banknote given to them and discriminates between banknotes within a pile for each test station.

Twenty participants of low and normal tactile sensitivity participated in the test. Tactile sensitivity of the participant was determined using two-point discrimination test.

If the distance of 3 mm or above between the two points were perceived as one point, the finger was classified as having a low level of tactile sensitivity. If it is greater than or equal to 2 mm but less than 3 mm, the finger was classified as having a normal level of tactile sensitivity.

In each test station, the participant is given 3 min to familiarize themselves with the feel of the banknotes and its tactile display. In the identification task, for 5 trials, the participant was asked to identify the banknote given to him/her. In the discrimination task, for 5 trials, the participants were asked to distinguish a specific banknote from the pile of banknotes of the same tactile design. Correctness of identification and discrimination, as well as the corresponding time of identifying and discriminating a banknote was recorded (Figs. 1, 2, 3 and 4).

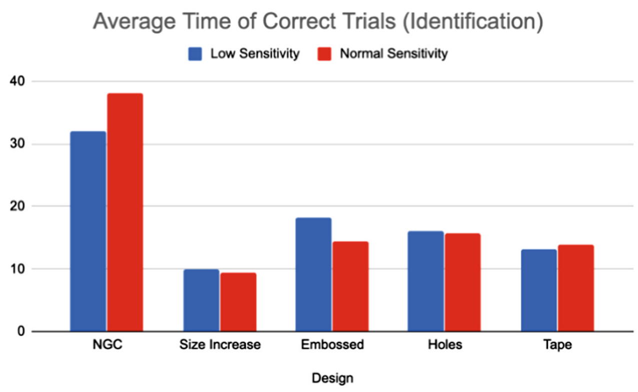

Fig. 1. Graph 1. Average time of correct trials (Identification)

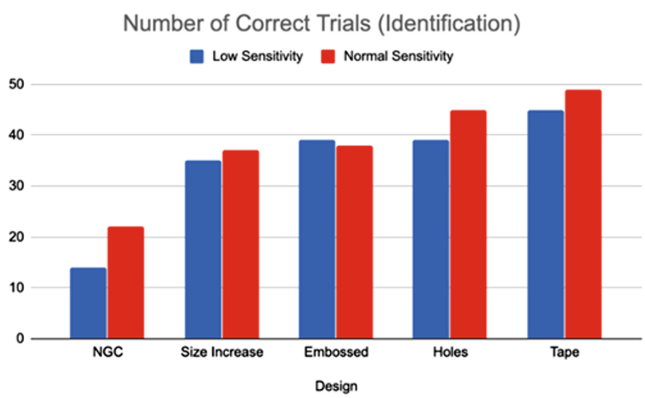

Fig. 2. Graph 2. Number of correct trials (Identification)

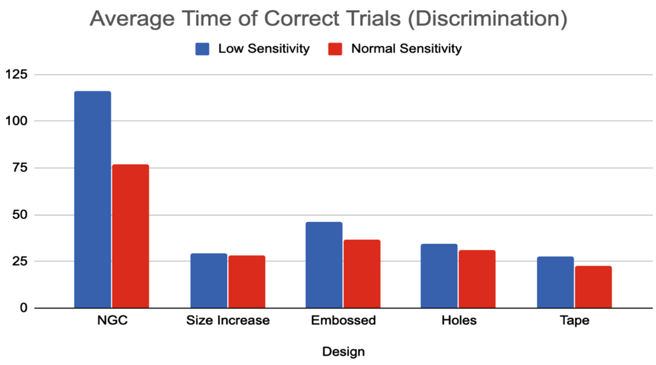

Fig. 3. Graph 3. Average time of correct trials (Discrimination)

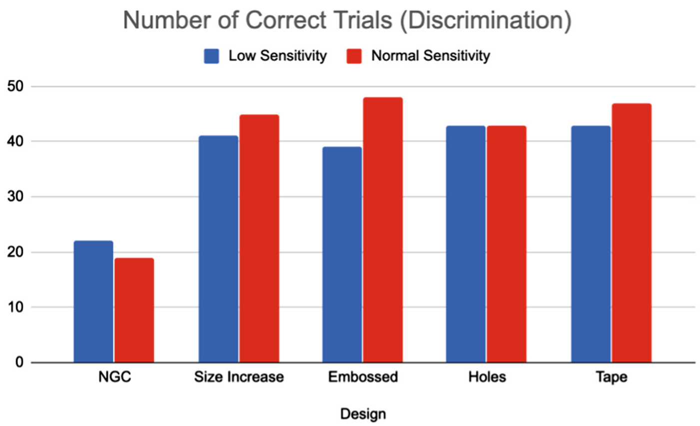

Fig. 4. Graph 4. Number of correct trials (Discrimination)

After the experiment, the participants were asked to answer a survey of their most preferred tactile display.

