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Marijke Melles
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Convergence: Breaking Down Barriers Between Disciplines

Proceedings of the International Conference on Healthcare Systems Ergonomics and Patient Safety, HEPS2022

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HEPS
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Springer

Editors
Marijke Melles
Department of Human-Centered Design
Delft University of Technology
Delft, The Netherlands

Armaĝan Albayrak
Department of Human-Centered Design
Delft University of Technology
Delft, The Netherlands

Richard H. M. Goossens
Department of Human-Centered Design
Delft University of Technology
Delft, The Netherlands

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Preface

What does the future of a safe and person-centered, high-quality healthcare system look like? What scientific developments are underway at the interface between the disciplines of Human Factors/Ergonomics and Medicine and Health? These topics and more were discussed and explored during HEPS2022, the 7th edition of the triennial international conference on Healthcare Systems Ergonomics and Patient Safety (HEPS). These proceedings of HEPS2022 present 30 full papers from the 85 conference presentations, providing a cross section of the current state of the art in the field of human factors in healthcare.

The triennial HEPS conferences are an initiative of the Technical Committee Healthcare Ergonomics of the International Ergonomics Association. The general objective of the HEPS conferences is to facilitate an international platform for the dissemination and exchange of scientific knowledge between the disciplines of Human Factors/Ergonomics and Medicine and Health, merging the different approaches to create new perspectives and solutions for the evolution of healthcare. An important mission is to attract contributions and participants from both the human factors and medical sciences and representatives of patient organizations.

We can look back on an impressive history of HEPS conferences with thought-provoking themes:

2005—*Human Factor: a bridge between care and cure* (Florence, Italy).
2008—*Creating and designing the healthcare experience* (Strasbourg, France).
2011—*An alliance between professionals and citizens for patient safety and quality of life: Healthcare systems ergonomics for hospitals and communities* (Oviedo, Spain).
2014—*Bridging research and good practices towards patients welfare* (Taipei, Taiwan).
2016—*Healthcare and society: new challenges, new opportunities* (Toulouse, France).
2019—*Building health and social care systems for the future: demographic changes, digital age and human factors* (Lissabon, Portugal).

2022—*Convergence: breaking down barriers between disciplines* (Delft, The Netherlands).

HEPS2022 took place in Delft, The Netherlands, from 2 to 4 November 2022, at the campus of Delft University of Technology. The theme of this 7th edition was "Convergence—Breaking down barriers between disciplines". With this theme we aimed to go a step further in the necessary collaboration between the human factors and medical sciences towards true convergence: the integration of knowledge, methods, and expertise from different disciplines and the emergence of novel frameworks to catalyze scientific discovery and innovation.

The 3-day HEPS2022 conference program offered five keynotes and 19 sessions in which 85 peer-reviewed work was presented. The session topics were on the one hand initiated by renowned scientists (special sessions), and on the other hand created by thematic grouping of the submitted abstracts. The 14 chapters in this book refer to different sessions of HEPS2022, reflecting current research at the intersection of Medicine and Human Factors.

In addition to these proceedings, there is an abstract book with the abstracts of all 85 conference presentations. A digital copy of the abstract book can be requested by sending an e-mail to Marijke Melles, m.melles@tudelft.nl, Co-editor of this book and Conference Chair of HEPS2022.

We thank the authors and reviewers for their contribution to this book and making HEPS2022 a great success.

Enjoy reading!

Scientific Committee HEPS2022
Marijke Melles
Armağan Albayrak
Richard H. M. Goossens

Delft, The Netherlands
January 2023

Contents

Surgical Ergonomics

Experimental Investigation of Anthropomorphic Forms of a Forearm Support of a Surgical Arm Assistance System in Precision Tasks

Ferdinand Langer, Tim Matschuck, Nora Dreshaj, and Thomas Maier

Abstract Laparoscopic surgery often results in static, uncomfortable arm and upper body postures, which lead to high stress on the surgeons' upper extremities. To counteract this, an interaction-based arm assistance system has been developed to physically unload the surgeon's upper extremities during laparoscopic procedures. This is achieved by actively supporting the forearms with a supporting force following the natural movements without restrictions. The release of the forearms from the system is achieved by a rapid vertical movement of the arms. The assistance system is controlled exclusively by a form fit and frictional connection of the forearms. Within the scope of this research project, the interface parameter form of the forearm rest is therefore investigated on the basis of five anthropomorphic shape variants of the form with dynamic and static tasks. The study shows an influence of percentile-adapted forms on the usability of forearm supports at an arm assistance system. The form percentile results in no correlation to the objective parameters examined in this study: the number of errors or errors per second. There are differences in the perception of comfort by different subject percentiles. The post-study survey shows that subjects prefer form percentiles close to their own forearm percentile and, on the other hand, find forms that are too large or small uncomfortable. Design recommendations and dimensional recommendations for the design of open anthropomorphic forms for the interaction with arm assistance systems are derived from the results.

Keywords Arm assistance system · Exoskeleton · Human–machine interaction · Forearm support · Anthropometry · Laparoscopic surgery

F. Langer (✉) · T. Matschuck · N. Dreshaj · T. Maier
Research and Teaching Department Industrial Design Engineering, Institute for Engineering Design and Industrial Design, University of Stuttgart, Stuttgart, Germany
e-mail: ferdinand.langer@iktd.uni-stuttgart.de

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1 Background

Laparoscopic surgery often results in static, uncomfortable arm and upper body postures, which leads to high stress on the surgeons' upper extremities (Choi 2012; Galleano et al. 2006; Szeto et al. 2012). This can lead to fatigue and reduction in effectiveness with increased error rates during precision tasks (Erbse 2002; Galleano et al. 2006). To counteract this, an interaction-based surgical arm assistance system (CAS) was developed as part of an interdisciplinary research project (IoC, 103) to physically unload the surgeons' upper extremities during laparoscopic procedures (Fig. 1). This is achieved by actively supporting the forearms. This involves a support force acting on the forearms that can be individually adapted to the body weight (Heidingsfeld et al. 2014; Karlovic 2019). The human–machine interface represents the forearm support, which follows the natural forearm movements without restrictions. According to Karlovic (2019), the design recommendations for the length of the forearm support are 40% of the forearm length and for the center of the support position 30% of the forearm length distal to the olecranon. The use of the surgical arm assistance system CAS has a positive influence on error reduction during dynamic task execution compared to no support, without negatively influencing the execution time (Langer et al. 2022).

It must be possible to detach the forearm from the surgical arm assistance system at any time in safety–critical situations. This is achieved by a rapid vertical movement of the arms upwards (Heidingsfeld et al. 2014; Karlovic et al. 2015). Consequently, the forearms cannot be firmly connected to the forearm support, for example by a Velcro

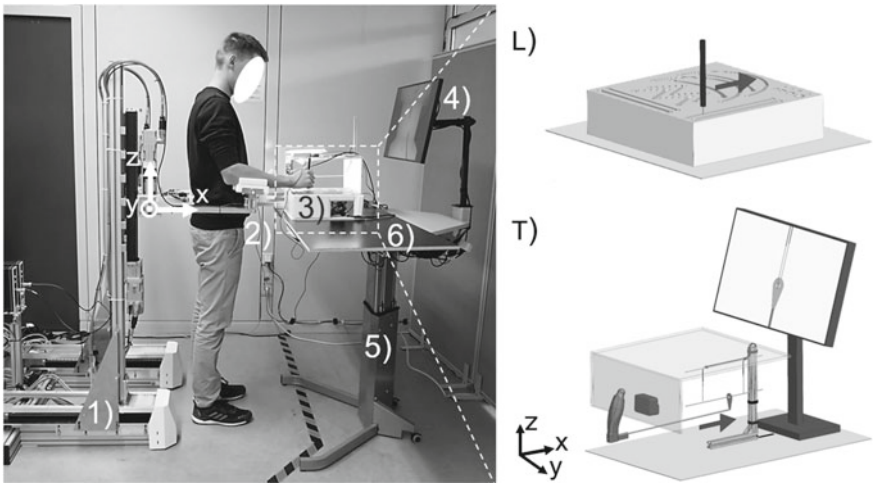


Fig. 1 Experimental setup with right-handed subject; interaction-based arm assistance system CAS (**1**), human–machine interface forearm rest (**2**), experimental task 'line tracing' (**3, L**) and 'trajectory tracing' (**T**) as 3D model with exemplary representation of the movement anteversion as an arrow, monitor for live view of the trajectory (**4**), height-adjustable table (**5**), movable tabletop (**6**)

strap. The arm support is controlled solely by a form fit and frictional connection of the forearms with the forearm support of the CAS. Investigations show an influence of the anthropomorphic shape of the form on objective and subjective operability of the arm assistance system and an advantage of the anthropomorphic shape of the form over no support and a flat form (Langer et al. 2022). It follows that the interface parameters form and material of the forearm support are criteria for effective and efficient interaction with the CAS. These interface parameters are being investigated as part of the research project (DFG 430136438).

This study aims to investigate the objective and subjective usability of the forearm support form using five percentile- and gender-adapted, anthropomorphic, open U-shapes form variants. The aim of this study is to gain knowledge about the objective and subjective usability of the form of the forearm support in the context of dynamic and static operating scenarios with the arm assistance system.

2 Methodology

In order to investigate the form of the forearm support, a trial scenario, based on different precision tasks, is set up and a subject study is performed. The selection of subjects is based on the characteristics age between 18 and 67 and no physical limitations in the shoulder, arm and hand area of the dominant hand. 32 subjects (age: Ø = 24.6 years, SD = 5.3 years, Range = 18–42 years; 37.5% female (f); 62.5% male (m)). The subjects were 93.7% right-handed and 6.3% left-handed. At the beginning, the body measurements of the subjects are recorded according to DIN EN ISO 7250-1 (2017) (Height: Ø = 178.9 cm, SD = 7.7 cm, Range = 162.2–194.5 cm; Elbow Wrist Length: Ø = 28.9 cm, SD = 1.7 cm; Range = 25.5–32 cm). The forearm circumference of the test subjects was measured in three different arm postures (according to DIN EN ISO 7250-1:2017), anthropometric database iSize (Avalution GmbH 2009) and most common usage posture of the arm assistance system during the study: 90° flexion between forearm and upper arm). The average was calculated (Forearm circumference: Ø = 27.0 cm, SD = 2.6 cm, Range = 23.1–34.7 cm). The forearm circumference can be assigned closest to the iSize classification of the 5th percentile for 5 subjects (f = 21.8 cm, m = 25.4 cm), to the 25th percentile for 11 (f = 23.4 cm, m = 27.1 cm) and to the 50th percentile for 10 subjects (f = 24.6 cm, m = 28.4 cm). The same applies to the 75th percentile for 3 (f = 26.0 cm, m = 29.8 cm) and to the 95th percentile for 3 subjects (f = 28.6 cm, m = 32.2 cm) (Avalution GmbH 2009). 18.7% of the subjects have prior experience interacting with arm assistance systems.

The first dynamic precision task is ‘line tracing’. The forearm is bent 90° (flexion). The test person takes a stylus in his hand like a pen (see Fig. 1L). The tip of the stylus consists of a metal rod (diameter = 2 mm). This is used to trace lines (width = 5 mm) in a metal plate, avoiding contact between the two in the style of the motor performance series (Schuhfried GmbH 2015). By touching a metal plate below the line at the beginning and at the end of the line, the subject starts and stops the task

independently. A contact between the metal bar of the stylus and the edges of the line is counted as an error. The number of errors, the duration of the errors and the execution time of the line tracing are recorded. The metal plate contains different lines that are traced one after the other. Straight lines are executed in abduction and adduction directions of the upper arm as well as in the anteversion and retroversion directions. A zigzag line is also executed in the abduction and adduction direction. Abduction and adduction occur depending on handedness. The height of the task is adjusted at the beginning of the experiment to suit the subject.

The second dynamic precision task 'trajectory tracing' consists of pushing an abstracted, minimally invasive instrument for laparoscopic surgery with a hole (diameter = 8.4 mm) over a rod (diameter = 3.0 mm), avoiding contact between the two. The trajectory is covered and transmitted live by a camera to a screen in front of the subject to mimic an abstracted minimally invasive task (see Fig. 1T). The direction of movement of the 90° flexed forearm corresponds to anteversion of the upper arm. By a contact at the start and the end of the movement, the objective parameters number of contacts (number of errors) of the instrument with the rod, duration of the errors and execution time are recorded.

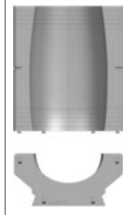
In addition to the dynamic precision tasks, a static task is performed. The stylus of the line tracing task is held in a hole (diameter = 5.2 mm) for 32 s, whereby contact between the metal plate and the stylus must be avoided (Schuhfried GmbH 2015). The number of contacts (number of errors) of the stylus with the metal plate and the duration of the errors are recorded. In the first run, the forearm is flexed to the upper arm by 90° (flexion) and in the second by 120°. After the start position is taken by the subject, the researcher starts the time.

In each task five anthropomorphic shapes of form of the forearm support (05P, 25P, 50P, 75P, 95P) are examined (see Table 1). The length of the forearm rest is adjustable in 5 mm steps due to a modular design. The length of the forearm rest corresponds to 40% of the forearm length of the individual subject. The support position is centered at 30% of the forearm length distal to the olecranon (Karlovic 2019).

The anthropomorphic negative shapes of the forearm support forms correspond gender-specifically to the 5th-, 25th-, 50th-, 75th- and 95th-percentile adults from RAMSIS NextGenAutomotive 1.5 (see Table 1). Table 1 also lists the largest diameter (major semi-axis of the ellipse along the y-axis) of the anthropomorphic negative shape and the orthogonal minor semi-axis of the ellipse (along the z-axis). The forearm rest is mounted with lateral and medial as well as flexion and extension degrees of freedom.

The precision tasks are performed as a practice first without support and then with a flat form to familiarize the subject with the arm assistance system. Then the tasks are performed with the anthropomorphic forms. To avoid habituation effects, the order of the form percentiles is randomized. The support force provided by the arm assistance system is set according to the bodyweight (support force: Ø = 24.2 N, SD = 4.2 N, Range = 16.2–37 N) (Karlovic 2019). The precision tasks and their objective parameters are selected because they record the result of task performance in contrast to recording physiological metrics of the subject. The posture of the upper

Table 1 Rendering of the forms of the forearm support (male) and the largest diameter (major semi-axis of the ellipse along the y-axis) with its orthogonal semi-minor-axis of the ellipse (along the z-axis) of the form (female ♀, male ♂)

Percentile of the form (P)		05P	25P	50P	75P	95P
Shape of the form of the forearm support (top view and back view)						
Largest diameter/ Orthogonal semi-minor-axis [mm]	♀	70.1/63.8	76.8/69.9	81.5/74.1	86.1/78.3	92.6/84.2
	♂	80.5/75.5	86.9/81.6	91.4/85.8	95.9/90.0	102.4/96.1

arm and the respective flexion of the forearm to the upper arm is controlled with line lasers in all tasks throughout the study.

In addition to the objective parameters, a subjective evaluation is carried out on the comfort and accuracy of fit of the respective form as well as the perception of precision, the feeling of safety and the promotion of task performance by the form. This is done with a bipolar 7-point Likert scale that is verbalized at anchor points after each task as well as after the study across all tasks.

3 Results

The results of the objective errors per second and the subjective comfort of the form during the execution of the line tracing tasks are shown in Fig. 2. When evaluating the results of line tracing, two subjects are excluded due to technical malfunctions.

Figure 2a shows the average errors per second of the tasks line tracing broken down by the form percentiles and the subjects' forearm percentiles to evaluate the overall performance of the form. These result from the average errors per second of all task executions per subject in the line tracing tasks. Figure 2a 05-95SP shows the average errors per second of all line tracing tasks for the subjects independent of their forearm percentile. The average errors per second across all subjects range from 0.52 errors per second (SD = 0.32, Median = 0.50 errors per second) for the 25P form to 0.55 errors per second (SD = 0.31, Median = 0. 57 errors per second) for the 75P form (see Fig. 2a 05-95SP). The distribution of errors per second of the specific subject percentiles (05SP to 95SP) is shown in Fig. 2a 05SP to 95SP. The average execution time at the line tracing tasks is 10.27 s (SD = 3.53, Median = 9.44 s) for the 05P, 10.08 s (SD = 3.10, Median = 10.11 s) for the 25P, 9.84 s (SD = 3.01, Median = 9.24 s) for the 50P, 9.96 s (SD = 3.58, Median = 9.06 s) for the 75P, and 9.77 s (SD = 3.30, Median = 8.77 s) for the 95P form.

Figure 2b shows the response distribution of the subjects on a 7-point Likert scale (−3 = strongly disagree, 0 = neutral, 3 = strongly agree) to the statement 'The form is comfortable.' for all subjects broken down by the form percentiles (P) and the subjects' forearm percentiles (SP). Across all subject percentiles, the 25P and 50P forms are perceived as more comfortable on average than either the smaller or the larger shapes (Fig. 2b 05–95SP). Subjects assigned to the 05-percentile forearm find the 05P form more comfortable than larger forms (Fig. 2b 05SP). For the 25-percentile subjects, it appears that 05P to 50P is perceived to be more comfortable than larger variants of the shape of the forms. However, 25P and 50P are perceived as more comfortable than 75P and 95P (Fig. 2b 25SP). 50-percentile subjects perceive 50P as more comfortable than smaller or larger forms (Fig. 2b 50SP). In the 75-percentile group of subjects, the 50P and 75P forms are perceived as more comfortable than smaller forms or 95P (Fig. 2b 75SP). 95-percentile subjects find the larger forms 50P to 95P more comfortable than 25P and distinctly more comfortable than 05P (Fig. 2b 95SP).

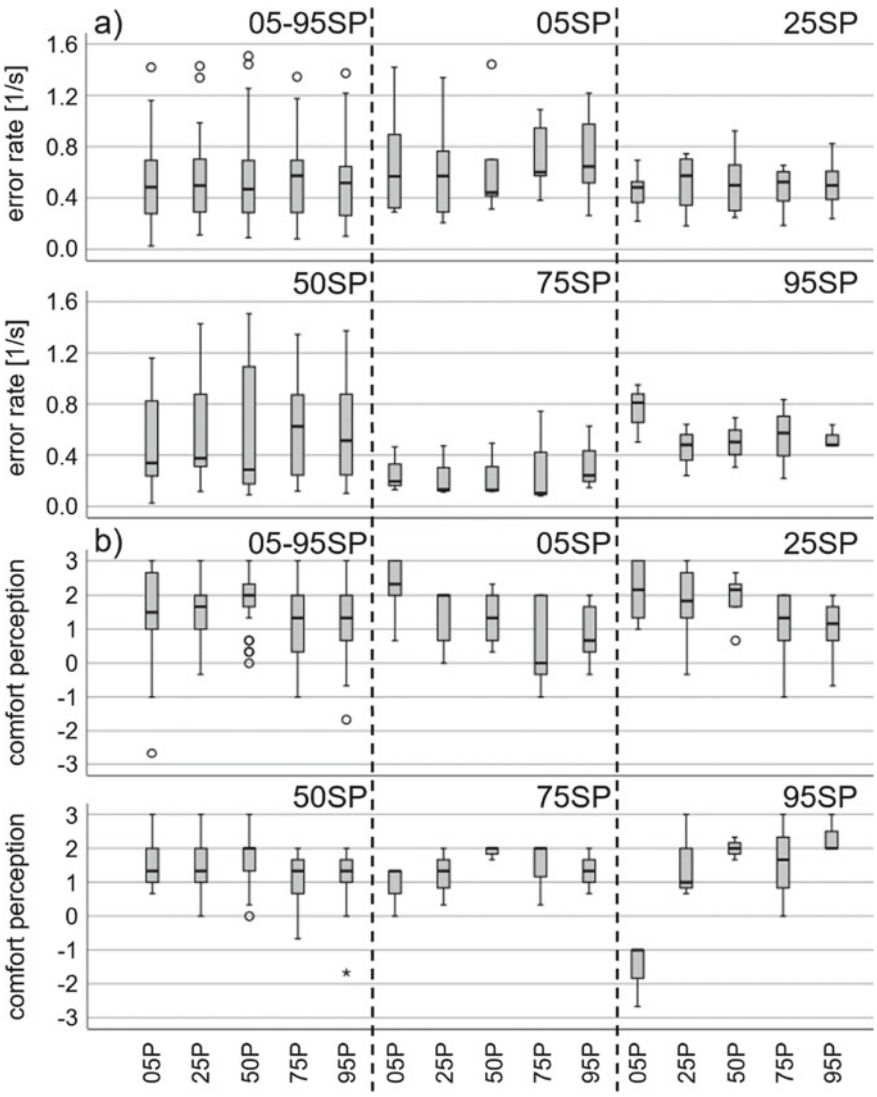


Fig. 2 Average error rate (errors per second) (**a**) and comfort perception (**b**) for the tasks line tracing, broken down by the form percentiles (P) and the subjects' forearm percentiles (SP; 05-95SP = all subjects, 05SP = 5-percentile subjects etc.)

Figure 3a shows the errors per second for the task trajectory tracing across all subject percentiles. The average errors per second across all subjects (05-95SP) range from 1.47 errors per second (SD = 0.43, Median = 1.39 errors per seconds) for 50P to 1.70 errors per second (SD = 0.67, Median = 1.80 errors per second) for the 95P form.

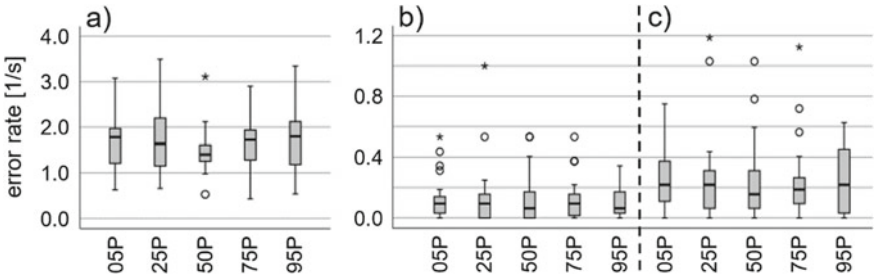


Fig. 3 Error rate (errors per second) for the task trajectory tracing across all subject percentiles (**a**) and error rate for the tasks steadiness 90° (**b**) and 120° (**c**) across all subject percentiles

Within the different form percentiles, on the Likert scale the average comfort per form percentile is between 1 and 2 in the trajectory task, which can be verbalized rather comfortable to comfortable.

Figure 3b and c shows the errors per second for the tasks steadiness 90° and 120° across all subject percentiles. The average errors per second across all subjects (05-95SP) for the task steadiness 90° range from 0.11 errors per second (SD = 0.14, Median = 0.05 errors per second) for the 95P form to 0.14 errors per second (SD = 0.21, Median = 0.07 errors per second) for the 25P form (compare Fig. 3b). For the task steadiness 120° the range is between 0.22 errors per second (SD = 0.23, Median = 0.16 errors per second) for the 75P form to 0.27 errors per second (SD = 0.32, Median = 0.22 errors per second) for the 25P form (compare Fig. 3c).

In the task steadiness 120°, 2 subjects had to stop the test with the form 05P because of slipping. The same applies to one subject with the form 25P, 3 subjects with 50P, 2 subjects with 75P and 4 subjects with the form 95P. As a comparison, 7 subjects slipped in the exercise prior to performing the experiment with the flat form. In terms of the subjective comfort of the form during the steadiness tasks, all forms are rated as more comfortable on average during flexion by 90° than during flexion by 120°.

Within the different form percentiles, on the Likert scale the average comfort per form percentile is between 1 (verbalization: rather comfortable) and 2 (verbalization: comfortable) for 90° flexion and 0 (verbalization: neutral) and 1 (verbalization: rather comfortable) for 120° flexion.

In the post-study survey, subjects are asked, among other issues, which form was the most comfortable and which was the least comfortable. For this purpose, the test subjects are allowed to try out the forms again in contrast to each other. Figure 4a shows the results of the post-survey on the most comfortable form and Fig. 4b of the most uncomfortable form, broken down by the form percentiles (P) and the subjects' forearm percentiles (SP) relative to the sample number (SN). It can be seen that 100% of the 5-percentile subjects (SN = 5) find the 5-percentile form to be the most comfortable. In contrast, 80% of this sample perceive the 95th percentile form as the most uncomfortable. Among the 25-percentile subjects (SN = 11), 45.5% find the 5-percentile form, 27.3% the 25-percentile form, and 18.2%

the 50-percentile form most comfortable. 80.9% find the 95-percentile form most uncomfortable. 30% each of the 50-percentile subjects (SN = 10) find the 5-, 25- and 50-percentile forms and 10% the 75-percentile form most comfortable. In contrast, 20% find the 5-percentile form and 60% the 95-percentile form most uncomfortable. One 50-percentile subject (10%) made no statement about the most uncomfortable form. Among the 75-percentile subjects (SN = 3), 33.3% each find the 05- and 25-percentile forms most comfortable, and 33.3% find the 95-percentile form most comfortable. 66.6% of them find the 95-percentile form most uncomfortable and 33.3% the 5-percentile form. Of the 95-percentile subjects (SN = 3), 33.3% find the 25-percentile form and 66.6% find the 95-percentile form most comfortable. 100% on the other hand, find the 5-percentile form most uncomfortable.

In the post-study questioning about which form provides the most safe task performance, of all subject percentiles, 53.1% indicate the 05P form, 21.9% the 25P, 12.5% the 50P, 6.3% the 75P, and 3.1% the 95P form. When asked which form provides the most precise task performance, 43.7% indicate the 05P form, 28.1% the 25P, 9.4% the 50P, 6.3% the 75P, and 9.4%the 95P form. Both questions are not answered by one respondent (3.1%) each.

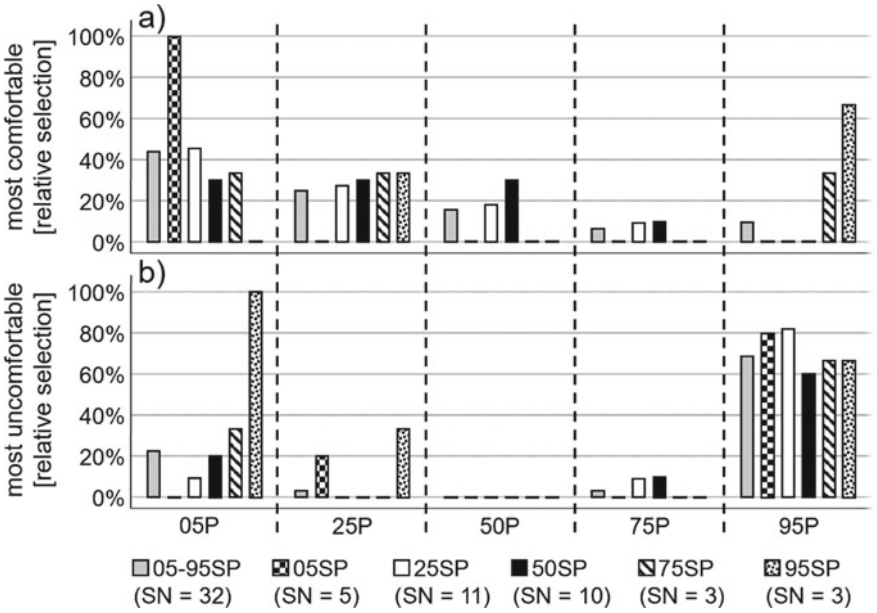


Fig. 4 Results of the post-study survey on the comfort of forms, broken down by the form percentiles (P) and subjects' forearm percentiles (SP) relative to the sample number (SN); most comfortable form (**a**), most uncomfortable form (**b**)

4 Discussion

The results of the objective parameter errors per second reveal no correlation between the form percentiles and the subject percentiles at the task line tracing (see Fig. 2a). At the same task there are differences in the perception of comfort by different subject percentiles, especially at the edges of the form percentiles (see. Fig. 2b). The survey shows that subjects find the form that corresponds to their forearm percentile comfortable. The edge percentile of the form 05P is perceived by the diametric subject percentile 95SP as considerably less comfortable (see Fig. 2b 95SP). For the tasks trajectory tracing and steadiness 90° and 120° the form and subject percentiles result in no correlation to the objective parameters examined in this study, the number of errors or errors per second (see Fig. 3). The static precision task steadiness shows that, on average, the forms are rated less comfortable at a forearm flexion of 120° than at a flexion of 90°.

The post-study survey shows that subjects prefer form percentiles close to their own forearm percentile and, on the other hand, find forms that are too large or small uncomfortable. Compared with the distribution of subject percentiles, the follow-up survey shows that smaller form percentiles are preferred in terms of safety and precision. It follows that the shape of the form influences the usability of the main task depending on the operating scenarios. In particular, subjective usability in terms of comfort and discomfort is influenced by the percentile-adapted form in the different tasks (see Figs. 2b and 4).

A weakness of the study is the limited selection of precision tasks as well as arm postures and the short task execution time or interaction time per subject and form. This should be considered in following studies. In contrast, the strength of the study is that five gender-specific form percentiles (05P to 95P) are examined regardless of a subject's forearm percentile. Thus, conclusions can be drawn about the parameter anthropomorphic shape of the form of a forearm support. In further studies, the parameter material consisting of surface and cushioning will be investigated in relation to the usability of the human–machine interface forearm support. Furthermore, it is interesting to investigate the parameter form for other support positions such as support of the distal forearm. For the future use of arm assistance systems, topics such as the integration of the arm assistance system into the surgical procedure and the interaction of the human with the system are worth investigating.

5 Conclusions

The study shows an influence of percentile-adapted forms on the usability of forearm supports at an arm assistance system. The form percentile results in no correlation to the number of errors or error rate. On the other hand, there are differences in the perception of comfort by different subject percentiles, especially at the edges of the form percentiles. It can be concluded that in terms of comfort, individual selection

of the form by the user may be preferred. However, for reasons of practicality and economy, it can be deduced from the results that the edges of the form percentiles (05P and 95P) should not be used. It is advisable to provide the two forms 25P and 75P or singly the 50P form, depending on gender, in order to cover the range of users.

Acknowledgements This research work was funded by the German Research Foundation (DFG) as part of the research project "Usability-Optimierung der Interfaceparameter Form und Material bei einem interaktionsbasierten Armassistenzsystem" (eng.: "Usability optimization of the interface parameters form and material in an interaction-based arm assistance system") (project number 430136438).

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Comparing the Active, Functional, and Passive Range of Motion of Finger Joints Using Dynamic Measurement

Tianyun Yuan, Yu Song, Richard H. M. Goossens, and Gerald A. Kraan

Abstract Studies on finger kinematics, especially the range of motion (RoM) measurements, are essential to understand the use of finger joints and the pathology of related disease. Limited literatures compared the active RoM (A-RoM) of finger joints with either their functional RoM (F-RoM) or passive RoM (p-RoM) using different measuring protocols and tools. This study aims to provide an overall comparison including all three types of RoMs. We measured A-RoM, F-RoM, and P-RoM, using a dynamic measurement system. Our goal is to investigate the relationships among the three RoMs by comparing their extreme rotation angles. The results suggested that P-RoM was the largest motion range, and F-RoM can exceed their A-RoM. The F-RoM of distal-interphalangeal joints may rotated 8–20° more than their A-RoM, mainly during precise and power manipulations. Besides to A-RoM, knowledge of F-RoM and P-RoM are also important for a comprehensive understanding for clinical practice, and thus, to support the optimization and evaluation of treatment devices for finger joint, such as implant replacement.

Keywords 3D motion analysis · Activities of daily living · Finger kinematics

1 Introduction

Range of motion (RoM) is one of the fundamental measurements (Lea and Gerhardt 1995) for studying the biomechanics and kinematics of finger joints. This understanding is crucial to the pathology study and treatment designs for related diseases. However, the significant flexibility of hand fingers challenges the measurement and the study on these joints. There are three types of RoM: active, passive, and functional RoMs (A-RoM, P-RoM, F-RoM). A-RoM presents the maximum motion range

T. Yuan (✉) · Y. Song · R. H. M. Goossens
Delft University of Technology, Delft, The Netherlands
e-mail: T.Yuan@tudelft.nl

G. A. Kraan
Reinier HAGA Orthopaedic Center, Zoetermeer, The Netherlands

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when the participants perform movements without any assistance; P-RoM is similar to the active one, but it covers the maximum motion range when the participants perform movements with an external force; F-RoM refers to the motion range for the participants to perform a spectrum of activities of daily living.

A great number of articles measured the RoMs of hips and knees during active or loading scenarios (Hemmerich et al. 2006; Kono et al. 2022), and these studies have contributed to the improvement of the implant designs for hips and knees (Mulholland and Wyss 2001; Dennis et al. 1998; Hirata et al. 2015). On the contrary, limited literatures reported the measurement of finger joint RoM, and only several of them compared the A-RoM with either F-RoM or P-RoM (Bain et al. 2015; Gracia-Ibáñez et al. 2017; Hume et al. 1990; Jarque-Bou et al. 2020; Mallon et al. 1991). In addition, these researchers adopted different study protocols and measuring tools. For example, an early study measured the A-RoM and P-RoM of index to small fingers using a goniometer (Mallon et al. 1991), and recent studies utilized a data glove to collect continuous data of finger joints during active and functional hand movements (Gracia-Ibáñez et al. 2017; Jarque-Bou et al. 2020). Most studies concluded that the F-RoM was within the range of the A-RoM (Bain et al. 2015; Gracia-Ibáñez et al. 2017; Hume et al. 1990), but one of the them mentioned that joints extension exceed the A-RoM in some moments of functional activities (Gracia-Ibáñez et al. 2017).

In this study, we aim to challenge the conclusion drawn from current literature by comparing the A-RoM, F-RoM, P-RoM of hand joints. Using an optical tracking system, we continuously measure the rotation angles of target joints during hand activities. Taking the extreme rotations as the boundaries of the RoMs, the initial hypothesis is: the F-RoM is smaller than the A-RoM, and the P-RoM covers both the A-RoM and F-RoM. Since not all three RoMs were combined in one study previously, examining all three ranges in one study can benifit a comprehensive understanding of finger joint movement.

2 Method

2.1 Measuring System

To acquire continuous joint rotation angles through hand activities, we used an optical tracking system with an accuracy 2.7° and a reproducibility 0.8° (Yuan et al. 2022). One part of the system consisted of five RGB cameras (GoPro Inc., San Mateo, CA, USA) which were strategically positioned around the tracking area, as Fig. 1a. All the cameras were in wide-view mode with 5 K (3280 × 2250) resolutions and 30 fps (frame-pre-seconds). The other part of the system consisted of 20 printed ArUco markers attached to the dorsal side of finger segments. ArUco markers are a type of fiducial markers that enable researchers to extract the orientation and the position of each marker in the camera coordinate system from a 2D image (Garrido-Jurado et al. 2014), and thus, to track the movement of each finger segment. The markers were

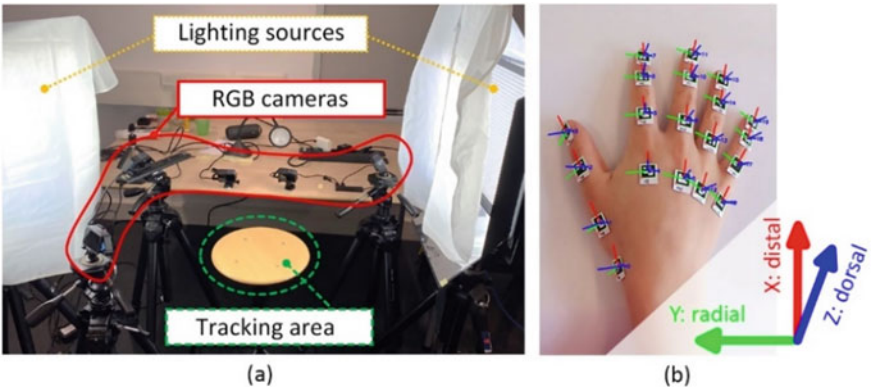

Fig. 1 The applied tracking system. **a** the setup of the cameras and lightening; **b** the marker placement and the corresponding local coordinate system

prepared in three sizes (side length): 7.0 mm, 8.6 mm, and 10.0 mm, for different hand sizes (DINED 2022). During the participation, all markers were coarsely aligned by placing the x-axis of the markers pointing towards the fingertips as Fig. 1b: each marker represented a finger segment.

2.2 Study Protocol and RoM Definition

This study included 20 participants (10 males and 10 females) without a history of hand disability or hand surgery. The average age was 31 years (range 21–59 years old). The Human Research Ethical Committee of Delft University of Technology approved this study. All participants signed the consent form before their participation and indicated their right hand as the dominant hand. The sample size was calculated for the two-tailed Wilcoxon signed-rank test (matched pairs) with an effect size of 0.8 and power of 0.9; and this sample size also effects for the one-tailed test with an effect size of 0.8 and power of 0.95 (Faul et al. 2009).

After attaching the markers, participants performed a set of actions in Fig. 2. The figure illustrates some critical posture for the active and passive activities, as well as some potential postures for the functional activities. Action (A1)–(A4) measures the A-RoM, including radial-ulnar (rad-uln) deviation of all fingers, and flexion–extension (flx-ext) of all finger joints. In these actions, we guided the participants to actively bend or rotate their fingers as much as they can. Action (P17)–(P19) also include similar movements, but with an external force applied on the fingers. These actions correspond to the P-RoM. We instructed participants to press the finger segment by themselves and increase the force gradually to the maximum that they can accept to avoid any pain or injury during their participation. Lastly, twelve daily activities were measured for the F-RoM. After comparing the included activities in

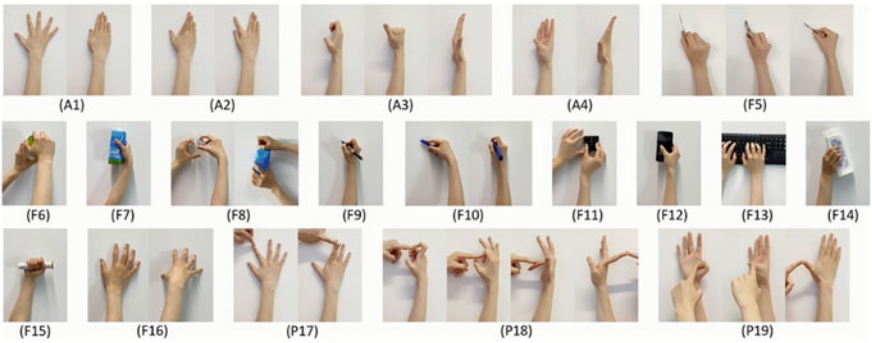

Fig. 2 Illustrations of included activities. Action (A1)–(A4): active activities, action (F5)–(F16): functional activities, action (P17)–(P19): passive activities

previous literature (Bain et al. 2015; Gracia-Ibáñez et al. 2017; Hume et al. 1990; Jarque-Bou et al. 2020; Halilaj et al. 2014), action (F5)–(F12) and (F14)–(F15) were selected to cover the most frequent grasp activities in daily life (Bullock et al. 2013); besides, action (F13) and (F16) represents non-prehensile actions (Dollar 2014).

With the rotation angles of all frames, each type of RoM was defined with the extreme rotation angles of the corresponding actions; from the minimal to the maximum values of the rotation angles.

2.3 Rotation Calculation

We first calculated the rotation of the target joints by extracting the 3D orientations of each marker frame by frame with a self-developed Python program and the OpenCV Library (Yuan et al. 2022). These detected orientations served as the local coordinate system (LCS) for the corresponding finger segments. The analysis included 18 joints: interphalangeal joint (IPJ), metacarpophalangeal joints (MPJ for thumb), and trapeziometacarpal joint (TMCJ) of thumb; distal interphalangeal joint (DIPJ), proximal interphalangeal joint (PIPJ), metacarpophalangeal joint (MCPJ), and carpometacarpal joint (CMCJ) of index to small fingers. Colored markers in Fig. 3a represent the joints, and the numbered squares indicate the markers of the corresponding finger segments. The rotation estimation of a joint was based on two adjacent LCSs: R_{dis} and R_{prx}, which are for the distal and proximal finger segments. For example, the rotation of the TMCJ was calculated from $R_{dis} = R_1$ and $R_{prx} = R_0$. Note that the calculation of the CMCJ of long fingers was relative to the 3rd metacarpal (marker number: 8) (Cooney et al. 1981). For example, the rotation of CMCJ-2 used $R_{dis} = R_4$ and $R_{prx} = R_8$. Here, the CMCJs and TMCJ analyzed in this study were based on the applied simplified kinematic model in Fig. 3a, which is based on but differ from hand anatomy.

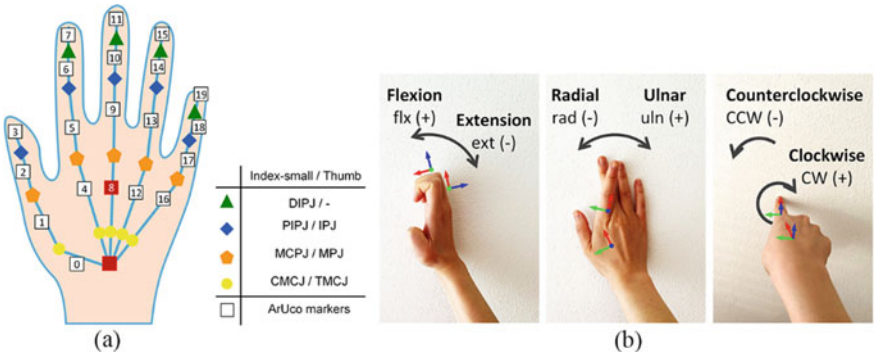

Fig. 3 **a** The applied simplified hand kinematics model and the corresponding markers. **b** The notation and the descriptions of the rotations along the three axes

Knowing the two LCSs, the rotation calculation employed the transformation matrix T in between: $R_{dis} = TR_{prx}$. The rotation angles were the Euler angles following the X–Y–Z sequence as suggested in the ISB (Wu et al. 2005). The positive values indicate flexion, radial deviation, and clockwise rotation (see Fig. 3b).

2.4 Statistical Analysis

With all three types of RoMs: A-RoM, F-RoM, and P-RoM, the normality of the extreme rotation angles of each range was first examined using the Shapiro–Wilk test. Consequently, the matched boundary values were compared using the Wilcoxon signed-rank (two-tailed) test to investigate if there were any differences between these ranges. The null hypothesis was that the extreme rotation angles of any two types of ranges are the same; for example, the maximal flx-ext angles of a joint during active movements is equal to the one during functional activities. Followingly, one-tailed Wilcoxon signed-rank tests were applied to study the relationships among the boundary values. In this study, P-value smaller than 0.05 was considered statistically significant.

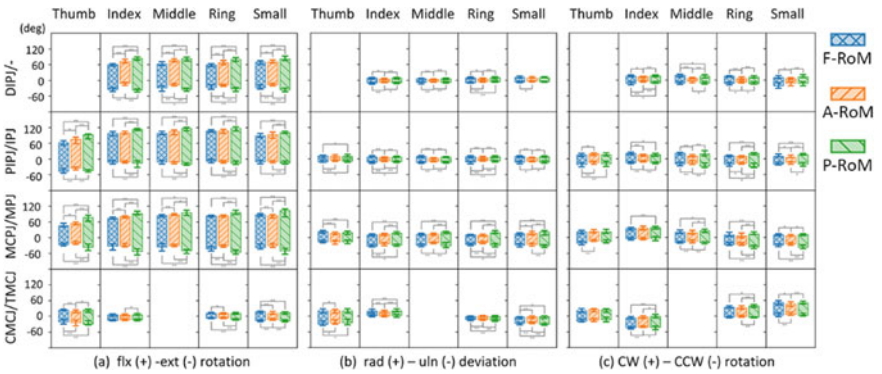

Fig. 4 The medium, 25, and 75 percentiles of the boundaries of the F-RoM, A-RoM, P-RoM of target joints of all participants, and the result of the two-side matched-pair statistical analysis. **a** flexion–extension rotation; **b** ulnar-radial deviation; **c** self-rotation. Vertical unit: degrees. "CW-CC": clockwise – counter-clockwise; "*", "**": the p-value is less than 0.05 or 0.01

3 Results

3.1 The Measured A-RoM, F-RoM, P-RoM

The extreme values of three RoMs along the three rotation axes had 324 sets of boundary values for comparison. The normality analysis of these boundary values suggested that 16% of their distribution failed to fit a normal distribution, and thus, Wilcoxon signed-rank tests was applied in the following statistical analysis.

The corresponding extreme values were compared between any two types of RoMs along each rotation axis (the RoMs of CMCJ-3 were excluded since the 3rd metacarpal bone was used as the reference). The two-tailed analysis suggested statistical differences between A-RoM and P-RoM for most joins as expected. Also, the differences were observed for the flx-ext F-RoM and A-RoM of some joints (see Fig. 4).

3.2 The Difference Among the Three RoMs

The differences between any two types of RoMs were calculated to assess the initial hypothesis: max(F-RoM) < max(A-RoM) < max(P-RoM), and min(F-RoM) > min(A-RoM) > min(P-RoM). Table 1 presents the mean (±SD) of all participants; where positive values support the hypothesis and negative values contrast the initial hypothesis. According to Table 1, larger F-RoM than A-RoM was found in extension, especially for most DIPJ and IPJ; the difference was about 8–20 degrees. Conversely, most differences between maximum boundaries were positive, which means that the

functional flexion range was within the active one. The negative differences for rad-uln deviation and self-rotation suggested that F-RoM are larger than the corresponding A-RoM in these rotations. The majority of the difference between A- and P-RoM are positive with statistical significance (see Table 2). Although a few pairs showed slightly negative differences, none of them presented significance. Similarly, no statistical significance was found in the negative differences in Table 3.

4 Discussion

The goal of this study was to compare A-RoM, F-RoM, and P-RoM that measured with continuous data during hand activities. The findings partially agreed with the initial hypothesis, as P-RoM was generally the largest motion range among the three and it covers A-RoM and F-RoM. The measurement in this study were consistent with previous literature (Bain et al. 2015; Gracia-Ibáñez et al. 2017; Hume et al. 1990); however, our F-RoM is larger than theirs, and the findings partially invalidate the hypothesis that A-RoM covers F-RoM.