Analysis of Variance (ANOVA) test and Fisher's LSD test were used to analyze the result of the tests.

4 Scope and Limitations

For this study, all the makeshift banknotes were done manually and by hand. Bond paper were used for all makeshift banknotes. Real paper money was used for the current Philippine banknotes.

As the experiment progressed, it was noticed that some designs did not hold as well as the others. This was noticed particularly in the third design (embossed numerical values) as the embossed numbers weren't as embossed as they were when they were made and first used. The group also had to use newly produced current Philippine banknotes as the banknotes tend to lose their embossed characteristics the more they are used.

5 Results and Discussion

Result of the tests showed that the NGC design had the least number of correct trials and took the longest time to be correctly identified and discriminated. Tactile design of varying sizes took the fastest time to be correctly identified, while the vertical strips of tape took the fastest time to be correctly discriminated. The tactile design of varying number of vertical strips had the highest number of correct trials for both the identification and discrimination tasks.

ANOVA results showed that there is at least one design that is different from the other designs in both efficiency (average time of correct trials) and effectiveness (number of correct trials) under identification and discrimination. The Fisher's LSD test was done to show if there is a significant difference when one treatment is compared to another treatment, whether it be the treatments in the design or the sensitivity level.

Result of the Fisher's LSD test showed that the NGC or the current Philippine banknote has significantly lower number of correct trials and significantly slower identification and discrimination time compared to the other four designs. In addition, tactile design of varying number of vertical strips of tape was found to have significantly higher number of correctly identified banknotes than that of increasing size tactile design (see Tables 1 and 2).

Table 1. Fisher's LSD test result for Identification task

Average time of correct trials (Identification)	Number of correct trials (Identification)
NGC is significantly slower than Size Increase	NGC is significantly lower than Size Increase
NGC is significantly slower than Embossed	NGC is significantly lower than Embossed
NGC is significantly slower than Holes	NGC is significantly lower than Holes
NGC is significantly slower than Tape	NGC is significantly lower than Tape
	Tape is significantly higher than Size Increase

Table 2. Fisher's LSD test result for Discrimination task

Average time of correct trials (Discrimination)	Number of correct trials (Discrimination)
NGC is significantly slower than Size Increase	NGC is significantly lower than Size Increase
NGC is significantly slower than Embossed	NGC is significantly lower than Embossed
NGC is significantly slower than Holes	NGC is significantly lower than Holes
NGC is significantly slower than Tape	NGC is significantly lower than Tape

Removing data of NGC, a second ANOVA test and Fisher's LSD test was conducted. The second test of ANOVA showed that at least one design is different from the other designs in terms of the average time of correct trials for both the identification and discrimination tasks. No significant difference was found for the number of correct trials both for identification and discrimination tasks.

As seen in Table 3, the value of a banknote with the tactile design of having varying sizes was identified significantly faster than the banknotes with embossed numerical values and punched holes. In addition, banknotes with tactile design of having varying sizes and varying number of vertical strips of tape were discriminated significantly faster than banknotes with embossed tactile design.

Table 3. Second Fisher's LSD test result

Average time of correct trials (Identification)	Average time of correct trials (Discrimination)
Size Increase is significantly faster than Embossed	Size Increase is significantly faster than Embossed
Size Increase is significantly faster than Holes	Tape is significantly faster than Embossed

Survey results showed that majority of the participants of both levels of tactile sensitivity prefer the tactile design of varying number of vertical strips of tape the most.

6 Conclusion

Test results showed that identifying and discriminating the current Philippine banknote is significantly slower and have higher error than the banknotes with other four tactile designs.

Identifying banknotes with varying vertical strips of tape design was found to have significantly lower errors than banknotes of different sizes. Identifying banknotes of different sizes was significantly faster than that of banknotes with holes and larger embossed numerical values. Discriminating banknotes of different sizes and banknotes with vertical strips of tape were significantly faster than banknotes with larger embossed numerical values. From a survey of the participants, the most preferred tactile display for banknotes is the incorporation of vertical strips of tape.

The study can be further explored by focusing on the best design and having different variations of it (tape shapes, tape lengths, tape widths, tape textures, etc.) in order to truly determine which tape variation yields the best results. Future studies can also check if age affects the results.

Acknowledgments. We would like to thank our participants as well as our parents for supporting our study.

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J. Kalra and N. J. Lightner (Eds.): AHFE 2020, AISC 1205, pp. 389–391, 2020.
https://doi.org/10.1007/978-3-030-50838-8