Comparing the boundaries of F-RoM and A-RoM (see Table 1) revealed that the rotation of hand joints can exceed their A-RoM during functional activities in joint extension, rad-uln deviation, and self-rotation; especially, the differences were pronounced for the extension of MCPJ and DIP/IPJ. This finding disagreed with the conclusion of previous literature (Bain et al. 2015; Gracia-Ibáñez et al. 2017; Hume et al. 1990). The definition of the RoMs can affect the results. In some studies, this phenomenon was mentioned, but the extreme values were excluded (Bain et al. 2015; Gracia-Ibáñez et al. 2017). Differently, we included all possible rotation angles during the functional activities, as these moments may be the key movement for the functional tasks.

The definitions of the A-RoM and P-RoM have little dispute as all studies defined them with the maximum and the minimum rotation angles of the collected data. In contrast, the definition for the F-RoM has two major approaches: (1) take the extreme range of the collected data, (2) use percentiles of the measurement, usually 90% of the extreme range. In this study, we adopted the first approach; we defined all three RoMs with the maximal and minimal rotation angles observed in the data. This method requires high-quality data, because any outliers in the measurement could influence the range. Contrarily, defining RoMs with percentiles of the measurement is more robust, but this can exclude extreme information. For instance, during the performance of a functional task, the duration of the extreme posture with large rotation angles is short, then this only accounts for a small percentage of the full movement and this large rotation angle is excluded. In this study, the extreme rotation angles were included, because although the duration of these hyper-rotations might be short, they are still part of the full activities.

Besides, the measuring approaches can introduce measurement differences among studies. This study applied an optical tracking system to collect continuous data of joint rotation angles and adopted LCS in space in the calculation. The advantage of

Table 1 Differences between F-RoM and A-RoM

	Flexion	Extension	Radial	Ulnar	CW	CCW
	(Amax-Fmax)	(Fmin-Amin)	(Amax-Fmax)	(Fmin-Amin)	(Amax-Fmax)	(Fmin-Amin)
TMC-1	−4.8 (±6) *	3.0 (±5) *	−2.6 (±5) *	−4.0 (±8) *	2.0 (±7)	−3.1 (±8)
MP-1	6.0 (±9) *	−5.8 (±13)	−6.9 (±8) *	1.0 (±4)	1.5 (±10)	−9.8 (±7) *
IP-1	7.9 (±15) *	−9.6 (±8) *	0.9 (±4)	−4.0 (±6) *	3.9 (±7) *	−7.9 (±7) *
CMC-2	−1.5 (±5)	−1.6 (±3)	−1.6 (±2) *	1.5 (±4)	1.8 (±4)	−5.6 (±6) *
MCP-2	5.1 (±7) *	−4.5 (±17)	0.8 (±6)	−6.6 (±6) *	1.9 (±7)	−0.6 (±8)
PIP-2	4.6 (±11)	−1.4 (±6)	−3.4 (±4) *	−5.3 (±5) *	−6.3 (±8) *	−6.3 (±6) *
DIP-2	11.6 (±13) *	−20.2 (±13) *	−3.1 (±5) *	−4.9 (±6) *	−4.3 (±8) *	−10.0 (±11) *
CMC-3	/	/	/	/	/	/
MCP-3	5.3 (±7) *	−5.7 (±19)	0.6 (±5)	−10.9 (±9) *	−2.2 (±9)	−4.5 (±6) *
PIP-3	2.9 (±9)	1.6 (±8)	−6.1 (±6) *	−5.3 (±4) *	−9.0 (±6) *	−6.3 (±6) *
DIP-3	12.4 (±8) *	−12.4 (±15) *	−2.5 (±5) *	−3.4 (±6) *	−9.8 (±9) *	−3.4 (±9)
CMC-4	−1.3 (±3) *	−1.4 (±4)	1.1 (±2)	−1.5 (±2) *	−2.1 (±6)	−1.5 (±5)
MCP-4	0.7 (±7)	−10.2 (±13) *	−1.5 (±5)	−6.6 (±5) *	−2.1 (±7)	−1.9 (±10)
PIP-4	−0.6 (±10)	2.9 (±6)	−4.5 (±7) *	−8.4 (±9) *	−3.4 (±8)	−4.0 (±7) *
DIP-4	9.8 (±9) *	−8.4 (±9) *	−2.5 (±6) *	−3.7 (±4) *	−7.9 (±7) *	−3.0 (±9) *
CMC-5	−4.4 (±4) *	−4.5 (±4) *	2.5 (±3) *	−3.4 (±3) *	−4.8 (±9) *	−2.7 (±5) *
MCP-5	−5.6 (±7) *	−5.1 (±12)	3.4 (±5) *	−3.1 (±10)	−2.3 (±11) *	−4.1 (±11)
PIP-5	1.4 (±12)	−0.5 (±4)	−4.4 (±5) *	−4.5 (±6) *	−3.2 (±6) *	−3.5 (±8)
DIP-5	5.1 (±14) *	−8.2 (±9) *	−1.9 (±8)	−2.2 (±7) *	−4.2 (±7) *	−4.0 (±15)

*: p-value < 0.05

Table 2 Differences between A-RoM and P-RoM

	Flexion	Extension	Radial	Ulnar	CW	CCW
	(Pmax-Amax)	(Amin-Pmin)	(Pmax-Amax)	(Amin-Pmin)	(Pmax-Amax)	(Amin-Pmin)
TMC-1	4.2 (±9) *	1.4 (±4)	3.3 (±8)	−0.7 (±9)	−0.2 (±7)	0.9 (±9)
MP-1	18.7 (±13) *	17.9 (±16) *	1.4 (±8)	−1.3 (±4)	−0.1 (±11)	4.4 (±11)
IP-1	13.6 (±18) *	8.9 (±9) *	1.3 (±5)	1.8 (±4)	−1.0 (±8)	1.9 (±8)
CMC-2	2.0 (±3) *	1.8 (±7)	3.6 (±4) *	−0.5 (±5)	3.5 (±5) *	3.6 (±6) *
MCP-2	11.5 (±21) *	23.7 (±12) *	6.0 (±4) *	3.3 (±8)	3.1 (±9)	−1.1 (±5)
PIP-2	11.5 (±7) *	8.1 (±10) *	2.4 (±3) *	3.0 (±2) *	1.7 (±5)	6.9 (±6) *
DIP-2	9.9 (±8) *	24.2 (±10) *	2.6 (±3) *	3.2 (±6) *	5.4 (±8) *	4.8 (±4) *
CMC-3	/	/	/	/	/	/
MCP-3	5.4 (±23) *	21.7 (±9) *	7.0 (±5) *	10.0 (±9) *	7.1 (±11) *	4.8 (±6) *
PIP-3	11.8 (±10) *	7.4 (±7) *	4.6 (±8) *	4.0 (±5) *	9.7 (±7) *	10.0 (±8) *
DIP-3	3.0 (±15) *	17.2 (±14) *	4.1 (±6) *	2.7 (±4) *	7.3 (±7) *	5.1 (±11) *
CMC-4	0.4 (±3)	5.7 (±4) *	−0.9 (±2)	3.2 (±3) *	7.6 (±8) *	4.1 (±6) *
MCP-4	12.2 (±20) *	22.0 (±10) *	11.2 (±8) *	10.9 (±7) *	7.8 (±8) *	10.9 (±11) *
PIP-4	9.0 (±11) *	5.2 (±6) *	5.1 (±8) *	3.6 (±5) *	11.3 (±7) *	10.6 (±10) *
DIP-4	8.0 (±15) *	15.7 (±9) *	2.9 (±4) *	1.0 (±3)	8.1 (±11) *	2.5 (±5) *
CMC-5	1.5 (±5)	6.1 (±3) *	−0.0 (±2)	5.5 (±6) *	6.8 (±8) *	1.5 (±6)
MCP-5	15.3 (±23) *	20.5 (±16) *	3.4 (±4) *	4.8 (±6) *	2.2 (±10) *	10.2 (±10) *
PIP-5	9.9 (±10) *	3.6 (±4) *	3.7 (±5) *	2.4 (±4) *	8.4 (±7) *	4.7 (±9) *
DIP-5	13.1 (±15) *	18.7 (±11) *	1.8 (±8)	0.7 (±8)	7.2 (±10) *	−0.7 (±13)

*: p-value < 0.05

Table 3 Differences between F-RoM and P-RoM

	Flexion	Extension	Radial	Ulnar	CW	CCW
	(Pmax-Fmax)	(Fmin-Pmin)	(Pmax-Fmax)	(Fmin-Pmin)	(Pmax-Fmax)	(Fmin-Pmin)
TMC-1	−0.6 (±9)	4.4 (±6) *	0.7 (±7)	−4.8 (±9) *	1.8 (±9)	−2.2 (±10)
MP-1	24.6 (±16) *	12.1 (±14) *	−5.5 (±6) *	−0.3 (±6)	1.4 (±11)	−5.3 (±12)
IP-1	21.5 (±22) *	−0.6 (±7)	2.2 (±4) *	−2.1 (±5) *	2.9 (±7)	−6.0 (±9) *
CMC-2	0.6 (±4)	0.2 (±7)	2.0 (±3) *	1.0 (±4)	5.3 (±6) *	−2.0 (±7)
MCP-2	16.7 (±21) *	19.2 (±19) *	6.8 (±6) *	−3.3 (±6) *	5.0 (±9) *	−1.7 (±9)
PIP-2	16.1 (±9) *	6.7 (±8) *	−1.0 (±4)	−2.3 (±5) *	−4.6 (±7) *	0.6 (±6)
DIP-2	21.5 (±13) *	3.9 (±8)	−0.5 (±4)	−1.7 (±5)	1.1 (±7)	−5.1 (±11) *
CMC-3	/	/	/	/	/	/
MCP-3	10.8 (±21) *	15.9 (±21) *	7.6 (±6) *	−0.9 (±11)	4.9 (±10) *	0.3 (±6)
PIP-3	14.8 (±11) *	9.0 (±9) *	−1.4 (±9)	−1.3 (±4)	0.7 (±10)	3.7 (±10)
DIP-3	15.4 (±17) *	4.9 (±7) *	1.6 (±7)	−0.6 (±5)	−2.5 (±5) *	1.7 (±7)
CMC-4	−0.9 (±3)	4.3 (±5) *	0.2 (±3)	1.6 (±2) *	5.5 (±10) *	2.6 (±7)
MCP-4	12.9 (±19) *	11.8 (±15) *	9.7 (±8) *	4.3 (±8) *	5.7 (±7) *	9.1 (±8) *
PIP-4	8.5 (±10) *	8.1 (±6) *	0.7 (±8)	−4.8 (±9) *	7.9 (±6) *	6.6 (±10) *
DIP-4	17.8 (±14) *	7.4 (±11) *	0.4 (±6)	−2.7 (±5) *	0.2 (±11)	−0.5 (±5)
CMC-5	−3.0 (±3) *	1.6 (±5)	2.4 (±4) *	2.1 (±4) *	2.0 (±11)	−1.1 (±7)
MCP-5	9.7 (±21) *	15.3 (±10) *	6.8 (±6) *	1.7 (±8)	−0.1 (±7)	6.2 (±8) *
PIP-5	11.3 (±11) *	3.1 (±5) *	−0.7 (±6)	−2.1 (±7)	5.2 (±7) *	1.2 (±11)
DIP-5	18.2 (±10) *	10.5 (±12) *	−0.1 (±5)	−1.5 (±8)	3.0 (±9)	−4.8 (±11)

*: p-value < 0.05

our system was that the rotations of all finger joints can be measured simultaneously, and all joints were considered as three degrees of freedom joints. In comparison, studies using (electro-) goniometers or flex sensors assumed the joint as a one degree of freedom joint, which is in contrast to the anatomy. The measured RoM of our study was consistent with another study that also calculated the rotation angles of finger joints along three axes using captured LCS (Coupier et al. 2016). We both found that self-rotation coupled with flx-ext and rad-uln deviation. The detected self-rotation and rad-uln deviation indicated that certain torque was applied on the joints during movements, as detailed in an in-vivo study that underlined the importance of self-rotation when considering the joint rotations of fingers (Degeorges and Oberlin 2003). With the accessibility to advance devices and techniques, we encourage considering the joints as three degrees of freedom in the measurement and analysis.

Moreover, the selection of the functional activities may also influence the results. In selecting the functional activities, we intended to include both prehensile and non-prehensile activities instead of focusing on the prehensile movement only. The reason was that the prehensile actions are mainly accomplished with finger flexion, then the extension will be excluded. The selected 12 activities in the present study

tried to cover more scenarios for the activities of daily living. The moments with hyper-rotation occurred mainly during fine manipulation or power grasp, when the force was crucial for controlling the object with fingers or stabilizing the object within the hand. For example, key pinch for opening the door or press for pushing objects. The reaction force during the interaction between the fingers and the object may increase the rotation ranges.

The two main limitations of this study were the sample size and the intervention of a nature movement. Although the number of included participants was adequate for matched-pair comparisons, increasing the sample size may enable detailed statistical analysis related to gender, handiness, and hand size (Mallon et al. 1991). The applied optical tracking system was a marker-based system. Marker loosening was observed when participants with small hands performed some functional activities and those frames were excluded. To avoid such issue and record more nature movements in the future, marker-less tracking system can be an option (Geelen et al. 2021). Nonetheless, these systems currently are less robust than marker-based systems and they require a larger database for training and ensuring the tracking accuracy (Yuan et al. 2017).

This study suggested that A-RoM had a large overlap but was unable to cover the range for some functional activities. Thus, the studying the F-RoM and P-RoM are as important as the A-RoM for a comprehensive understanding of the kinematics of hand joints. The knowledge of all three types of RoMs can support clinical diagnosis and treatment, also, it can contribute to the optimization and evaluation of the hand-related designs, such as implant designs for fingers or hand splints.

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Using Inflatable Cushions is Significantly Less Straining than Manually Proning Patients

Stephan Tomlow, Tom Geens, Ellen Suy, and Filip Buckens

Abstract For many health care professionals, transferring patients poses a substantial risk to develop musculoskeletal disorders. Reducing manual handling during these patient transfers by proper use of adequate tools can lower the number of injuries and the duration of unavailability for work. A challenging case for patient positioning is seen in spine surgery in the procedure that is known as proning: after sedation, the patient is rolled over and then positioned onto supporting thoraco-pelvic supports (the prone position). This way of patient positioning is normally carried out manually, where the patient is either tilted or lifted. In this study, we compare three proning methods: working with inflatables (one for the proning and another one for the prone position), manually lifting and manually tilting the patient onto the thoraco-pelvic supports. Surface electromyography of the m. erector spinae and the m. trapezius pars descendens is used to evaluate the effect of using inflatables for proning and prone positioning in neurosurgical procedures. Prone positioning with inflatables generally results in less strain (lower median as well as peak surface electromyography results) compared to positioning without inflatables. Compared to manual lifting the results where significant for all investigated muscles. Compared to manual tilting the results show also significantly lower muscle strain, except for the peak strain in the lower back. From the comparison between both manual methods (lifting and tilting), no preference can be expressed for either method.

Keywords Proning · EMG · Inflatables · Musculoskeletal disorders · Health care professionals · Patient transfers

S. Tomlow (✉) · T. Geens
Liantis Occupational Health Services, Brussel, Belgium
e-mail: stephan.tomlow@liantis.be

S. Tomlow · F. Buckens
VerV, Professional Society of Ergonomics, Aalst, Belgium

E. Suy · F. Buckens
Ghent University Hospital, Ghent, Belgium

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1 Background

Carrying out patient transfers is a substantial risk factor for the development of musculoskeletal disorders (MSD) and, more specifically, low back pain (LBP), in health care professionals (Andersen et al. 2014; Jensen et al. 2012; Yassi and Lockhart 2014). MSD can lead to reduced workability, absenteeism or even leaving the labour market (Andersen 2020). Reducing manual handling by proper use of adequate tools can lower the number of injuries and the duration of unavailability for work (Andersen et al. 2014; Garg and Kapellusch 2012; Teeple et al. 2017).

Also in the operating room personnel, MSD are present to a large extent (Gadjradj et al. 2020; Mavrovounis et al. 2021; Yizengaw et al. 2021). A systematic review and meta-analysis shows a high prevalence of MSD in operation room personnel, specifically for lower back (61.48%), followed by ankles and feet (57.06%) and shoulders (55.63%). LBP is considered as one of the main reasons for absence from work and even career change among the operating room personnel (Tavakkol et al. 2020). The ergonomic condition of the operation room was one of the factors substantially associated with work-related MSD (Yizengaw et al. 2021).

A good example of challenging patient positioning is seen in spine surgery in the prone position. We can see a clear example of this in neurosurgical procedures, such as back operations. In these cases, after sedation, the patient is rolled over into the prone position and then positioned onto supporting thoraco-pelvic supports. This procedure is know as proning and the surgical position is know as the prone position.

More conventional tools are not suitable for this type of patient transfer, hence the most common way to transfer and position the patient into the prone position is by manually lifting or tilting the patient. In this study, we will evaluate the effect of reducing manual handling during proning by using inflatable cushions.

2 Methodology

In order to evaluate the potential benefits of using inflatable cushions on tackling MSD in health care professionals, 3 proning methods were compared. We worked with inflatables, one for the proning and another one for the prone position (IF), or we manually lifted (ML) or manually tilted (MT) the patient onto the thoraco-pelvic supports.

With the IF method, the patient is transferred and tilted from the bed to the operating table via an inflatable board. With a prepositioned inflatable cushion at the thorax and the pelvis, the positioning is finished by inflating (Fig. 1). With the ML method, the patient is transferred onto the operating table using a roll board and then turned and lifted manually, so another colleague can put the supporting thoraco-pelvic supports underneath the patient (Fig. 2). With the MT method, the patient is rolled onto the thoraco-pelvic supports which were put on the operating table beforehand (Fig. 3).

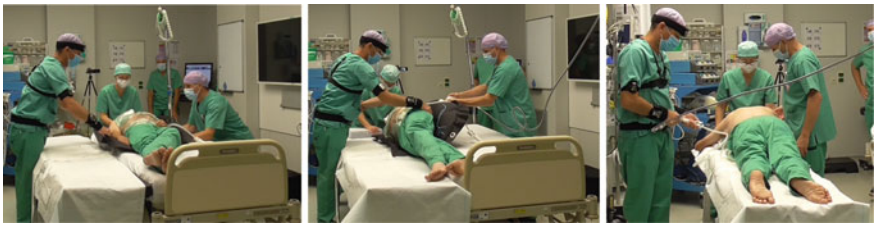

Fig. 1 Snapshots of the IF method: horizontal transfer to the side of the bed by sliding, followed by inflating the inflatable board for turning the patient over and finished by inflating the prepositioned thoraco-pelvic supports

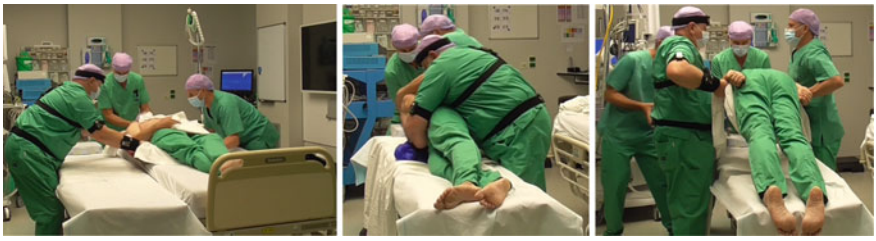

Fig. 2 Snapshots of the ML method: horizontal transfer to the operating table by sliding, followed by manually turning the patient over and finished by manual lifting the patient

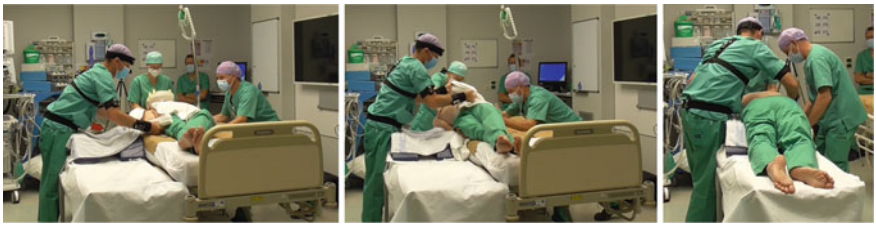

Fig. 3 Snapshots of the MT method: horizontal transfer to the side of the bed by sliding, followed by manually rolling the patient over on the thoraco-pelvic supports and finished by manual repositioning on the thoraco-pelvic supports

Six experienced health care professionals performed the three different proning methods (in randomised order) three times, with a standardised rest period in between of 5 min, with a single same male patient weighing 80 kg.

In order to assess the difference in physical strain between the three proning methods, bilateral muscle tension measurements were performed with surface electrodes (s-EMG) of the m. erector spinae (ERS) and the m. trapezius pars descendens (TRD). The raw s-EMG signal was processed (band-pass filitered 15–273 Hz, RMS sliding window 508 ms). A sub-maximal normalisation was done by expressing the

processed s-EMG as a percentage of the peak strain in the MT method (most common proning method).

Partials results of 2 subjects had to be excluded because of the loss of signal (sensor failure) or the poor quality of the signal (bad skin contact due to excessive sweating). Both the median (P50) and the peak strain (P95) of the normalised ERS and TRD signal were analysed through linear mixed effect modelling.

3 Results

Figure 4 (P95) and Fig. 5 (P50) shows lower estimated marginal means of almost all s-EMG values for IF compared to ML and MT; clearly significant when the 95% CI of IF (in blue) does not overlap with the estimated marginal mean (black dot) of corresponding ML & MT values for the same muscle.

Compared to ML, using IF results in a reduction in TRD of 12% (left) and 28% (right) for the median strain and 39% (left) and 34% (right) for the peak strain. In ERS of 15% (left) and 18% (right) for the median strain and 19% (left) and 35% (right) for the peak strain. These differences are highly significant for TRD left (TRD.L) and right (TRD.R) ($p < 0.001$). This is also the case for ERS left (ERS.L) ($p < 0.05$) and right (ERS.R) ($p < 0.001$) (Fig. 6).

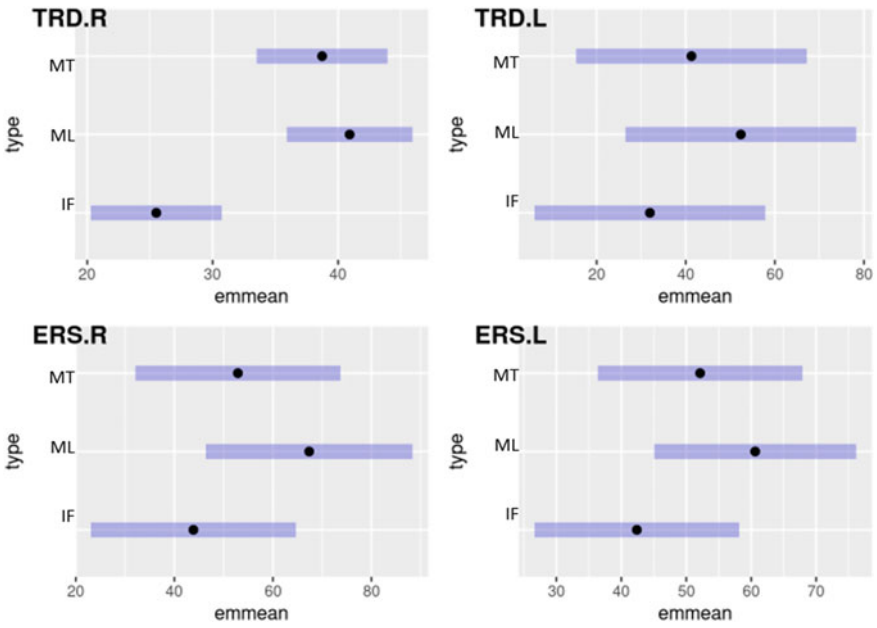

Fig. 4 Estimated marginal means of the peak strain (P95) of the different muscles

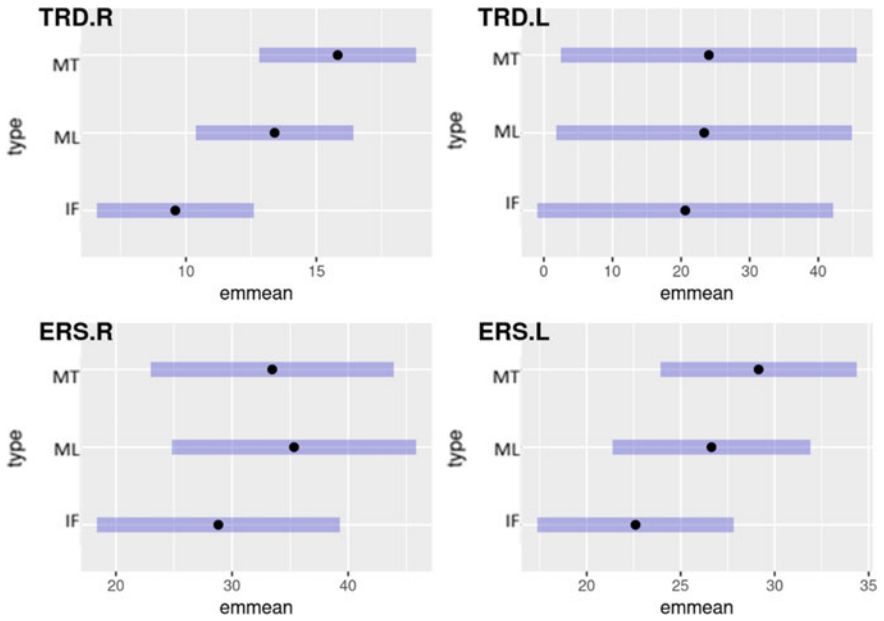

Fig. 5 Estimated marginal means of the median strain (P50) of the different muscles

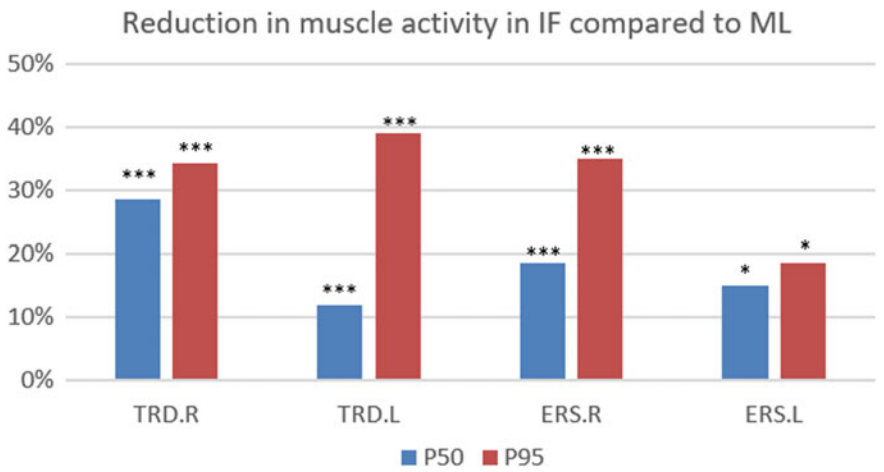

Fig. 6 Reduction in muscle strain in IF compared to ML for the median (P50) and peak strain (P95) of the different muscles. * ($p < 0.05$) and *** ($p < 0.001$) show the significance levels of the reduction

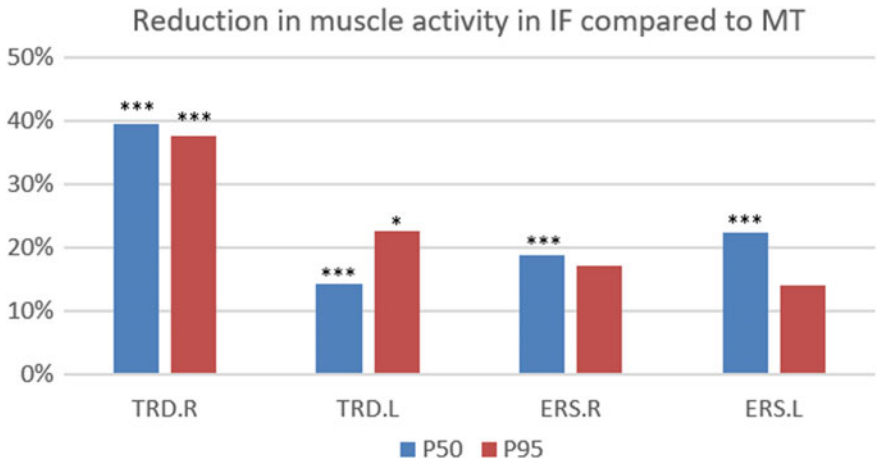

Fig. 7 Reduction in muscle strain in IF compared to MT for the median (P50) and peak strain (P95) of the different muscles. * ($p < 0.05$) and *** ($p < 0.001$) show the significance levels of the reduction

Compared to MT, using IF results in a reduction in TRD of 14% (left) and 39% (right) for the median strain and 23% (left) and 38% (right) for the peak strain. In ERS 22% (left) and 19% (right) for the median strain and 14% (left) and 17% (right) for the peak strain in ERS. These differences are significant for TRD.L ($p < 0.001$) and TRD.R (P50: $p < 0.001$; P95: $p < 0.05$). In ERS significance was found only for the median muscle strain ($p < 0.001$) (Fig. 7).

The comparison of both manual proning methods is less clear. Asymmetric results were found for both TRD and ERS. ML in relation to MT, results in a significant decrease in the muscular activity of TRD.R (median) of 15% and, at the same time, an increase of TRD.L (peak) of 27%. In the peak strain of ERS.R a significant increase of 27% is found.

4 Discussion

The use of inflatable cushion results in less physical strain during proning: the force exertion to tilt and lift the patient is exerted by filling the inflatables with compressed air. Therefore, the measured reduction in muscle strain in IF compared to ML can be explained by the absence of manual tilting and lifting the patient in the IF method. The lack of significant reduction for only the peak strain in ERS in IF compared to MT can be explained by the fact that there is no lifting in both proning methods: most likely the lifting of the patient itself causes the greater peak strain in ERS.

These results are similar to a previous study reporting lower muscle activity in the upper extremities and low back, reduced awkward postures and lower L5/S1

moment by using a wedge shaped inflatable compared to manually turning a patient. Furthermore, the authors compared different turning devices and concluded that the air-assisted turning device was the most effective device in reducing the muscle activity in as well the upper extremities as the low back. The investigated draw and friction-reducing sheets showed limited benefits compared to the manual turning without devices: for grasping the draw sheet or the handles of the turning sheet on the opposite side, a greater reach distance and thus a longer moment arm is required, so the potential of these sheets for turning a patient may be limited (Hwang et al. 2019, 2020).

Since the comparison of both manual proning methods is less clear, there can be no preference for either method: ergonomic solutions should be searched in developing and using proper tools to avoid manual force exertion and manual handling. Hwang et al. (2020) suggests to consider to embed patient tilting assistance in patient turning devices for reducing caregivers injury risk in the low back and upper extremities.

Proning reflects only a portion of the tasks (and the strain), therefore further research needs to be conducted in order to form an overall picture of the physical strain in the operation room. Besides ergonomic conditions, among others, breaks between procedures, overtime, nightshift, absence of assistance and duration of the procedure are factors associated with work-related MSD (Yizengaw et al. 2021). Besides providing proper tools to avoid manual handling and to diminish manual force exertion, also organisational measures are necessary to tackle MSD.

5 Conclusions

Studies have shown that the ergonomic condition of the operation room is one of the factors substantially associated with work-related MSD (Yizengaw et al. 2021) and that reducing manual handling by proper use of adequate tools can contribute to tackling the impact of MSD (Andersen et al. 2014; Garg and Kapellusch 2012; Teeple et al. 2017). Based on our results the use of inflatable cushions is preferable above the manual execution of proning. Since proning reflects only a portion of the tasks (and the strain), further research needs to be conducted in order to form an overall picture of the physical strain and to take additional targeted measures to improve the physical workability.

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Medication Safety from the Perspective of Human Factors: How to Design Safer Systems for Protecting Patients and Workers?

Using Cognitive Ergonomics and Metacognition Processes for Understanding and Improving Medication Safety Systems

Angela Caro-Rojas

Abstract Cognitive ergonomics implies understanding how people make decisions, and how to design safer systems for the people involved. Understanding how experts in medication safety management think and make decisions, give a new vision of how to design safer systems. A study was achieved for characterizing ergonomic cognitive and metacognitive processes developed by some experts in medication safety (pharmacists, doctors, nurses) solving problems related to unsafe medication (prescription, preparation, dispensing, and administration). Using a "think aloud" methodology was possible to identify how the experts think and which are the principles to have in mind for designing safer medication management processes. We found that the experts think about the goal in a task, balancing how to keep a Patient out of risk against it, this requires planning and developing task-oriented thinking in mitigating every risk rather than just performing the task. While monitoring the task, experts reflect on whether the patient is responding in the same way as would be expected. Any alteration of the medication's therapeutic effect may be the result of a possible mistake. They find a better way of controlling the task by taking alternative decisions using their knowledge and previous experiences for developing their task. Using a critical mindset, they modify their actions dynamically in the process. Finally, evaluation includes a metacognition process to identify improvement opportunities, which could be used in situations they might face later. Using cognitive and metacognitive process descriptions is possible to design a safer medication system.

Keywords Cognitive ergonomics · Metacognition · Medication safety · Pharmacovigilance

A. Caro-Rojas (✉)
Medication Errors SIG Co-Chair, International Society of Pharmacovigilance and Pharmacy Career Director, Pontificia Universidad Javeriana, Bogotá, Colombia
e-mail: rangela_caro@javeriana.edu.co

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1 Background

Medication errors (ME) are one of the most important problems in patient safety and have a big impact on public health, recognized as such by the World Health Organization (WHO) in the challenge "Medication without harm" (WHO 2004; Donaldson et al. 2017). Multiple strategies have been tried to minimize its incidence and impact, however, apparently, no improvement has been obtained in this indicator (Kohn et al. 2000; Bates and Singh 2018). On the other hand, cognitive and metacognitive processes have been studied for some health careers and it is considered feasible for professionals to reflect on their practice (Andersson 2012; Banning 2008; Crosckerry 2003; Cutrer et al. 2013; Nielsen et al. 2007). Cognitive Ergonomics and cognitive biases could be useful to better define tasks to use medications safely and design safer processes in complex systems (Zhang et al. 2002).

This article characterizes the metacognitive strategies of planning, monitoring, control and evaluation used by 8 experts in safe medication (pharmacists, doctors, nurses, ergonomists) when solving, through role plays, problems related to unsafe situations for patients when using medications.

Knowing the cognitive and metacognitive processes that the experts develop when solving problems of prescription, preparation, dispensing and administration of medications, allows to establishing educational implications that could be developed to encourage students and professionals in the health areas to understand the risky situations in the use of medications, and the mechanisms to mitigate them through a better system design.

The goal of this article is to understand how cognitive ergonomics and metacognitive processes help to establish safer systems in Medication management.

2 Methodology

Within the framework of a Master's thesis in Education, an investigation was carried out based on a qualitative, interpretive paradigm, using a case study method. It implies asking each participant that she/he must consider that they have a specific role and they needed to solve the case from that role, acting as if they have all the tools for resolution. Previously some authors used simulated cases for analyzing metacognitive processes (Burke and Mancuso 2012; Figueroa et al. 2016; Jimenez 2016).

The first step was the design of the cases. It was designed considering real cases of medication errors reported in the news or in the literature. Of these cases, important common elements were characterized to be considered, such as, if that had happened in vulnerable patients (pediatric or neonatal), including high-risk medications ad problems related to "human factors" such as deficiency of leadership, effective communication, and teamwork, additionally considering the cases happened

within complex systems with the interaction of multiple stakeholders such as doctors, pharmacists, nurses, patients, and family members.

For each element of the real cases, the author defines which metacognitive strategy could be characterized, for example, if the cases include taking a bad decision, it was considered part of the "planning" strategy, or if the element was a decrease in the security of the patient during the treatment it was inside the strategy of "monitoring", etc. The most important elements were chosen to elaborate the cases for the experts.

Two cases were finally written for the author and each participant was located in 3 different roles for 3 different moments during the case (for case 1: pharmacist, nurse, Medication Safety Officer/Ergonomist; for case 2: doctor, nurse, Medication Safety Officer/Ergonomist). The cases included the information that the medicines were administrated to pediatric patients (one of them to a newborn).

2.1 Case 1

Moment 1: A pharmacist attends to a vulnerable patient (newborn) and is faced with a prescription that is not clear in terms of dosage, sense of urgency (asks to administer "now"), date of issue, legality (not has a medical sign), the doctor's specialization (medication for a newborn and it is not clear if it was issued by a neonatologist or pediatrician).
Moment 2: A nurse who must administer the medication with the same unclear prescription.
Moment 3: A Medication Safety Officer/ Ergonomist needs to analyze a case of the death of a neonatal patient due to the dispensing and administration of a high-risk medication (adrenaline) that has been dispensed erroneously, he must base his analysis on the same prescription of the previous moments and additional information provided.

2.2 Case 2

Moment 1: A nurse is confronted with a confusing prescription issued by a doctor from the previous shift, in which he prescribes dextrose and which has inconsistencies such as the use of non-standard interpretation acronyms, a request to prepare a mixture without indicating the dosage exact, without administration speed, with the contradiction of initially ordering low-concentration dextrose and then high-concentration dextrose.
Moment 2: A doctor must answer the doubts that arise to the nurse of Moment 1, make the decisions and assume the responsibilities of the patient.

Moment 3: A Medication Safety Officer/ Ergonomist must analyze a case of death of a pediatric patient due to dextrose overdose, she/he must analyze the case with confusing prescription information and other elements.

After designing the cases, they were validated by healthcare professionals considering the information clarity and sufficiency in both cases. Any information that might not be clear to the reader was adjusted. Likewise, a "Self-observation questionnaire of metacognitive strategies" was developed, It considers each type of strategy (Planning, monitoring, control, and evaluation). Each participant was invited to explore the metacognitive strategies that they used during the resolution of the problems and to be aware of the learning achieved by developing the case. The self-observation questionnaire was also validated. Eight healthcare professionals (pharmacists, doctors, nurses, and ergonomists) were invited to solve the cases.

The participants were selected considering the following criteria:

- Healthcare Professionals with big experience in medication errors analysis.
- With extensive knowledge of safe drug use, patient safety, human factors, or cognitive ergonomics (at least 10 years of experience).
- Recognized in their countries as referents of the topics previously exposed for their intellectual production in this regard. (Lecturers, consultants, researchers)
- Willing to participate in research and develop the analysis of problem scenarios by solving them with the Thinking Out Loud technique.

The only exclusion criterion was rejecting the invitation. All the guests signed the informed consent in which the objective and methodology of the research were explained.

The process of capturing the information was developed through problem-solving sessions. Each session consisted of the following moments:

1. Verification of the understanding and signing of the informed consent, as well as the resolution of doubts, if any.
2. A Think Out Loud method training.
3. The resolution of cases.
4. The development of the self-observation questionnaire of the metacognitive strategies used.

The cases were resolved by 2 Physicians, 2 Pharmacists, 2 Nurses, and 2 experts in Ergonomics and Human Factors. Each one analyzed the cases assuming the defining roles. For the self-observation questionnaire, the experts answered it by remembering their performance and analysis processes from their own role in their profession and, in a second moment, as Medication safety officers.

The analysis of the information was carried out through the analysis of categories and subcategories by metacognitive strategy as shown below.

3 Results

The metacognitive strategies characterization was carried out considering the profession of the participants and reviewing the strategies used for Planning, Monitoring, Control, and Evaluation (Flavel 1979; Allueva 2002; Efklides 2008; Robson 2015). This article just described the ergonomist's answers, and how they consider the medication management systems must be improved.

3.1 Planning Strategy

Regarding the organization of the tasks and the steps to follow for achieving them, the experts talked about the present risks and the mitigation activities in preparation and administration processes, they said some sentences as follows:

> I ask her to give me the prescription and the medication that she picked up at the pharmacy, I review and verbally reiterate the instructions: "Ma'am, the doctor tells me to apply a vial"", "I would tell the lady that it is a venous injection, she may have minimal problems, that it is a bit painful, but with my experience she may not have pain.
>
> Well, I greet her, I ask her what she needs, the lady gives me the medicine prescription, and well I check the prescription, I check that it matches the medicine that the lady has in her hand, if everything matches then I proceed to the administration, in this exercise generates distrust in me but from the exercise I must assume…

The interest of the experts in human factors was the interaction with the family member (user of the system) and the interest in maintaining effective communication by engaging them in the process.

The most important considerations in the planning process were: The interest of the active participation of the patient, for which effective communication processes are generated, they are educated and included as a security barrier; the standardization of processes, considering the model "work as it is done" and the tool of analysis of cases by tasks; the use of technologies embedded in the process as security barriers; other elements of the medicine such as the packaging and the utensils included for the medicine administration.

In the "Self-observation questionnaire of metacognitive strategies" for the Planning strategy it was evidenced:

- A metacognitive knowledge on issues of knowing how to plan, recognize a problem and the objectives to be achieved.
- A metacognitive knowledge compared to the option of being able to use knowledge and resources to solve them, which were focused on technical knowledge in healthcare areas (pathology, pharmacology, physical chemistry, pharmacotechnics, etc.), knowledge about patient safety (medication errors, usual risks in medication management and how to mitigate them) and knowledge from human factors (effective communication, teamwork, process standardization, and leadership)

- The option of making use of their previous experiences to solve problems, turning them into metacognitive experiences that promote awareness and internalization of problem-solving mechanisms, to be used in planning new solutions when facing similar problems.

3.2 Monitoring and Control Strategy

In accordance with the case solution and the questionnaire solved by the ergonomists, was evidenced:

- A metacognitive knowledge to identify the need to monitor the tasks verifying that these was carried out properly and understanding if the task development deviates from the stated objective (the safe use of the medication). In this sense, experts contemplated at least two conditions to be monitored:
  1. The tasks are executed as it was designed, in the closest way that it should be, considering particular patient conditions, and
  2. The evolution of the patient shows that the process is developed properly.
- A metacognitive knowledge of the strategies that exist to successfully accomplish the task, contemplating not only the basic elements, such as the execution and control of the "correct" ones in medication management but also the alternative strategies based on the analysis of complex systems and human factors, empathy, critical thinking, the possibility of refusing the development of the task and the analysis of tasks from real conditions.

3.3 Evaluation Strategy

A final task developed by the participants was the analysis of the medication error from the role of Medication Safety Officer/Ergonomist. A question based on the study of complex systems and human factors was included in this analysis.

- The participants agreed that within the complex system, the relationship among the different stakeholders (pharmacists, physicians, nurses, managers, and other leaders) as well as their communication processes, was key. They showed that a large part of the inconveniences generated could have been solved with adequate communication processes, such as, for example, a direct number to communicate with the prescriber physician in both cases.
- Regarding communication, the experts expressed the importance of teamwork to provide mutual support and filter medication errors that could occur, so that it doesn´t reach the patient. Within the framework of the leadership factor, was considered the importance of managers for generating environments with a Culture of Safety and promoted it to each HCP involved.

- A commonly mentioned topic was the standardization of processes, as well as the existence of protocols, guidelines for handling procedures, and other information that would allow them to recognize which was the correct path to carry out the task. It was also mentioned having monitoring and evaluation procedures such as checklists, and controls by peers, other professionals, or supervisors to ensure that the performance of the task was adequate.
- Since the requested task was to analyze the error, they all considered that an in-depth evaluation should be carried out to determine the interactions that could have generated the event and take the corresponding measures, such as, for example, training in patient safety culture, minimizing the possibility of distractions or risk situations derived from the work environment like overload, stress and physical and mental exhaustion.
- The importance of recognizing the frequent existence of human error and, therefore, the need to implement constant adjustment measures, through supervision, participation of the work team and continuous improvement, is also highlighted.
- Patient Safety Expert 2 makes an interesting reflection on the difference between how tasks are executed, and how they are described as having to be executed. From this, it promotes the development of procedures linked to the real and operational performance of the people involved in the tasks. He suggests doing an analysis from ergonomics to establish the minimum requirements that each of the tasks must have to be safe and protocolize them from that point of view.
- Finally, as previously mentioned on several occasions, the participants consider the conditions in which the interactions between the officials of the healthcare area and the administrative staff to be very relevant. The hierarchical relationship that may exist between them is considered, where the interest in minimizing economic losses may prevail over the interest in guaranteeing conditions that favor patient safety. In this sense, it is key to understand the codependency of the actors, the interests of each one and how to achieve a win–win relationship, without the superiority of administrative aspects, mainly financial, arising over health actions that, as in the case described, involve invaluable loss of human life, but also a very strong economic risk in case of lawsuits against the hospital, or loss of the reputation of the institution.

4 Discussion

Patient safety issues and particularly medication errors could be intervened and prevented considering Human Factors and ergonomics, (WHO 2009) including Cognitive Ergonomics, it means understanding how the complex system of medication use could be modified or designed considering the interests of people who are involved in that system (Patients and healthcare workers) and analyzing the cognitive factors of each person. With the methodology of metacognition strategies characterization is possible to define how experts in medication safety think, understand the

processes, and make decisions for having safer systems for all the stakeholders. These strategies include planning monitoring, control, and evaluation (Efklides 2008).

When ergonomists are solving problematic cases about medication errors, they could use their knowledge for considering different ways of analyzing and deciding how to change the systems. These experts think about the goal in a task, balancing how to keep a patient out of risk. This requires planning and developing task-oriented thinking in mitigating every risk rather than just performing the task (Sibbald 2011).

While monitoring the task, experts reflect on whether the patient is responding in the same way as would be expected. Any alteration of the medication's therapeutic effect may be the result of a possible mistake. They find a better way of controlling the task by taking alternative decisions using their knowledge and previous experiences for developing their task. Using a critical mindset, they modify their actions dynamically in the process.

The evaluation includes a metacognition process to identify improvement opportunities, which could be used in situations they might face later. The process of analyzing their performance helps to create new knowledge so it can be used for learning about mistakes before it happens in real life. Some researchers have found similar results in other healthcare topics (Hong et al. 2015; Cho et al. 2017; McFarlane et al. 2018; Medina et al. 2017; Wuryanto et al. 2017).

The option of being involved in hypothetical situations related to possible adverse events, allows HCP to "live" and experience uncomfortable situations which offers the experience of learning and understanding how they think and realize how they make decisions, and define how to act in a safer way. This knowledge could be shared with other HCP and students for giving information such as the best way for planning, monitoring or evaluating an action related with patient safety.

Ergonomists consider not just the necessity of developing the task but the way that this task is done inside complex systems, then they referred other important visions like, promoting a culture of safety, teamwork, leadership, and minimizing stress and unclear or undefined processes.

Other considerations informed in the processes designed include: To understand the cognitive biases that humans could have when using medications, minimizing the risk of mistakes limiting the choices of medication, and including the metacognitive process in regular training of healthcare students and professionals.

They list activities to be carried out, like checking that the risks are being controlled, which could be interpreted as an internalization of the presence of risks at each moment of medicines use, it should be achieved that the students in the approach of test environments detect, analyze and mitigate the present risk situations. This coincides with the research by Andersson (2012), Cutrer et al. (2013) and Lee (2016), on the frequent analysis of risky situations in health care and the clinical reasoning to be used.

It is suggested to use the cases built for this article, or develop other cases, with different situations and stages of medication use, from complex systems and human factors perspective for HCP training, it allows to consider how to act in a problematic situation related to medicines use. It helps the HCP to understand how they act compared with how an expert in medication safety act.

The use of these test environments is based, among other considerations, on what was stated by Hardin and Richardson (2012) in "Teaching the Concept Curricula: Theory and Method", as opposed to the student being able to transfer the knowledge generated in one environment to the others, in a continuous learning process.

One of the limitations of this study is that is not possible to consider every ergonomist thinks and makes decisions in the same way, but this study allows to analyze from a metacognitive experience how to modify systems.

5 Conclusion

Using cognitive and metacognitive processes is possible to identify strategies for minimizing the risk of patients building safer medication management systems.

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Qualitative Assessment of a New Labelling Design of Injectable Generic Medicines

Carlos Aceves-Gonzalez, Angela Caro-Rojas, John Rey-Galindo, Adriana Aristizábal-Ruiz, and Karen Hernández-Cruz

Abstract Medication label design is among the frequent contributing factors to medication errors in clinical practice settings. Several safety organisations have published recommendations on the design of optimal medication labels. Objectives: This study aims to uncover perceptions of the new labelling design developed under those recommendations by a pharmaceutical company compared to its existing labels and characterise participants' opinions of usability and medication safety. Method: A descriptive study using a structured version of the focus group method was undertaken. A convenience sample of twelve pharmacists and eight nurses with experience in medication management and working at two critical hospital departments (emergency and intensive care unit) were recruited and participated in four focus groups. Group discussions were audio recorded and thematically analysed. Results: Several positive opinions on the new labelling were identified, from less effort in identifying critical information due to the use of colour, enhanced contrast and tall lettering for LASA medicines to improvements in participants' perceived safety. However, also feedback was received for those labelling features that still need improvement. This study provides evidence of the effectiveness of adopting the human-centred design principles suggested by medication safety agencies.

Keywords Safer medicines · Safer labelling · Usability · Patient safety · Human factors/ergonomics

C. Aceves-Gonzalez (✉) · J. Rey-Galindo
Centro de Investigaciones en Ergonomía, Universidad de Guadalajara, Guadalajara, Mexico
e-mail: c.aceves@academicos.udg.mx

A. Caro-Rojas
Pontificia Universidad Javeriana, Bogotá, Colombia

A. Aristizábal-Ruiz · K. Hernández-Cruz
Vitalis, Bogotá, Colombia

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1 Background

The third World Patient Safety Challenge was launched in 2017 with the theme "Medication without Harm" for the significance of medication errors. The cost associated with medication errors is estimated at $42 billion annually. The scale and nature of this harm differ between countries, with a higher impact on those patients living in low-income countries (WHO 2017). Medication label design is often a contributing factor to medication errors. Research has shown that one-third of reported medication incidents may be due to confusion over packaging and labelling (Berman 2004). Poor labelling design can contribute to medication errors by making it difficult for end users to identify and understand critical safety information (FDA 2022).

Based on the idea that well-designed labels could improve medication safety, several organisations have published recommendations on the optimal design of medicines labels (ISMP 2016; NPSA 2008). Although the recommendations are based on human-centred design principles, there is minimal evidence to support their adoption (Estock et al. 2018). This research project is based on assessing a new labelling design of injectable generic medicine developed by a pharmaceutical company in Colombia. The company trades almost one in every four units of injectable medications used in Colombian hospitals. In 2017, the company performed a risk analysis of its injectable medicines, and several products were identified as high risk based on their label design and similarity (Garnica and Aristizabal 2017). Following guidelines for safer medication provided by the Institute for Safe Medication Practices and the National Patient Safety Agency (ISMP 2016; NPSA 2008), the pharmaceutical company designed new labelling and packaging for their medicines. The new design included colour differentiation between products (inter-class), using a white background, avoiding dangerous abbreviations, tall-man lettering and vertical text to allow better readability (Garnica and Aristizabal 2017).

This was the first effort of a pharmaceutical company in Colombia to develop a structured medicines design program for patient safety. However, there is still a need to assess the impact of the new design on usability and medication safety. This study aims to uncover nurses' and pharmacists' perceptions of the new labelling design compared to existing labels and characterise their opinions of usability and medication safety.

2 Methodology

The study used a structured version of the focus group method to understand the perception of healthcare professionals on the impact of the redesign applied in drug labelling regarding the usability and safety of medicines.

Participants A convenience sample of hospital pharmacists and nurses from two critical hospital departments (emergency and intensive care unit) were recruited and

participated in four focus groups. This arrangement was intended to obtain information on the impact of labelling on the dispensing and administration of medications, respectively. The inclusion criteria were that they worked in such critical services, with experience in dispensing or administrating medication. People with different levels of expertise and from public and private health entities in Bogota, Colombia, were invited to encourage greater diversity in the data collected.

Study design All focus group sessions were moderated by ACR and CAG, using a guide with moments and questions to facilitate group participation and discussion. Initially, participants were invited to read and sign the informed consent form, and a moment was provided to answer any questions. Participants were given a sheet where they were asked to briefly write down their answers before verbally participating in the discussions. This facilitated the order and involvement of all more equitably. Verbal contributions were audio-recorded for transcription and subsequent analysis.

It is essential to underline that the previous (Fig. 1) and the new label design (Fig. 2) were shown to the participants in the second stage of each focus group discussion to explore their previous experience with medication labels first. The structure and topics of each moment in the focus group discussion are described in Table 1.

Fig. 1 Medicines with the previous label design (ampoules and vials)

Fig. 2 Medicines with the new label design (ampoules and vials)

Table 1 Overview of the moments and topics discussed within the focus group sessions

Moment	Topic	Leading questions
1. Exploring participants' experience with the medication's labelling (this topic was discussed before the participants observed the new label design)	Usability: barriers and enablers	a. Please identify some elements of drug labelling that make your job easier b. Please identify some elements of drug labelling that make your job difficult
	Medication safety	a. Please identify some elements of drug labelling that could have implications for patient safety
2. Interaction of participants with previous and new labelling		a. At this time, participants had the opportunity to meet and interact with ampoules with the previous and new labelling
3. Perception of the impact of the new labelling design compared to an existing label (this topic was discussed after the participants observed the new label design)	Usability	a. Can the new labelling make a difference or not to the one who dispenses or administers? b. Do you think the new labelling can contribute to what you do every day? c. How could this labelling improve your dispensing or administering activity?
	Patient Safety	a. What could be the patient safety implications of the new labelling?
	Health worker safety	a. What could be the implications of the new labelling on your level of confidence and perception of safety when performing your dispensing/ administration activities?
4. Opportunities for improvement for the new labelling	Usability and patient/ health worker safety	a. What aspects of the label are working well? b. What are the strengths and weaknesses of the new labelling? c. Please mention some suggestions for improvement of the new labelling

Data analysis The discussions and participants' writing were transcribed and imported into NVivo V11 (QSRInternational). A theoretical-driven thematic analysis was undertaken from the concepts of usability and safety (Braun and Clarke 2006; Robson 2011). The analysis was conducted at a semantic and realist level (Braun and Clarke 2006), i.e., themes, subthemes and codes were identified within the explicit meaning of the data. These themes were initially derived from theoretical perspectives and then developed based on participants´ opinions. Two researchers independently identified themes and codes (CAG and JRG). The themes were then discussed to reach consent with the entire research team.

3 Results

Twelve pharmacists and eight nurses participated in the focus groups, including fifth teen women and five men. Regarding years of medication management experience, eleven participants had more than ten years of experience; two were in the seven to ten range; four participants had between five and seven, and three participants had between one and five years of experience. The participants were organised into four groups. Two groups had five participants, and the other two had six and four, respectively. It must be noted that, since the new label design is already on the Colombian market, some participants had already used the new label in their daily activities.

The results present the topics that were addressed in the focus groups according to the structure/order of the discussions: (1) Exploring participants´ experience with the medication's labelling (before observing and analysing the new label design); (2) impact of the new design in comparison with the previous labelling in regards to usability and patient safety; (3) suggestions for improvement.

3.1 Exploring Participants' Experience with the Medication's Labelling

Three broad themes emerged from the analysis regarding the labelling elements that enable the dispensing and administration of drugs. These themes were (1) the differentiated appearance between labels, (2) good legibility in label design, and (3) the information on the package. A standard view amongst participants was that the differentiation between the labelling of medicines facilitates their work. Some participants mentioned using colour to differentiate between drugs as being most helpful. In contrast, others said the use of upper- and lower-case letters in the name of the medicine. Most of those who mentioned this theme felt that this is particularly important in the case of LASA (Look-a-like, Sound-a-like) medications. An overlapping and recurrent theme in this stage of the focus groups was a sense amongst participants that labels legibility is another enabler in doing their work more straightforward. For example, some participants mentioned the relevance of the size of the letters, while others talked about the need for excellent contrast with the background. In addition, some information on the package was mentioned as facilitator; some informants pointed out the relevance of having the name of the drug in large letters, concise information on the drug, and a clear explanation of medication use and its reconstitution data.

In contrast, participants identified a lack of information on the package or label, similar appearance between medications, and poor legibility as the main barriers to dispensing and administering medications. However, some participants also added, as part of the barriers, workload, limited time to do their tasks, as well as inadequate storage of drugs. All of these elements were also mentioned as part of the concerns of

pharmacists and nurses as risks to patient safety. Participants added comments about human performance in terms of patient safety risks. Some participants mentioned the presence of human error, lack of verification (double checking), and inadequate dispensing and administration.

3.2 Perception of the Impact of the New Labelling Design Compared to an Existing Label

After observing the previous labelling and contrasting it with the new design, when participants were asked about the impact it could have on the performance of their activities, all participants commented that the new label design would make their work easier. More than 80 comments were identified concerning facilitating the activities of dispensing and administering medications. The opinions of the participants were that the new design could improve everything from storage tasks to the moment of the administration itself. Participants said it makes identifying, reading and obtaining relevant information easier, including double-checking between pharmacy and nursing staff. One respondent argued that it makes a difference because there is colour identification in addition to the difference in the size of the names. Additionally, the vials are more legible, and the information is contrasted with the background.

According to the comments of the pharmacists and nurses, facilitating the tasks seems to be related to the improved legibility of the new label. Among the points, they highlighted that the information on the labels is more explicit. Therefore, due to better legibility and more straightforward dispensing and medication administration tasks, almost two-thirds of the participants (70%) said that the new labelling would reduce the time to complete tasks safely.

In response to the question, what could be the patient safety implications of the new labelling? Over half of the participants in the focus groups reported that the previous labelling increased the likelihood of error or confusion due to the similar appearance and lack of legibility. Several participants said their experiences of medication mistakes and errors with the use of labels with poor design. In addition, they mentioned that they often notice the risk of confusion.

On balance, most participants noted that the new design has a favourable implication for patient safety. Some participants pointed out that the new labelling will decrease medication errors due to less confusion about active ingredients or concentrations. Just over half of those who answered this question reported that the new design by adding tall man lettering might also serve to reduce medication errors generated by LASA drugs. Interestingly, one of the participants mentioned that the new design contributes to improving patient safety culture since it shows that things (in this case, labels design) can be done differently.

When the participants were asked about the implications of the new labelling on their confidence and safety perception level, a recurrent response was a sense of

improved confidence and safety perception when performing their activities. Several participants said better colour identification, better readability of the name and relevant information, and better contrast give a greater sense of safety when handling LASA drugs. One participant said that the new design allows staff to be more confident and may even make it easier to stop when a potential error has occurred between dispensing and receiving medication. Another participant mentioned that it means more safety and confidence during the process because it means an additional safety barrier implemented by the pharmaceutical company.

Although there was an explicit acceptance of the new design and a tendency to highlight its positive impact, some participants expressed concern about potential problems associated with the new labelling. Among the main thoughts is the lack of universality in the use of colour. One participant suggested the need for better colour coding to improve the identification of certain groups of drugs. Another participant said that the problem is that there is no coincidence with what other laboratories do or even the use of colours in each health organisation or hospital.

3.3 Opportunities for improvement for the new labelling

Two broad themes emerged from the request to express some suggestions for improvement of the new labelling design. The most significant number of comments were about the use of colour. On the one hand, several participants suggested using colours that are easy to identify and associate. One participant mentioned that red could be used as a warning measure for some drugs, e.g., benzathine penicillin. Some participants agreed with the idea that colour should be unique for each drug or at least for each therapeutic group. Finally, two participants suggested using a white background for all ampoules. On the other hand, a shared view among all participants was that the use of colour must be universal. Participants said it would be worthwhile to make a joint effort among laboratories and seek a strategy to homogenise the use of colour in high-risk drugs.

Another issue as part of the recommendations was related to adding or changing the information on the labels. Some participants suggested adding a warning sign for high-risk drugs among the main recommendations. Participants also said that data such as the amount of diluent for the pharmaceutical and information related to the proper use of the product (handling—opening) should be added. Other informants said that it was necessary to place the expiration date and lot on the same side as the name of the drug and to increase the font size for the mode of use, composition, batch and expiration date. To address these demands, one participant suggested including a double label or a usable QR code to provide additional information or better distribute the information to be more legible.

A final theme was related to potential problems with the new labelling. One is related to the material, which is made of paper and could come off more easily if it

gets wet. Another concern was about the functionality of the QR code because, in some of the vials, the code did not provide the corresponding information.

4 Discussion

This exploratory study aimed to elicit nurses' and pharmacists' perceptions of the new labelling design compared to existing labels and to typify their views on usability and medication safety. The study results suggest that participants recognise and frequently experience problems of similar appearance (Look-a-like) and poor legibility in medication labels in their working systems. These label characteristics, within complex environments such as emergency and intensive care settings, may increase the likelihood of medication error. Look-a-like labels are well defined in the literature. They have frequently contributed to product selection errors, leading to the dispensing and administering the wrong drug, wrong strength, and wrong dose (FDA 2022). This risk is recurrent in most regional hospitals since the trend of designing with the end-user in mind is not yet well established in the pharmaceutical industry.

The results of this study also indicate that the pharmacists and nurses positively evaluated the new label design in this research. There are several possible explanations for this result. One may be related to the fact that the new design reduces the similar appearance between labels. Likewise, the new design improves legibility, thus increasing the potential to detect critical drug information. In line with that, a more compelling explanation could be that participants associated the new label changes with making their tasks more manageable, saving time, but above all, with the fact that they felt more confident and safe when using those medications. That perception of feeling safe can be understood if it is considered that pharmacists and nurses must make hundreds of decisions daily about the use of medications. In each of these decisions, the probability of error can be latent, especially when acting in complex systems such as a hospital, where it can be latent work overload, physical and mental fatigue, and distractions, among other working conditions.

Another significant finding was that most participants suggested that the new design has a favourable implication for patient safety. Although this suggestion is based on participants' perceptions, this finding is in line with several studies that have supported that using human-centred principles in label design might improve patient safety. For instance, in a study with hospital nurses in which the colour was used to codify high-risk medicines, it was found that the use of colour improved patient safety and medical staff efficiency by reducing the time required to perform the tasks and to identify errors in the process (Porat et al. 2009). In another study with hospital physicians in which the contrast between the font colour and background was modified, results suggest an improvement in recognition time and, potentially, a critical item to reduce medication errors (Gupta et al. 2015).

The study had some strengths and limitations. In general, focus groups were an effective method for gaining information about pharmacists' and nurses' views on the new label design compared to the previous one. The structured version of focus groups used in this study provided the benefit of avoiding bias caused by the domination of one or two people in the group, which is often a disadvantage of the focus group method (Robson 2011). Nevertheless, the study's main potential limitation relates to its inherent self-report bias. Although Self-report is a valuable technique to identify participants' perceptions, the subjective experience might also be disproportionate to reality.

5 Conclusions

This study describes two pioneer efforts for improving medication safety in Latin America. On the one hand, developing a new labelling design for generic injectable medicines following human-centred design principles. On the other hand, to the best of our knowledge, this is the first study that has examined healthcare workers' views on a real-world example of a new medication label design in the region. The study results suggest there is a real need for labelling design in the context where the study was undertaken, and we have the ambition that these efforts might help diverse stakeholders to move forward in developing safer medicines. In line, this study offers evidence of the effectiveness of adopting human-centred design principles for such purpose.

The healthcare workers who participated in the study suggested several advantages of the new design, such as enhanced labels´ legibility and reduced similar appearance, which facilitates their activities and potentially improves patient safety in medication dispensing or administration. Moreover, feedback was received for those labelling features that still need improvement. Participants raised the need for continuing with efforts to find the best use of colour coding in high-risk medications. Additional research needs to be done to measure the impact of the new label on patient outcomes from a quantitative perspective and within the complexity of actual clinical practice settings.

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Workforce Safety and Wellbeing as a Driver for Healthcare Safety and Quality: Convergence of Human Factors, Workforce Management, and Safety Management Science

Patient Handling in a General Critical Unit: An Ergonomics Evaluation Guided by MAPHO Tool

Angélica Garcia Juns and Natália Teixeira Braga

Abstract The objective is to determine the level of exposure of workers to ergonomic risk through the application of the Handling and Assistance to Hospitalized Patient Tool (MAPHO). This is a descriptive cross-sectional study in a General Critical Unit of a private philanthropic hospital in the state of São Paulo. The study was carried out through the evaluation of the environment, work tools, dependency profile, and aspects of work organization. A medium level of exposure of workers to ergonomic risk was determined, through the score obtained in the tool, mainly arising from the absence of employee training and an insufficient number of assistive devices for lifting patients. The study confirmed the importance of health institutions investing in the acquisition of an adequate number of auxiliary devices for patient handling, in the adequate training of the nursing team, and inadequate storage places for them in order to collaborate with occupational health. It is understood that this study will help in the elaboration of proposals for a local intervention directed to the critical information pointed out by the tool.

Keywords Ergonomics · Occupational health · Nursing care · Working condition

1 Background

Syrian-Lebanese Hospital (SLH) is a Brazilian philanthropic hospital complex, internationally recognized in health, serving more than 40 different specialties, working in preventive medicine programs, urgent and emergency medical care, high complexity therapeutic hospitalizations and rehabilitation, among others. Another hospital priority is the commitment to teaching, aiming to produce and share knowledge.

The hospital's clinical staff is composed of 8289 employees, according to information consulted in the database of workers provided by the Occupational Medicine

A. G. Juns (✉) · N. T. Braga
Syrian-Lebanese Hospital, São Paulo, Brazil
e-mail: angelica.gjuns@hsl.org.br

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sector of the SLH in September 2021. Among these, 3749 are nursing professionals directly linked to patient care in different levels of care complexity.

Within the context of the institution, according to internal reports from the Occupational Medicine area, from January 2019 to September 2021 there were 13,490 medical certificates presented referring to sick leave due to musculoskeletal symptoms at the Bela Vista unit by care employees, with an average sick leave of 718,375 days lost work in the last three years and average total absenteeism rate of 2.3% in the last three years at the institution.

Specifically in the Syrian-Lebanese General Critical Unit, there are currently 47 nursing workers, distributed in 12 × 36 h shifts, working day and night, in addition to 14 professionals working 6 h shifts daily, also divided into morning and afternoon. Also in this unit, according to information provided by the Occupational Health and Safety sector in September 2021, 4080 h of work were lost due to musculoskeletal symptoms of the care team, with an annual average of 680 lost hours of work since 2017.

Nursing workers often lift and handle excessive loads incorrectly, repetitively and for a prolonged time (Alexandre 1998). Sometimes, they perform activities that require physical effort, such as changing positions or helping the patient to get out of bed. These occupational characteristics lead to a high prevalence of Work-Related Musculoskeletal Disorders (WRMD) among these professionals (Yao et al. 2019). Patient handling is the technical term used when the professional, the nurse/nursing technician, applies the use of force to lift, push, lower, carry, move, or restrict any object or person in any activity (WorkSafe Victoria 2009).

While manually lifting, transferring and moving patients, nursing workers are gradually accumulating potentially pathogenic strains on the musculoskeletal system. These activities are intrinsic to nursing work and require a direct interaction between the worker, the individual to be moved, the equipment used and the work environment (OSHA 2007). For these workers, pain and discomfort can prevail for years, affecting not only the work but also their activities of daily living, their family and affective relationships.

As the manual movement of the patient is a work activity that demands investigations of the adequacy of work to workers, Ergonomics shows itself as a science of great value for approaching this topic. According to the International Ergonomics Association (IEA), Ergonomics is the science that seeks to understand the interaction between human beings and work elements in order to optimize well-being and work performance (IEA 2021). This science seeks to understand the interdependent factors that affect people's quality of life and their work. In addition, it seeks to analyze the postures performed in the execution of nursing work, adapting them to the principles of biomechanics (Marziale and Robazzi 2005).

The International Organization for Standardization ISO 12296: Ergonomics—Manual handling of people in the healthcare sector is an important technical report that provides recommendations on how to assist and control risks associated with patient handling (ISO 2012). Among the recommendations proposed by ISO 12296 is the use of the ergonomic conditions assessment tool: "Movement and Assistance of Hospital Patients" (MAPHO), originally in Italian named "Movimentazione e

Assistenza Pazienti Ospedalizzati" (MAPO), which evaluate the risk in order to identify the hazards, analyze the type of movement performed, organizational aspects of the work, the use of auxiliary devices, the work environment and the characteristics related to the degree of dependence of the patients (Menoni et al. 1999).

In this way, it was noted the importance of evaluating the work activity and the risks to which the nursing workers of the Hospital Sírio-Libanês are submitted, using an appropriate tool, according to the criteria chosen by the researcher, in order to improve the practice and minimize damage to the musculoskeletal system of these employees in order to respect the principles of ergonomics.

2 Methodology

This is a cross-sectional descriptive study with the application of the MAPHO tool locally in the General Critical Unit, during the months of December 2021 and January 2022.

This unit has a medical team with qualifications in emergency medicine and a physiotherapy team, exclusive to the unit, available 24 h a day. In addition, patients commonly receive basic and advanced multi-parameter monitoring in the unit, with hemodynamic and respiratory support. In general, it receives patients in the immediate postoperative period of high and medium-complexity surgeries, from vascular, cardiac, neurosurgery, thoracic and abdominal clinics.

Information was collected on the organization of work, such as the scales, of Nursing Professionals, Nurses and Nursing Technicians, and evaluation of patient records regarding the degree of dependence for movement, from the General Critical Unit.

In general terms, to apply the tool, the researcher went through the environments analyzing architectural features, furniture and equipment; collected data related to the organization of work (number of workers per shift and work schedules), observed the average frequency of movement and type of patients found in that unit, consulted records of the unit regarding the training of the nursing team in patient handling, in accordance with the application steps of the MAPHO tool in ISO 12296. All observation, measurement and data collection served as a source for the calculation of each coefficient necessary to obtain the MAPHO index and to then carry out the ergonomic evaluation of the unit.

The MAPHO index is calculated using the following formula:

$$\text{INDEX} = (\text{NC/OP x} \mid \text{LF} \mid \mid \text{PC/OP} \mid \times \mid \text{AF} \mid) \times \mid \text{WF} \mid \times \mid \text{EF} \mid \times \mid \text{TF} \mid$$
$$= \_\_\_\_\_$$

The Totally Non-Collaborating Patients (NC) coefficient indicates the daily average of patients admitted to the unit who need to be fully lifted in transfer operations. Like the Partially Collaborative Patient (PC) index, it is the daily average of

patients who are only partially lifted. The above indices can be obtained by searching by careful evaluation in electronic medical records, as well as in records of continuity of care available at the unit on the days of collection. The Number of Operators (NP) is nothing more than the value of the number of nursing employees per shift and can be obtained from documents for the quantification of nursing dimensioning on the day of collection. The Lifting Device Factor (LF) is calculated based on the quantification and physical state of the different transfer and lifting devices present in this unit, as well as the Wheelchair Factor (WF) and they are obtained through on-site inspection by the researcher. The Environmental Factor (AF) is obtained by inspecting and measuring the rooms where manual movement takes place, by the researcher without interfering with patient care. The Training Factor (TF), on the other hand, requires an analysis of the training records carried out by the unit's employees provided by the local nursing coordination.

3 Results

The application of the tool took place on 12/30/2021 at the General Critical Unit on the 8th floor of block D and was attended by both researchers. On this day, the unit had 100% occupancy of its 45 beds available in the four wings, with an average bed turnover of five days. During the day, the unit had 10 nurses, 21 nursing technicians and 03 more preparers, employees who are known to have restrictions on manual patient handling and, therefore, were not included in the application of the tool. At night, there were 06 nurses and 14 nursing technicians directly involved in patient care and manual handling. In a configuration of six hours a day, in the morning there were 03 nurses and 03 nursing technicians and in the afternoon, 03 nurses and 05 nursing technicians. At night, there are no employees working 6 h a day.

Regarding the type of patients, there were 29 patients classified as non-cooperative (NC) patients and 16 patients classified as partially collaborative (PC). In short, non-cooperative patients were elderly, obese, bedridden patients due to impaired motor function, patients with severe chronic neurological impairment, presenting only spontaneous eye-opening. The partially collaborative patients were in post-orthopedic surgery, whose ambulation was somewhat compromised, or patients with preserved mobility, but with deteriorated respiratory function due to an infectious process by COVID-19 or the influenza virus, limiting physical capacity.

Regarding the training factor, it was necessary to call the continuing education sector by telephone to seek records of previous training carried out at the unit, as they are not stored in the unit or in the possession of the coordination. After obtaining all the training carried out at the unit in the last three years, we analyzed the themes of all of them, seeking which ones were related to manual patient handling or training on patient transfer/elevation devices. Only one training slightly related to this research was found in April 2019, carried out by the company Arjo on bath chairs and lasted 30 min.

At the on-site inspection, a round of the entire floor was carried out in search of all lifting devices, transfer devices, bath chairs, wheels and stretchers. The presence of two transfer boards (Transfer) were identified, one of them with damaged sliding material and would later be sent for maintenance, in addition, according to the unit's records, there should be 03 units of it. It is not known where the third is. There was only one wheelchair intended for the internal transport of patients, with good functioning, although also, in the records, there should have been two units of the same on the floor and the location of it is not known. Hygienic chairs have only two sizes: the common and the obese. Available in the equipment room of the unit there are 11 spare chairs of the regular size and one of the obese size, in addition to the chairs that are in each bed.

As for lifting devices, the unit has two SaraPlus units from the Arjo Company on record, although only one unit was on the floor and two MaxiMove units also from the Arjo company. It is known that the other unit of SaraPlus was on loan to some other unit and that it has not been returned. Regarding transfer stretchers, the unit presented both units, according to records.

In addition to the site inspection, the researchers met with the maintenance engineering supervisor to study the unit's plans and identify the different types of architectural configurations the unit presents for the rooms, including the measurement in centimeters of the distances that the tool requires, such as width of doors, distance from the bed to the walls, etc.

From all the data obtained with the application of the tool, it was then possible to transcribe the data into a digitized version of the tool to obtain the Ergonomic Exposure Level. Considering the 06-h shift, the tool indicated an irrelevant ergonomic risk of 1.13, while for a 12-h shift, the tool considers an average ergonomic risk of 2.25 to workers at this unit.

Of the factors analyzed by the tool, the ones that stood out the most and increased the risk were the survey factors—pointing out equipment present, but insufficient or inadequate, and the training factor, indicating the absence of appropriate or insufficient training for the unit's employees. In sequence, the environmental factors, wheelchair and the minor aids factor, have little influence on the final result of the Exposure Level.

4 Discussion

The results obtained through the present study confirm the importance of health institutions investing in the acquisition of an adequate number of auxiliary devices for the manual movement of the patient, in order to collaborate with occupational health. However, not only having the devices in sufficient number will bring the desired impacts, it is known that it is also important that employees know how to handle such equipment with dexterity, as well as invest in adequate spaces for storage close to the workplace (Alexandre and Angerami 1989).

Regarding the tool, some difficulties were noted, especially in the assessment of patient movement, which does not take into account the particularities of each patient in their needs, in the sense that there are patients with constipation, there are patients with acute diarrhea, patients who walk, but only the respiratory condition restricts it, as well as disregards the manipulations made by the multi-professional team or for activities outside the unit. As well as disregarding the equipment that should be in the unit, but were somehow lost. Another difficulty is if the researcher is based only on the printed version of the tool, he will find it difficult to manually perform the calculations, where the formulas are often not fully elucidated.

In addition, in the case of large units with complex patients, it is impossible to follow all manual manipulations at the same time. Thus, it is important that the researcher has sufficient knowledge about the care routines of that unit and the classification of the complexity of patients to the point of being able to infer, by profile and routines, how many times the team will handle this patient in shifts.

5 Conclusions

However, the application of the tool offers the nursing team the opportunity to understand the risks inherent to the activities performed during the working day in this unit. Therefore, the results obtained may help in the production of safe protocols for nursing care in the manual handling of patients in inpatient units of the Sírio-Libanês and in the prevention of occupational illness of the professional team. It is expected that such information will be useful for the elaboration of solutions for the assistance processes and implementations to improve working conditions.

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A Multi-professional Approach to Investigating Musculoskeletal Injuries Among Medical Radiation Technologists: A Case Study for New Equipment

Jean-Pierre Brunet, Anita Jogia, J. Brown, Amanda Stuyt, Kayley Perfetto, Greg Leblanc, Jerry Plastino, and Jill Smith

Abstract A multi-disciplinary team of professionals applied ergonomic tools, and principles to investigate reports of musculoskeletal injuries among Medical Radiation Technologists (MRT), working in a designated X-ray imaging suite in an academic acute care hospital. Following this investigation, a proposal was submitted for the purchase of new X-ray equipment. This study demonstrates how end-users applied ergonomic and human factor principles during the new equipment selection process.

Keywords Musculoskeletal · Medical radiation technologist · X-ray · Ergonomics

1 Background

Medical Radiation Technologists (MRT) are susceptible to musculoskeletal injuries (Siegel et al. 2010), and reports of stress in the lower back, neck, shoulder, leg and hands/wrists are not uncommon even among students of the profession (Lorusso et al. 2010). Studies have reported that shoulder and lower back injuries are more prevalent, and it has been suggested that hospital staff require education about the concept of musculoskeletal injuries (Kim and Roh 2014; Kumar et al. 2004).

Due to the significant capital cost, the purchase of new X-ray imaging equipment in an acute care hospital can be challenging and end-users will continue to use current equipment as long as it can be maintained and is functional. This case study demonstrates how end-users applied ergonomic and human factor principles to identify challenges with existing equipment and how to apply the same tools and principles during the new equipment selection process.

J.-P. Brunet (✉) · A. Jogia · J. Brown · A. Stuyt · K. Perfetto · G. Leblanc · J. Plastino · J. Smith
London Health Sciences Centre, London, Canada
e-mail: Jean-Pierre@sjhc.london.on.ca

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2 Methodology

Clinical leadership initially contacted the Ergonomic Specialist to provide guidelines for purchasing new X-ray equipment. However, following reports of musculoskeletal injuries a multi-disciplinary team of professionals was involved in a more detailed assessment that included:

1. Review of injury data (from LHSCs online incident reporting system);
2. Repeated on site observation of work performed in the Medical X-ray Imaging Suite with the Medical Radiation Technologists, Biomedical Engineering, Safety Analysts, Patient Safety, Ergonomic Specialist and the maintenance crew from the current equipment supplier (external stakeholder);
3. Onsite reviews completed over a period of several non-consecutive days;
4. Informal interviews with staff (and students) who worked within the designated Medical X- ray Imaging Suite (completed during on site review);
5. Informal interviews and discussions with area leadership (completed during and following onsite review);
6. A review of the repair work history was conducted with the hospital's contracted third party service provider for the device;
7. The force required to manipulate the imaging arm was measured using a Shimpo Digital Force Gauge, with repeated direct measures and repeated force-matching technique (user estimates force applied on gauge following immediate push/pull of imaging arm).

3 Results

Following an initial consultation with the Ergonomic Specialist, regrading one staff incident related to the amount of force required to move the X-ray arm, the Clinical Leader used the strain gauge to take force measurements. The force required to move the X-ray arm was added to an existing guide for the purchase of capital equipment for new X-ray equipment.

The focus of the measurements was on the major X-ray system components, the X-ray ceiling tube suspension and the patient table. Both of these components that directly contributed to the reported musculoskeletal injury. Both the X-ray ceiling tube suspension and patient table were assessed to establish the required input force of an MRT to produce the desired movement. The ceiling tube suspension was tested bi-directionally in three planes (vertical, longitude and lateral) under normal settings and operating conditions.

During site visits to other hospitals as part of the purchasing Request For Proposal (RFP) process, the patient table component was tested bi-directionally in two planes (longitudinally and laterally) under load with one RFP committee member volunteering to simulate a given patient for all equipment assessed during the site visits. The force measurements were performed under normal operating conditions to assess the required input force.

Also noted during the site visits were any auto-assisted/robotic movements of the proposed X-ray components that would decrease or eliminate the need for manual handling from the X-ray technologist.

The results of the measurements identified in some cases a disparity of 28N of force required to overcome inertia and produce an intended movement between the systems assessed for potential purchase. See Appendix A for the tool developed and measures taken during site visits.

One advantage to this study was to have a team of multi-disciplinary professionals complete a more comprehensive assessment of the X-ray equipment following additional reports of staff injuries and to have ongoing feedback from various Medical Imaging staff throughout the process.

Information gathered from the hospital's online reporting system on staff injury is summarized in Fig. 1 and includes the actual incident severity level. The first incident was a level 4 (lost staff time due to injury) and subsequent injuries were reported as level 2 (first aid required) and level 1 (no harm).

MRTs work 8 and 12-h shifts (including weekends) according to a master a schedule. They rotate between working in General X-ray, Operating Rooms, Sports Medicine, Portable X-ray and the Medical X-ray Imaging Suite. Although MRTs only work 2–3 days per week in the designated Medical X-ray Imaging Suite, this was the area they reported as a primary concern. The number of patients seen per shift/tech/day can vary, and the amount of time needed to complete a patient's X-ray can vary by body region i.e., 10 min for foot/ankle or chest X-ray to 20 min for an abdomen.

MRTs were randomly observed working in the designated Imaging Suite on different days by a team of multi-disciplinary professionals. The typical process

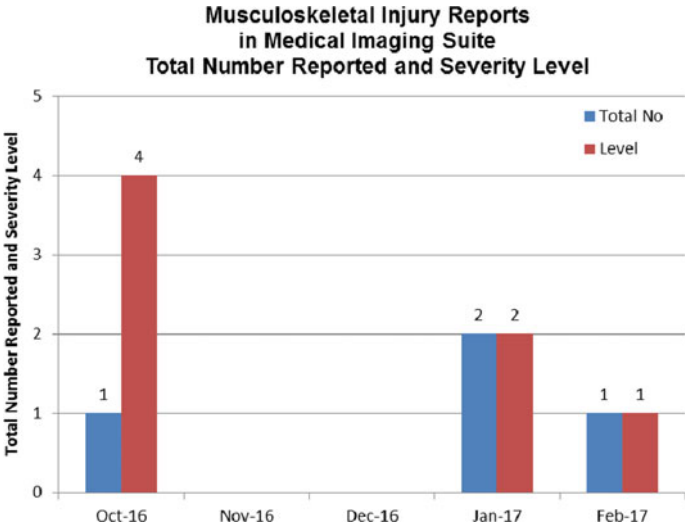

Fig. 1 Total number of MSD injuries report and actual severity level for medical imaging suite

involved: verifying patient information, body region to X-ray, setting up the patient, performing the scan, and returning the patient to the unit. The team observed challenges in setting up patients but of greatest concern were the difficulties that staff experienced in moving and adjusting the X-ray arm, an inherent part of the MRT's role.

During one observation period, the external maintenance personnel were in the area performing repairs, and they were asked about the frequency of maintaining/repairing the unit. Their reply was that the unit is an older system and as such will require frequent repairs. Upon further investigation, it was noted that the device had reached its end-of-life support for service making it difficult to source parts. Given the age of the equipment, it was more prone to breakages and mechanical system failure such as rails and brakes requiring increased service levels to maintain. Figure 2 shows the increase in servicing the equipment over the years and past the end of service date of the equipment.

MRTs were very cognizant of patient safety throughout the study, and the team included input from patient safety concerning patient concerns throughout the process. During the time of this study, Patient Safety was reviewing the department's patient fall data. However, no incidents were mentioned about the designated X-ray imaging suite.

One of the challenges during the study was determining what kind of quantitative data to gather to evaluate the MRTs concerns with manipulating the equipment. A number of MRTs would rotate with working in the designated imaging suite, and although they did not all formally report concerns, the majority, including students, did informally share concerns in manipulating the equipment during the onsite review.

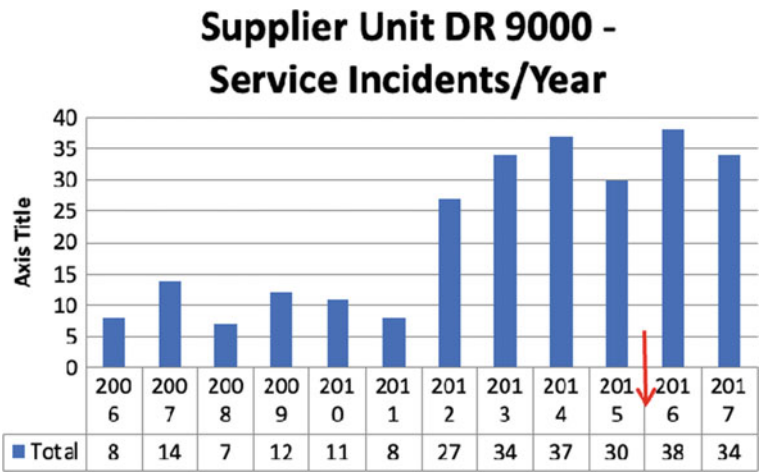

Fig. 2 Maintenance summary of designated X-ray equipment

Table 1 Force measurements of the machine (lbs and N)

Task	Measure	Comment
Force required to depress buttons	2.0 lbs (8.7N), height range 42″–77″	
Force to push on unit on x-axis	23 lbs (100N) (ave) (range in height)	Sometimes performed at or above shoulder
Force to push on unit on y-axis	7.5 lbs (33N) (ave) up to 9 lbs(39N)	Depends if track has been recently serviced or not
Force to push/pull table with 175 lbs (78 kg) person (weight based on random selection of volunteer during the review)	16. 7 lbs (73) (average) up to 23 lbs (100) (height of push/pull is 26″ to position table under unit)	Table's centre of gravity is off set to accommodate positioning under the machine; staff will push from side to align patient but table doesn't steer well

Based on injury reports and verbal feedback from the imaging staff, the required force to manipulate the current equipment was measured using random force-matching techniques (when MRTs must simultaneously continue to depress a button while moving the X-ray arm) and direct measures (when not simultaneously depressing a button) on the equipment using a Shimpo Digital Force Gauge.

Table 1 summarizes the force measures taken of the machine (measures taken with staff and leader representation).

4 Ergonomic Criteria

The forces required to manipulate the X-ray arm exceeded acceptable limits of push/pull for this type of activity; recommended maximum levels are 5 lbs (22N) (shoulder abduction/adduction); 11 lbs (48N) (forward flexion), and the forces to depress the buttons should be 0.25 lbs (1N)– 1.8 lbs (8N) (Diffrient et al. 1993).

The forces to move the X-ray table did not exceed acceptable values of initial push/pull, max. value 37 lbs (161N) but did exceed sustained values of push/pull at 15 lbs (65N) (Snook and Ciriello 1991). Of note, is that the table did not steer well from the side, and the majority of staff explained that they keep the table in the lowest height position to avoid having to re-adjust again after moving it to the X-ray machine.

5 Discussion

By having a multi-professional team as part of the assessment, the staff and leaders were actively engaged in the assessment process and as such were supportive of implementing many of the procedural recommendations to immediately address the challenges in working with the equipment. These recommendations included: refresher in-services on good body mechanics and safe patient handling, testing of different type of patient handling equipment that may better support patients, ensuring that staff take their designated breaks throughout their shift, continuing a fair rotation throughout the unit, and to encourage staff to formally report concerns through the hospital's online reporting system. It was recommended to have a regular schedule of maintenance by the external repair provider.

A recommendation, provided in an SBAR (Situation, Background, Assessment, Recommendation) format, was also submitted for senior leadership to consider funding to replace the current equipment within the Medical Imaging X-ray Suite at the designated LHSC site. The request was put forward through the capital equipment purchasing process and funding was approved. The frontline staff and leaders were involved in the selection of new equipment and travelled with a strain gauge taking force measures during the selection process to help them in making their decision.

Capital funds were not available at the time of the initial staff incidents. Concurrent to the first musculoskeletal disorder incident, a Request for Proposal (RFP) for replacement equipment was underway with the vendor responses forthcoming as the next milestone. In consideration of the initial reported musculoskeletal injury, leadership felt it prudent to revise the selection criteria to include human factors, specifically technical, quality and performance metrics. Specifically, the criteria developed included evaluation of the measured required forces of the frontline staff to produce the intended movement of the X-ray equipment. Leadership used the force gauge to compare forces required to move the X-ray tube during field visits to select new equipment. In this, leadership created evaluation criteria based on force measures required of front-line staff (MRTs) to operate the equipment.

The incidents and follow-up actions herein underpin the importance of considering ergonomics and human factors when purchasing equipment to be used daily by MRTs to mitigate risk of injury. Furthermore, the inclusion of frontline staff and ergonomics in addition to technical and clinical experts, provides the context and insights of potential hazards related to use of equipment.

One of the challenges may be the initial time required from front-line leaders to be actively involved in the process. However, the initial time investment resulted in the creation of tools that proved valuable in identifying potential benefits or concerns for equipment purchases.

6 Conclusions

Healthcare ergonomics can be very challenging specifically when investigating incidents that may be related to defective or non-functional expensive medical equipment. Appropriately, equipment is generally selected based on its benefits to patients, however, when the equipment requires frequent interaction by staff, end-user feedback should be equally considered in the selection of new equipment.

It is recommended that the practitioner consider a multi-professional team approach when investigating challenges with medical equipment. Specifically, when the equipment may still be able to provide safe patient care and no noticeable defects are apparent. Appropriate time should be taken to investigate all possible risk factors, and all stakeholder input should be considered. It is also recommended to allow stakeholders to be involved in taking relevant measurements and to understand ergonomic analysis. While they may not be ergonomic experts, they will quickly understand how the measurements are relevant when using them in selecting new equipment.

As a result of this study, the Medical Imaging Department at LHSC has reaffirmed the need to consider human factors from the outset of a capital purchasing process. Frontline leadership support for a multi-disciplinary team, including input from ergonomics and frontline staff will provide robust assessment and potential validation of the vendor purported ergonomic benefits in the selection process for new equipment.

Appendix A: New X-Ray Equipment Assessment Tool

	Criteria	Score	Comments
1	Time to position equipment from park -**hips to ankles**	100	Quick
2	Time to position equipment from park -**Supine abdomen**	100	Quick
3	Time to position equipment from park - **Erect Chest**	100	Quick
4	Time to position equipment from park -**Cross-Table Hip**	100	Quick
5	Force required & ease to move/set up hips to ankles apparatus	100	tube auto, stand easy to move, great ruler attachment behind pt. so that slides easily behind pt.
6	Force required for tube movement in manual positioning - **lateral movement**	100	Ergonomically friendly with very little force required (11N average) to produce desired movement
7	Force required for tube movement in manual positioning - **vertical movement up**	100	Ergonomically friendly with very little force required (11N average) to produce desired movement
8	Force required for tube movement in manual positioning - **lateral movement down**	100	Ergonomically friendly with very little force required (11N average) to produce desired movement
9	Force required for table movement manual positioning of table in **lateral and transverse floating movement**	60	
10	Force required for table movement manual positioning of table in **movement under load**	60	
11	Range of table travel - **Vertical**	60	
12	Range of table travel - **Transverse**	60	
13	Range of table travel - **Longitudinal**	60	
14	Minimum and maximum table height	60	
15	Tabel float control (kick plate, floor mounted pedal, fixed pedal, wireless pedal)	100	Wireless remote control foot switch control. Light to move and simple to operate.
16	Control of automation (remote, in-room, tube head, console)	100	Fully automated with no dead-man switch. Safety with respect to equipment movement/collision is provided via sensors on the tube head assembly.
17	Automation of X Ray table - (remote, in room, tube head, console)	100	Comprehensive functionality includes technique and positioning tutorial and also image display in addition to technical factor setting and patient demographics.
18	Low contrast resolution	N/A	
19	High contrast resolution	N/A	
20	Line pairs/mm	N/A	
21	Time to turn on	N/A	
22	Soft reset	N/A	
23	Full shutdown and reboot	100	Fastest out of all systems considered <2 min
24	Time to acquire image (preview and full) from exposure	100	Near immediate display of preview with nominal interval to display full fidelity image.
25	Ease and speed of transition/navigation through menus and windows	100	Logical layout and intuitive. I could navigate the menus and produce imaging for the resolution testing without the need for instruction.
26	Method to set up stitching (ease of use)	100	This functionality was demonstrated both supine and erect. The set up was quick and intuitive. Stitching was automated with little user intervention required.
27	Overall impression	100	Ergonomics are outstanding with very little effort required of the user to produce the desired movement. Automation of several fundamental functions such as the automatic tube angulation to the detector for out of bucky work produces significant efficiency gains. The double pedestal table base allows for the use of a hoyer lift that grately reduces risk in transferring patients who have limited mobility. Overall the safety, ergonomics, ease of use and efficiency of this system is far beyond any other system evaluated in this process.

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Shared Sensemaking and Clinical Decision-Making in Critical Care from a SA-Oriented Dashboard

Lise Boudreault, Philippe Jouvet, and Philippe Doyon-Poulin

Abstract At the start of the COVID-19 pandemic, Intensive Care Units (ICUs) admitted an unusually high number of patients suffering from the most severe respiratory effect of the disease. The clinicians worked in teams in a context where resources were limited, and efficient resource management was key to ensure on-time healthcare delivery. Our team of researchers adopted the situation awareness (SA) model to design a SA-oriented dashboard. The main research objective was to improve clinicians' situation awareness, through the visualization of resource management key indicators to perceive on what is going on, comprehend its meaning and project future actions. A total of 17 clinicians participated to the dashboard design. We used the conceptual framework of the staff-stuff-space-system-of-care (4S) factors to resource management in critical care. A user-centred design method allowed to define the dashboard key indicators from the clinicians' situation awareness goals (perceive, comprehend, project) and 4S information requirements. However, the outcomes revealed that little was known on how the 4S factors to the clinician situation awareness contributed to a shared sensemaking and to clinical decision-making among the team members. We found a core factor to a shared sensemaking identified as "health Status at bedside". This 5th "S" factor informs the clinician team on both the 4S (staff-stuff-space-system regulation) resources in used and the clinical condition at bedside. From then, we identified the 5S factors as the drivers of the clinicians' cognitive processes in critical care. We synthesized the research outcomes in the Situation Awareness and Shared Sensemaking Decision Model (SASS). We conclude by suggesting that much can be gained from the evaluation of the SASS model in critical care.

L. Boudreault (✉) · P. Doyon-Poulin
Department of Mathematics and Industrial Engineering, Polytechnique Montreal, Quebec H3T 1J4, Canada
e-mail: lise.boudreault@polymtl.ca

P. Jouvet
Centre de Recherche du Centre Hospitalier Universitaire Sainte-Justine, Quebec H3T 1C5, Canada

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1 Background

During the COVID-19 pandemic, in support of the clinicians working in the largest Canadian mother–child hospital located in Quebec, our research team designed the situation awareness-oriented (SA-oriented) dashboard (Boudreault et al. 2022). We adopted the situation awareness model to study the human and ergonomic factors impacting the clinicians' cognitive processes to perceive, comprehend and project actions in complex and dynamic environments of critical care. The SA model (Endsley and Jones 2004) is recognized as one of the most prominent models to study cognitively complex functions in demanding real-world situations (Roth et al. 2022).

A total of 17 clinicians participated to the SA-oriented dashboard design (Fig. 1). We used the conceptual framework of the staff-stuff-space-system-of-care (4S) factors to resource management in critical care (Christian and Kissoon 2020). A user-centred design method allowed to define the dashboard key indicators from a Goal Directed Tasks Analysis (GDTA). GDTA is a modified form of cognitive task analysis that has been utilized by proponents of SA theory for determining SA requirements in varied fields like aviation, army, railroad, nuclear, assistive technologies and computer science (Sharma et al. 2019). We applied the GDTA in the field of critical care, from the association of the clinicians' situation awareness cognitive goals (perceive, comprehend, project) with their clinical tasks and 4S resources requirements. This resulted in the display of 15 key indicators (KIs) at bedside and 6 KIs related to the overall unit in the central area. In the end, we expected the 21 KIs of the SA-oriented dashboard would improve the clinicians' SA and decision-making processes.

However, we found that little is known on how the visualization of resource management KIs contributed to clinical decision making. Staff loading ratios (patient-to-nurse, patient-to-doctor) and list of incoming patients displayed in the central area favored the team's discussion on how many new patients could be admitted to the unit. This information was not readily available to clinicians on the previous dashboard and discussions on admission rate were more laborious for them to make sense of the unit status. Hence, this paper studies this gap in knowledge through a review of theoretical work on the cognitive processes of situation awareness, sensemaking, shared sensemaking and clinical decision-making. We propose a new model that synthesizes the major findings on the clinicians' cognitive drivers of clinical decision-making from three resource management levels: bedside, critical care organizations and the system-of-care.

The rest of the paper is organized as follows. First, we present related work on the 4S factors to resource management followed by studies on individual and team cognition. Second, we present the outcomes of our research on the design and

Fig. 1 SA-oriented dashboard prototype

usability of a SA-oriented dashboard. Third, we synthesize the findings in a new theorical model. We conclude with the research perspectives.

2 Related Work

2.1 4S to Resource Management in Critical Care

Resource management in Intensive care unit (ICU) is often referred by the 3S factors of staff, stuff and space: teams need to know the medical staff on duty, their skills and competencies, the materials and medical supplies available or lacking, as well as the beds spaces available to treat patients (Fiest and Krewulak 2021). Whether the context of critical care is in ICU or in pediatric intensive care unit (PICU), the unit requires a standard of care to sustain the 24 h/7 days changes in the personnel (staff) providing critical care, the places where critical care may be delivered (space), and the supplies available for providing this care (stuff) (Christian et al. 2011).

The capacity to deliver care and clinical decision were strengthened or limited by the strongest or weakest link powering the 3S resources management. This was obvious at the start of the COVID-19 pandemic, as there was a lack of ventilators

(stuff) to treat patients, followed by shortage of clinicians (staff) for care delivery while they needed to isolate themselves after having caught the virus (Grasselli et al. 2020; Thompson et al. 2020; Vranas et al. 2021). Although the triage and treatments of patients in hospital-centric plans were previously based on the 3S factors, there was a clear need to prioritize the allocation of scarce medical resources from an integrated population-based, system-wide solution (Christian and Kissoon 2020). It emerged as the 4th S factors under the name of System of care regulation. Public health authorities in most of the countries in the world hold this mandate, reinforced collectively by their inner adaptation of guidelines and rulings at the institutional level by the world health organization (WHO 2022). The WHO's recommendations on a new modus operandi emphasized the countries' requirements to put in force public health policies and ruling. Rules formulated at the system-of-care level (4th S) directly influenced the clinician's situation awareness and decision for resource allocation at bedside.

2.2 Team Cognitive Processes

Situation awareness (SA) is one of the most influential model in human factors research to study cognitive processes impacting decision and performance (Stanton et al. 2017). SA is a state of knowledge attainable from three levels of non-sequential, ascending cognitive processes defined as "the perception of the elements in the environment within a volume of space and time, the understanding of their meaning, and the projection of their status in the future" (Endsley 1988). Endsley's SA model was originally developed in the field of aviation to study the origins of human errors in aircraft accidents (Jones and Endsley 1996) and has since made its way to other complex, dynamic settings to improve the operator's assessment and decision making in military operations (Riley et al. 2006), marine navigation (Haffaci et al. 2021) and medicine (Schuster and Nathan-Roberts 2017).

However, the cognitive emphasis in the SA model is on the individual. In health-care settings, even if one person is leading the decision to action, a prior step is sharing the knowledge and expertise to make sense of a situation (Abbasgholizadeh Rahimi et al. 2017; Hoffmann et al. 2014). During the pandemic, when hospitals were asked by the system-of-care to postpone surgery to care the sudden increase of patients suffering from the worst effect of the COVID-19 respiratory disease, the clinicians had to share their understanding of the situation to decide on actions. Shared sense-making, situated cognition and shared SA are required to study decision-making at teams' level. All three are recognized as critical input to decision-making, but they differ in their research approach and methods.

Sensemaking is defined as the ability or attempt to make sense of an ambiguous situation; it is the process of creating situational awareness and understanding in situations of high complexity or uncertainty in order to make decisions, often in response to surprise (Klein et al. 2006). Information is at the heart of the sense-making process. Problems arise when information may be missing; in this case,

the sensemaking process starts by making guesses using retrospective knowledge (Ntuen et al. 2010). This is observed with experts when they use their more efficient rational "slower thinking system" and their more intuitive but risky "fastest thinking system" (Kahneman 2003, 2011). The theory of the fast and slow "thinking systems" is useful to explain how he visualization of real-time information on the SA-oriented dashboard could sustain a balanced shared sensemaking from a real-time learning process during a chaotic situation created by an unusual flow of patients as during the first waves of the COVID-19 crisis. Moreover, if the SA-oriented dashboard information is not updated, and do not reflect the real situation, a shared sensemaking could contribute to correct the cognitive dissonance emerging from the fast and slow "thinking systems".

In organization theory, shared sensemaking among team members is considered a situated cognition process mostly studied in naturalistic context i.e., when and where the actions take place (Klein 1993; Orlikowski and Baroudi 1991). When team members have a problem to solve, they share their perception and understanding of events and project a solution or solutions, allowing them to adapt to an evolving situation of deciding in action (Kaplan and Orlikowski 2013). In organizational settings, where groups of individuals work, there exist cognitive mechanisms of memory recall of actions in similar circumstances, which also lead to imitation and acceptance behaviors to cope with solutions proposed by others (DiMaggio and Powell 1983). Then, a mutual learning of the members of a team influence the individuals SA. The construction of meaning is a dynamic process of shared sensemaking which is more than the sum of the individual SA of each team member. Then, we cannot ignore in the design of a SA-oriented dashboard, the cognitive phenomenon of shared sensemaking from the dynamic process of learning in action which eventually lead to deciding.

In systems and engineering research, team SA is defined as "the degree to which every team member possesses the SA needed for his or her job" (Endsley 2021, p. 12). Within each teams, there is a need for shared SA (SSA) which is "the degree to which team members have the same SA on shared SA requirements" (Endsley 2021, p. 12). In the SA theory, teamwork and shared sensemaking are considered an outcome of individual decisions aggregated to the level of a team, leading to a posteriori rather than a "real-time" measurement of the decision and performance of action. However, there is no explanation as to how the individual SA participates to the building of a shared sensemaking among team members and why this influence decision-making.

In this work, we studied how the 4S resource management factors contributed to the building of a shared sensemaking among team members in "real-time" situations in critical care. This understanding will be helpful to improve the cognitive processes of the clinicians in the design of an "intelligent" SSA-oriented dashboard. To this end, we proposed a new model on Situation Awareness and Shared Sensemaking (SASS) that synthesizes this knowledge.

3 Methodology

We conducted a goal directed task analysis (GDTA) with 17 ICU clinicians working in ICU to identify their SA requirements (perception, comprehension, projection) according to their everyday goals, activities and tasks. To trigger clinician's SA and decision making, we used as a probe a SA-oriented dashboard (Hébert-Lavoie et al. 2021) under scenarios of increasing patients' load. We transcribed the interviews and analyzed the verbal protocols, categorizing the clinicians' SA requirements (perception, comprehension, projection) under the resource management 4S factors.

4 Results

We found three evidence that clinicians perceive and comprehend the information presented on the SA-oriented dashboard according to their priorities (Tan et al. 2019).

First, we found the clinicians SA was driven by the 4S factors informing the clinician team on the management of resources in the PICU. What was determinant to them were the displayed of both information, 4S resources at bedside, and the clinical condition at bedside. This revealed a 5th S factor—health Status at bedside—informing the clinician on the clinical condition of patients was pivotal to a shared sensemaking. When the clinicians were asked if they could admit new patients, the clinicians first built their sensemaking of the overall health condition of the patients from 5S indicators displayed at bedside: the number of nurses at bedside (staff), equipment and material (stuff), bed localization (space), COVID status (system-of-care) and nurse workload and clinical condition at bedside identified as the "health Status at bedside".

Second, the visualization of the SA-oriented dashboard speeded up a shared sensemaking on the overall admission capacity. We found the display of the 32 beds' occupancy was not the dominant factor of the decision to admit. It was the staffing of nurses at bedside and the patient-to-nurse ratio that were the two most influential factors to decide how many patients were admissible (Wynendaele et al. 2019). These two S factors (staff, health Status at bedside) reduced the mean time to clinical decision to admit, wait to admit or transfer in other PICUs since it took less than 30 s to make sense of the situation with the SA-oriented dashboard and between 30 and 60 s from the dashboard in used before the pandemic.

Third, the PICU status indicator—open to admission (green), selective (yellow), very selective (red)—contributed to the clinicians' perception on the capacity to admit. However, before deciding to admit, they looked at the overall situation to make sense from a comparative assessment between their comprehension of the 5S indicators displayed on the SA-oriented dashboard. It revealed that the SA indicators were also participating to a shared sensemaking, since similarities of their cognitive processes were influential to clinical decision-making.

The SA-oriented dashboard usability limitations to the understanding of the impact of a shared sensemaking on clinical decision-making were the following: the interviews were conducted remotely, on an individual basis due to the COVID-19 confinement measures, the PICU status indicator to decide on admission was refreshed manually instead of being automatically evaluated in real-time situation, and the display of the 32 beds arrangements in the PICU was static, limiting its use in other critical care hospitals.

5 Discussion

The results presented above put in evidence two major information requirements of a SA-oriented dashboard. The clinicians use and integrate the information provided by the SA-dashboards when they reached some sort of common goals on resource management and clinical condition of the patient before deciding on action. We found the visualization of the SA-oriented dashboard helped the clinicians to cope with an uncertain future regarding clinical decision-making. Specifically, under conditions of ambiguity and competing interpretations, without some shared understanding of the future, plans or decisions are hazardous (Kaplan and Orlikowski 2013).

We found 5S factors being influential to a shared sensemaking on what is going on. This is coherent with the fact that in acute care settings when the problems are ill structured, that time is urgent rather than ample and the environment is dynamic and uncertain, the stakes are high to share information and create a common ground of understanding to come out with shared decisions (Klein et al. 2005). It is aligned with the evidence that a shared decision-making (SDM) is essential in healthcare settings (Abbasgholizadeh Rahimi et al. 2017).

We also found the key indicators displayed on the SA-oriented dashboard shaped a shared sensemaking from three levels of decision in critical care hospitals. An operational level at bedside, a tactical level in the critical care hospital and a strategic level through regulation by the system-of-care. This is coherent with the results from a literature review on the typology of dashboards in hospitals: strategic at the organizational level, tactical at the unit level (e.g., ICU), and operational at the individual level (patient/clinicians in ICU) (Buttigieg et al. 2017). It reinforces the point that in hospitals where the teams of clinicians work, clinical decision-making depends on a shared understanding of the operational, tactical and strategic decisions to action (Pace and Buttigieg 2017).

Our study on resource management in critical care hospitals added new knowledge to the work on dashboards for public organizations (Kaplan 1996; Kaplan and Norton 1992, 2001a, b). In a system-of-care, hospitals' managers and clinicians have a role of accountability to society, which is present in the research findings. We contributed to new knowledge on the capacity of a SA-oriented dashboard to improve clinical decisions from the integration of the information requirements present in three system-of-care levels: regulation at the strategic level, resource management at the tactical level and bedside health status at the operational level. These three levels

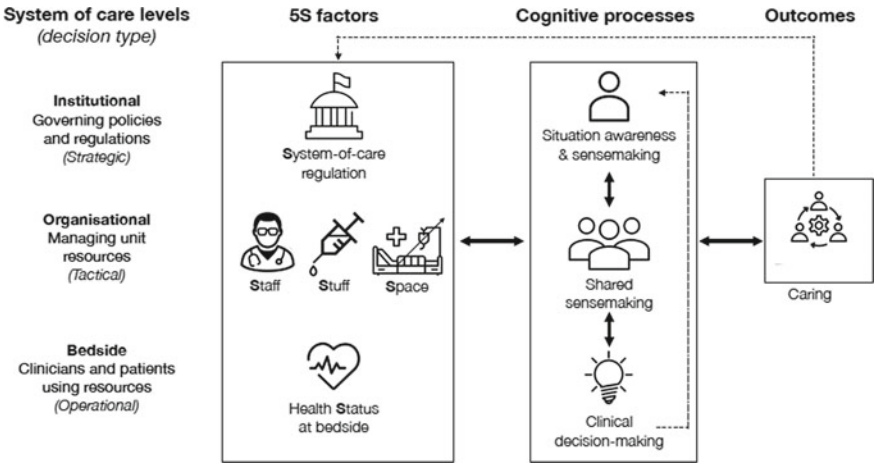

Fig. 2 Situation awareness and shared sensemaking decision model (SASS)

contributed to an individual situation awareness and sensemaking, which in turn participated to a shared sensemaking of the clinicians before they decide on action.

We synthesize our findings in a Situation Awareness and Shared Sensemaking model (SASS). The SASS model illustrated in Fig. 2 presents the 5S factors "System-of-care-Staff-Stuff-Space-health Status at bedside) as an input to three cognitive processes: an individual's SA and sensemaking (perception, comprehend, project) and at the team level a shared sensemaking and clinical decision-making. The ultimate decision may be taken by only one individual in the group of individuals, but the model emphasizes the way a team of clinicians comes out to a decision from a shared sensemaking cognitive process. The outcome of the cognitive processes is caring. It could be evaluated from its impact on the quality and safety of care. However, this aspect is beyond the scope of our study.

The SASS model conforms to the input-transformation-output and feedback loops present in sociotechnical theories (Langley 1999; Nutt 1984; Rogers 1983) and engineering systems theories (Karsh et al. 2006). Sociotechnical theories are present in two dominant models on resources management in healthcare organization: the structure-process-outcome (SPO) model (Donabedian 1966, 1988) and the system-processes-outcome of the model of Systems Engineering Initiative for Patient Safety (SEIPS) (Carayon et al. 2006) and extended models SEIPS 2.0 (Holden et al. 2013) and SEIPS 3.0 (Carayon et al. 2020). When compared to the SPO and SEIPS models, the SASS model presents a new understanding on how the cognitive process of a shared sensemaking among the clinicians contribute to the cognitive clinical decision-making process and the final decision on caring.

6 Conclusion

In this study, we explained the main drivers to a shared sensemaking for resource management and clinical decision in critical care. We identified the main factors as the 5S: health Status at bedside, Staff-Stuff-Space in the ICU and the hospital and the rules and directives from the System-of-care regulation. We showed that the 5S factors shaped three cognitive processes: an individual's SA, and two at the team level for shared sensemaking and clinical decision-making. We synthesized these findings into the SASS model that explains the relationship between the 5S factors on resource management and clinical decision types from three levels of understanding: institutional, organizational, at bedside. The 5S factors are input to the five cognitive processes: SA, shared sensemaking, clinical decision-making, involved in the outcomes on caring.

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Artificial Intelligence

Accountable Risk Management in Healthcare During the COVID-19 Pandemic; the Role of STSA and AI

Nick McDonald, Marie E. Ward, Lucy McKenna, Rebecca Vining, Julio Hernandez, Brian Doyle, Una Geary, John Guilfoyle, Arwa Shuhaiber, and Rob Brennan

Abstract Effective governance necessitates going beyond compliance with rules, regulations and procedures; particularly as adverse events are generally the result of a combination of human, organisational, technological, and economic factors. This study explores the use of socio-technical systems analysis (STSA) in an Artificial Intelligence (AI) platform called Access-Risk-Knowledge (ARK) to go beyond established accountability frameworks by linking evidence, outcomes, and accountability. The aim of the ARK-Virus project was to use the ARK Platform to support mindful risk governance of infection prevention and control (IPC) for healthcare organisations during the COVID-19 pandemic. ARK was deployed across three healthcare organisations: a fire and ambulance service, an outpatient dialysis unit, and a large acute hospital. Each organisation conducted an IPC case study, the three of which were then compiled into a synthesis project. A set of guidance principles for a pandemic preparedness strategy were proposed using the synthesis project findings. A Community of Practice (CoP) enabled the successful deployment of ARK, including intense interdisciplinary collaboration and was facilitated by practitioner-researchers in the implementing organisations. Data governance methods and tools supported a whole organisation and multi-organisation approach to risk. This first

N. McDonald (✉) · M. E. Ward · R. Vining · B. Doyle
Centre for Innovative Human Systems, The University of Dublin, Trinity College, Dublin, Ireland
e-mail: nmcdonld@tcd.ie

M. E. Ward · U. Geary
Quality and Safety Improvement Directorate, St. James's Hospital, Dublin, Ireland

L. McKenna · J. Hernandez
ADAPT Centre Dublin City University, Dublin, Ireland

J. Guilfoyle
Health and Safety Unit, Dublin Fire Brigade, Dublin 02 RY99, Ireland

A. Shuhaiber
Beacon Renal, Sandyford Business Park, Dublin 18 TH56, Ireland

R. Brennan
ADAPT Centre, University College Dublin, Dublin, Ireland

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full implementation trial of the ARK platform deployed dedicated STSA within a semantically structured AI framework, demonstrating accountable risk management that addresses the complex antecedents of risk, links to evidence, and has the potential for managing the full cycle of risk mitigation and improvement.

Keywords STSA · AI · Infection prevention control · COVID-19 · Accountable risk management

1 Background

Organisations want to be able to manage the risks that they face in a manner that is coherent, comprehensive and effective. Excellence in operational risk management means going beyond reacting to specific incidents or regulatory compliance; it implies being able to muster the evidence to support the transformation of system performance to meet strategic goals in a proactive and generative way. This involves meeting a range of challenges:

- Harnessing data to generate evidence
- Generating system understanding
- Building joined-up governance
- Developing the capability to change
- Developing networks of support, learning and the exchange of knowledge.

1.1 The ARK-Virus Project

The Access-Risk-Knowledge (ARK) software platform was developed around a socio-technical methodology for analysing complex risks and mitigating these through a managed process of change. The basic theoretical concept behind ARK is McDonald et al.'s (2019) Mindful Risk Governance model. ARK links a structured socio-technical system analysis (STSA) to relevant data and documentary evidence to support the assessment of risk and the management of that risk through a sequence of project stages. Users and stakeholders are supported by report generation, visualisations and flexible navigation of the linked risks, projects, analyses and evidence. During the ARK-Virus project, the ARK platform was deployed within three collaborating healthcare organisations to manage risks associated with infection prevention and control (IPC) in the context of the COVID-19 pandemic.

The deployment of the ARK platform is based on best practice in data governance through developing extensive metadata and an evidence catalogue that includes datasets and publications. The platform uses privacy by design (data protection in data processing incorporated in the design of the technology) for controlled data sharing between organisations. A Community of Practice (CoP) has been formed between developers and users of the platform. The CoP facilitates learning and

collaboration by connecting platform users, primarily risk experts, from different healthcare organisations. The ARK platform leverages Semantic Web technologies (Gutierrez and Sequeda 2021), with WWWConsortium (W3C) standards, and security and privacy information standards—ISO 27001 (ISO 2013), to model, classify, integrate, and secure risk and operational data.

Since May 2021, ARK has supported IPC risk management projects in a large acute hospital (O1), a fire and emergency medical services organisation (O2), and an outpatient dialysis unit (O3). Each organisation used ARK to carry out an IPC-related case study. O1 focussed on improvement of data governance related to the prevention and control of healthcare-associated infections (PCHCAI). O2 and O3 focussed on issues relating to prevention of COVID-19 infection among staff. Throughout the three trials, participants used the platform and gave feedback to direct its improvement (see McDonald et al. 2021). This paper focuses on Trial 3 (January-April 2022). The project generated a Stakeholder Report (ARK-virus 2022) which supported a wider consultation with a diverse set of stakeholders, including both regulatory and technology focussed agencies.

2 Methodology

ARK provides a risk management platform that guides users in carrying out a risk mitigation project from identification of the risk (typically via risk assessment) to verification of the mitigation project's outcomes. Each ARK project focuses on one specific risk and is organised in five stages: Problem, Solution, Plan and Prepare, Implement, and Verify and Embed. At each project stage, analysis is done using these features (Fig. 1):

- An assessment of the risk and the value (potential loss and gain) of the project.
- STSA using the Cube framework, which guides users in managing organisational change by asking them a series of questions. The Cube links goals, actions, and outcomes to operational processes, developing awareness of multiple dimensions

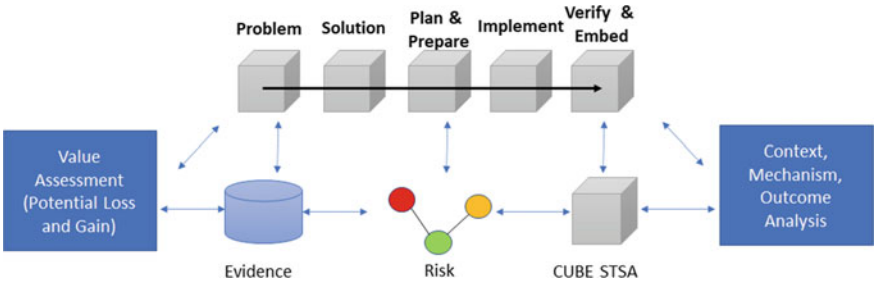

Fig. 1 ARK risk mitigation project phases with linked risks, evidence and analysis

of the system through engaging with it (see Geary et al. 2022; McDonald et al. 2021; Ward et al. 2022 for examples of the Cube in use).
- A Context-Mechanism-Outcome analysis (Pawson and Tilley 1997), which synthesises the findings of the Cube under three headings: Context (the general conditions which define the relevance of this particular intervention), Mechanism (the modes of leverage that can act to sustain or transform the situation) and Outcome (the generated products of that activity or intervention).
- An evidence catalogue containing infection rates, IPC protocols, PPE compliance rates, etc., which is linked to specific parts of the analysis.

ARK projects assist risk experts in evaluating risks and managing mitigation projects through this high-level evidence-based analysis. By integrating all available evidence and making it available at the point of decision-making, it is possible to prioritise key factors and adopt a more proactive approach to risk management.

Semantic features of the ARK platform, including a core unified knowledge graph, ontologies with suggestion capability, and similarity comparisons between projects, enable the high-level synthesis of multiple ARK projects. Learnings from three organisational-level projects outlined in this chapter were integrated into a synthesis project, the results of which are outlined below. The project was used to create a shared understanding of IPC practice in emergencies and to develop a set of evidence-based recommendations for practice.

3 Results

This section describes the synthesis project in stages (Problem, Solution, Plan & Prepare, Implement, and Verify & Embed) that supports the development of IPC guidance, which is summarised in the Discussion section.

3.1 Problem

Trial 3 dealt with issues of platform usability and aimed to apply the IPC learnings from previous trials. Key challenges were:

- Having too much data or a complete lack thereof; for example, O1 tracks over 110 PCHCAI metrics, while in O2, occupational health data is scarce and difficult to access.
- The lack of a clear and consistent relationship between data linked to IPC risk and follow up measures aimed at risk mitigation.
- There is a need for better documentation of organisational roles and structure and incorporation of that documentation into the ARK platform.

- While there was good communication within the Community of Practice, communication with non-expert staff within the organisations was limited, the ARK platform was perceived to be complex and lacked interfaces for effective engagement with non-experts..
- Users had a limited amount of protected time for engaging with the ARK platform and because the STSA approach to risk management is time-intensive, the level of engagement in some organisations was limited, particularly in O3.

3.2 Solution

The CoP identified a three-part solution to the problem outlined above: (1) Further develop the ARK platform and deploy the next version, (2) continue developing the working relationships in the CoP, and (3) apply ARK to an IPC case study in each organisation. The three case studies selected were:

- O1: Improve monitoring, oversight, and continuous improvement of PCHCAI data through improved data governance.
- O2: Improve staff PPE compliance in order to reduce COVID-19 infection risk for staff.
- O3: Track PPE compliance and identify key areas of COVID-19 IPC risk for staff and patients.

3.3 Plan and Prepare

A new version of the ARK platform was developed (version 1.5) (McKenna et al. 2021) and the CoP worked together to develop a plan for deployment. Feedback channels and individualised support were made available to user organisations in order to address emerging issues and bugs. In the plan stage, the evidence linking feature was highly emphasised and organisations focussed heavily on increasing the amount of evidence uploaded. At this stage, O1 and O2 identified key IPC risk mechanisms:

- O1: Lack of unified data governance means that although a large amount of data is collected, it is generally not deployed in a way that can improve staff decision-making.
- O2: Staff need access to social support areas (e.g., break rooms) which can conflict with their responsibility to comply with PPE protocols. When infections occurred, staff felt that they could have a higher impact on operations because there were high levels of contact at work and because the organisation had pre-existing staffing issues.

3.4 Implement

Version 1.5 of ARK was deployed in each of the three case studies. It was deployed fully in O1 and O2 and deployed partially in O3.

- O1: Created a new global view of PCHCAI monitoring through system-wide data lineage mapping of PCHCAI measures. This map will be very useful in directing future analysis of PCHCAI clinical effectiveness.
- O2: Combined explicit knowledge of staff COVID-19 infection and exposure rates with implicit knowledge of impacts on service delivery. This was used to generate a better understanding of the relationship between the exposure and impact and identify geographic and temporal areas of high COVID-19 infection risk.
- O3: Gathered six months of data on PPE compliance and used this to better understand the problem/solution space with regards to COVID-19 prevention.

The three case studies were then combined to generate a set of recommendations for IPC practice in emergencies (see Discussion).

3.5 Verify and Embed

Users of the ARK platform and internal stakeholders from collaborating organisations were asked for their feedback on the project and the IPC practice document in order to assess the quality of implementation against the initial plan. At the same time, the general usability of the platform was assessed using the Simple Usability Scale (SUS) (Brooke 1996). The results of this exercise are as follows:

- For the ARK platform to be adopted, it has to become part of the methods and processes an organisation uses to manage its risks. O1 has been developing an Enterprise Risk Management framework; the organisation's risk management structure and data streams for PCHCAI have been addressed using ARK and a new data-led PCHCAI project has been developed. This has enabled the wide range of existing data sources to be catalogued, better understood, and selected data streams integrated and analysed to support a proactive assessment of system risk. This improved data management is enabled by the evidence features on the ARK platform and in turn facilitates a more effective data governance framework.
- O2 is using ARK to support the development and implementation of an entirely new communications infrastructure.
- Progress has been made towards a data management framework that allows for proactive risk management by linking different data sets in order to support decision-making. ARK's evidence linking feature was especially helpful for this. However, a higher level of data governance maturity is still needed.
- There is a training need for advanced systemic risk management in general and for use of the ARK platform in particular. A new short course in Systemic

Risk Management has been developed and delivered, complementing an existing Masters program in managing risk and system change.

- ARK's SUS score has progressively improved but remains below average. Even domain experts find it difficult to use. While, hitherto, development has prioritised core functionality over user experience, these results support further interface developments combined with increased project data on the platform that will enable usability to be progressively addressed.

4 Discussion

The findings of the ARK-Virus project were integrated with the academic literature and input from the CoP and used to iteratively develop a set of recommendations for practice (Table 1), which were first presented to collaborators in the project's final stakeholder report (ARK-Virus 2022). The recommendations provide a good overview of the three organisations' experiences with IPC risk management during the COVID-19 pandemic, as well as their hopes for the future. It is hoped that as more case studies are completed, the recommendations will feed into more substantial guidelines on effective IPC risk management in emergencies.

5 Conclusions

This paper described the first ARK Platform operational trials in healthcare settings as part of the ARK-Virus project. This novel embedding of STSA in clinical risk management is a new departure for healthcare organisations. These trials have resulted in several significant outputs: (1) a new version of the ARK platform with enhanced features, and (2) a new machine-readable and reusable ARK knowledge base that describes the healthcare setting (IPC), ontologies, and taxonomies for risk mitigation projects. All aspects of the knowledge base are linked to evidence. We observe that the ARK Platform is becoming embedded in the risk management systems of two of the ARK-Virus CoP members. We have agreed and initiated plans for deeper adoption. The potential value of ARK has been illustrated but further progress of the trial risk projects is required to establish the value of ARK in governing core strategic risks in the organisations.

ARK was received favourably by each of the participating organisations, who had overwhelmingly positive feedback on its potential for improving IPC risk governance. Participants recognised the benefits and further potential of intra-organisational collaboration experienced by applying the mindful governance methodology. In addition, the CoP was highly valued for providing a venue for the transfer of knowledge relating to IPC, AI, knowledge management, and risk governance; in fact, it was considered to be critical for successful ARK deployment. There was an intense interdisciplinary collaboration between ICT/AI and STSA

Table 1 Key findings—recommendations for IPC implementation in emergencies (ARK-Virus 2022)

1. Core operational processes: adequate personnel and physical resources at all times are critical to maintaining service delivery and allowing for resilience during a crisis
2. Performance standards: evidence-driven standards should be in place ahead of a crisis so that organisations can monitor their IPC performance
3. Quality and flow of information: mature data governance programmes should be in place so that in an emergency, data can be rapidly found and shared; communication channels need to be in place to transfer information and knowledge to the point of decision-making
4. Situational awareness and informed decision-making: implicit and explicit knowledge must be leveraged to create a collective understanding of the situation; access to data is important, but equally important is knowledge about that data and its provenance, quality, and intended use
5. Responsive risk governance infrastructure: a risk governance framework (such as ERM) that links clinical and operational data should be in place. The infrastructure must be flexible and responsive so that measures can be escalated or de-escalated
6. Quality and consistency of task performance: in order to monitor and validate implementation of control measures, data are needed about the outcomes of interest (i.e., transmission rates). Feedback loops must be in place that generate information back into the system for continuous performance improvement
7. Embedment within behavioural norms: maintaining strict control measures may be difficult, particularly in stages when the emergency is perceived as less severe; transparent and open communication foster trust that the measures are necessary, and enhanced supervision may be needed to reinforce them. A stronger culture of vigilance contributes to maintenance of control measures
8. Quality of collaboration, training, and leadership: more intensive collaboration and increased social support within the organisation is needed during an emergency, particularly as staff roles may change. Personnel need to be trained in their new roles ahead of a crisis
9. Trust and transparency: a high level of trust across the organisational hierarchy is needed, engendered by a trust that the data is of high quality and that organisational decisions are made based on an understanding of that high-quality data
10. Shared understanding: a comprehensive system of communication and reciprocal feedback is critical to generate a shared understanding of a collective response to risk

academics, as well as between the academic team and risk experts working in healthcare; researchers who also worked within the healthcare organisations were instrumental in realising the project. There are still some issues with usability of ARK, based upon feedback from users and the SUS score, which will be improved through further development of the user interface and of specialised interfaces for users in different operational roles (i.e., non-expert users).

Data governance tools, such as data catalogues, data dictionaries, metadata, and data lineage models, were used to improve data integration, sharing, trust, and quality both within and between organisations (Vining et al. 2022). Mature data governance systems are important for developing intra- and inter-organisational patient safety systems built on a diverse range of data and evidence sources.

ARK-Virus is being extended beyond the original project lifecycle:

- Higher Education Authority (HEA)-funded extension on cross-sectoral analysis of ARK in aviation as well as healthcare domains

- O1 will perform a behavioural analysis of clinical time series data on PCHCAI with Science Foundation Ireland (SFI) and ADAPT Centre
- O2 will use ARK to conduct a risk project on a national-level emergency communications infrastructure change

The project members are interested in engaging with new partners for further deployments.

Set within the context of the COVID-19 pandemic, this study represents the first full implementation trial of the ARK platform deploying a dedicated STSA within a semantically rich AI framework. It demonstrates accountable risk management in healthcare that addresses the complex antecedents of risk, links to evidence and has the potential for managing the full cycle of risk mitigation and improvement, in the context of a multi-project strategic risk profile.

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Qualitative Investigation of the Novel Use of Shopping Loyalty Card Data in Medical Decision Making

Alexandra Lang, Elizabeth Dolan, Laila Tata, and James Goulding

Abstract This paper describes early results of a small qualitative study investigating the potential impact of shopping loyalty card data (SLCD) in the diagnostic pathway for ovarian cancer. There is early evidence that pharmaceutical products such as pain relief and medications for irritable bowel syndrome and bloating are bought by women to manage the early symptoms of ovarian cancer. Designed to be a formative interview study, two General Practitioners (GPs) in England were recruited to discuss the current pathway of ovarian cancer from a primary care perspective and to consider the value and impact of SLCD in medical decision making, and its potential role in supporting improved referral times and patient outcomes. The findings indicate a potential role for SLCD, specifically in extending the diagnostic pathway to support earlier health information seeking and consultation with GPs. Communication with patients about this would need considering in regards to well established understanding about personal health behaviors and the wider system of primary and community care.

Keywords Healthcare · Medical decision making · Shopping loyalty card data · Diagnostic pathway · Health information seeking

A. Lang (✉)
Human Factors Research Group, Faculty of Engineering, University of Nottingham, Nottingham, UK
e-mail: alexandra.lang@nottingham.ac.uk

E. Dolan · J. Goulding
NLAB, Business School, University of Nottingham, Nottingham, UK

L. Tata
Faculty of Medicine and Health Sciences, University of Nottingham, Nottingham, UK

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1 Background

Within this world of ubiquitous digital technologies there are many sources of data now supplementing healthcare monitoring and decision making. On an individual level the data from fitness monitors/watches and smartphones are most common and provide immediate feedback and real time information on physiological parameters. These data sets are now increasingly being utilised in a connected, positive way to support medical decision making by patients (service users) and healthcare professionals (HCPs). Beyond the use of devices which have been designed to capture health and wellbeing data there are other data sets which have the opportunity to provide a wealth of knowledge about a person's health, one such data set it that of shopping loyalty card data (SLCD).

Several academic centres are currently investigating the use and value of (SLCD). Set within a wider academic investigation exploring the concept of data donation for public benefit (Skatova and Goulding 2019), current research is exploring the potential role of SLCD in a number of clinical applications. The exploration of SLCD for early detection and prevention of certain conditions has implications for early diagnosis, health promotion and medical decision making on both a micro personal level and macro public health level.

This paper presents early scoping work to examine the use of SLCD within the specific use case of ovarian cancer referral in the UK. The enquiry delivers an initial qualitative exploration of GP perspectives on how SLCD could be utilised within the clinical pathway to improve referral times and patient outcomes. It provides early insight into the potential novel interactions of SLCD within the system of work, specifically how this new data set may disrupt current behaviours and decision making for women experiencing symptoms which could be indicative of ovarian cancer.

2 Case Study Background

Ovarian cancer survival rates in the UK are notoriously poor with less than half of those diagnosed being at an early stage of the disease (Funston et al. 2019). Symptom awareness and recognition (Barrett et al. 2010), late-stage care seeking (Low et al. 2013), late referrals and variation in initial assessment and investigation (Funston et al. 2019) all contribute to high mortality rates.

Evidence suggests that symptom awareness may facilitate earlier attendance at GP consultations resulting in earlier referral and detection (Goff et al. 2007), thus enabling more women to be diagnosed at a stage when the disease is possibly treatable (Funston et al. 2022). As a result of the poor outcomes for this and other cancer pathways, there is increasing work to understand symptoms (Dilley et al. 2020) and raise awareness of symptoms to encourage earlier consultation and for HCPs to proactively consider cancer within those consultations, all of which is articulated

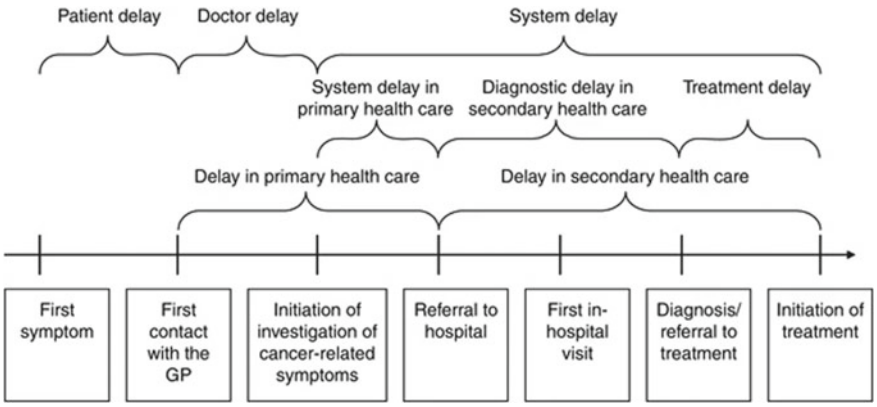

Fig. 1 Delays in cancer diagnosis, The Arhaus Statement (Olesen et al. 2009; Weller et al. 2012)

by the current goals of NHS England (2019) to expedite and increase referrals for suspected cancer (DHSC 2022).

Works by Olesen et al. (2009) and more recently Williams et al. (2019) provide insight into the complex and multiservice issues that may result in delays to diagnosis. Figure 1 is a high-level schema depicting how that occurs within a clinical pathway.

The National Institute of Clinical Excellence (NICE) in the UK established evidenced based guidance for the recognition and initial management of ovarian cancer (NICE 2011), much of the detail of which has been replicated around the world in other healthcare industry guidance (Cancer Australia 2019). There is however suggestion that the guidelines might contribute to shortening intervals in secondary care but that they fail to consider the primary care component of the diagnostic pathway (Low et al. 2013). Currently there are three main routes to diagnosis, with a recent study providing evidence that two thirds of cases are the result of referral by a patient's GP for outpatient investigations (although not necessarily to gynaecology), and nearly 20% of cases presenting as emergencies at A&E. A final cohort of 17% are identified via investigations within primary care itself (Barrett et al. 2010). This demonstrates the key role of the GP in the pathway. However, despite in depth understanding of the routes to ovarian cancer diagnosis there are many barriers to service users' health information seeking behaviour and delays to referral within primary care. Recent work has looked into the important role of primary care nurses in this pathway, and their contribution to early cancer diagnosis (Skrobanski et al. 2019) something which up until recently has been overlooked.

2.1 SLCD

Current research is investigating the role of specific over the counter products and whether they could be indicative of early ovarian cancer symptom management.

Dolan et al. (2023) report on the early potential of machine learning and big data in understanding the relationships between frequency and duration of purchases of medications for pain relief, bloating, irritable bowel syndrome (IBS) and the risk of ovarian cancer. Other health conditions and medical diseases such as long COVID and diabetes are also being investigated using these methods (NLAB 2022). It is important that in parallel to these technical studies we begin to examine the potential value of this new data and insight and consider how it could be implemented in practice by all potential users.

3 Methodology

This is a small-scale scoping study and is designed to be a formative piece of research to inform a scaled-up investigation into the same topic. Literature review and in-depth review of existing clinical guidelines (NICE 2011) were utilized to develop an interview schedule. Two subject matter experts (SME's) were invited to remote interview. The SMEs were two female General Practitioners (GPs) both with over 15 years' experience of healthcare provision within the National Health Service (NHS), 12 each in primary care. Both work in the southeast of England but within different healthcare organizations within that region. Each interview took 75 min.

Interviews were designed to facilitate the SME's in talking through the current ovarian cancer pathway, describing their experiences of decision points and the patient role. They were asked to consider decisions identified in the process and any additional ones that are currently unseen or not well documented. This verbal walkthrough of the pathway was structured to elicit

- Information/data sets currently used
- Other cues and considerations
- Strategies for decision making
- Wider system challenges.

Following the verbal 'walkthrough' of the pathway, the researcher introduced the concept of SLCD sets and the potential use of pre-diagnosis purchases to understand self-medication of early ovarian cancer symptoms as described by Dolan et al. (2023). SMEs were then asked to consider the pathway and decision points but in relation to the potential use of SLCD as a supplementary data source.

4 Results

The data captured from the interviews was thematically analyzed to gain a preliminary understanding of how SCLD might influence the pathway, patient choices and medical decision making associated with ovarian cancer primary care consultations and referral.

4.1 Patient Behavior and Seeking of HCP Advice

In support of the current literature there was acknowledgement that symptoms of ovarian cancer are difficult to identify as they are vague and often attributed to more common, but less high-risk conditions such as IBS, stress or general gastrointestinal complaints. This was discussed in relation to the current NHS strategy for improving cancer referrals and survival rates.

> From a GP perspective there is a massive agenda to increase early cancer detection. It comes from NHS England and is borne out of all referral pathways. So, there is this thing called positive predictive value of doing a referral, which is conversation rate of symptoms to cancer diagnosis. NHS England want it to be about 3% which means for every 100 referrals you only pick up 3 cancers. But it's really difficult with ovarian cancer…it is so vague and for some it might be perceived as spending a lot of money on tests and referrals that come to nothing. The good thing about the new strategy is that it tries to remove the old view that we (GPs) had to be conservative when considering cancer in our investigations and referrals.

Considering the established pathway, both SME's felt that there was inadequate awareness of ovarian cancer symptoms in the general public and that more should be done to encourage women to seek medical advice when experiencing symptoms. It was believed that any additional mechanisms or data sets to support that awareness would be a good thing, especially in light of workload issues experienced in primary care. It was also discussed how, from the professional side there is variation in the awareness of and willingness to consider cancer referrals at an early stage. They expressed the view that recent changes to national cancer strategies (DHSC 2022) will help this but that there is a time lag between change in guidance/strategy and change in clinical practice.

> Once you walk through the door at the GP there shouldn't be barrier to you being investigated for cancer. There's an easy blood test and an easy scan, they are readily available without much of a waiting list. Certainly, in my area that is the case. If someone also told me, they had bloating and abdominal pain they would get those tests.

There was consensus from both interviewees that there is variation in when and how women seek health information and advice and that improving this is a key factor in reducing time delays to diagnosis as depicted in Fig. 1. Existing blood tests and scans that are used for ovarian cancer referral are relatively cheap and so it was felt that early utilization of these should be a priority for patients who are in consultation with GPs for any of the cancer symptoms.

> We are all knackered, we are all over worked. And sometimes we will miss things……more information, if it can be made available but not a burden, well that could be good. But also, if there is something that helps them (patients) get through the door then that can only be a good thing.

The SME's considered at length the reasons why women experiencing symptoms (even if unaware of the potential risk of ovarian cancer) may not seek medical help. They explicitly referenced the five established triggers that are understood to lead individuals to present at a doctor's appointments (Zola 1973)

(a) Perceived interference with vocational or physical activity.
(b) Perceived interference with social or personal relationships.
(c) Occurrence of an interpersonal crisis.
(d) Temporizing—"if not better by Monday", or "just two more nosebleeds".
(e) Sanctioning pressure from family and friends.

> "It can be a battle to get some patients to see us" (relating to Zola's triggers) "If we can bring the pharmacist into that conversation….and try to get women in earlier it could make a huge difference to outcomes. This is the problem with ovarian cancer, the symptoms are so vague, and it catches you out often with those who don't have strong family history or very clear indications"

Braunack-Mayer and Avery (2009) pose how individuals have a tendency to attribute symptoms to other causes and may not be cognizant of their relation to other conditions which might have more of an influence on the Zola's triggers. There was suggestion within the interviews that 'making the link' and highlighting how long-term experience of those symptoms could relate to the triggers as a communication could be the way in which to utilize the SLCD to alter patient behavior.

> So, if well, the shopping data picked up a pattern and that it was communicated in a way that might influence those triggers then it might well help patients think about coming (to the GP) earlier.

The work by Leydon et al. (2009) investigated health behaviors related to uterine conditions and in this study prospective patients followed a pattern of self-care first: they identified that they had a problem; then they attempted to address it. Only when the symptoms began to interfere significantly with everyday life did they finally make a visit to the doctor. The interviews established that this kind of pattern was a reality for women with ovarian cancer symptoms and that more needed to be done to overcome the barriers to health information seeking and attendance.

The opportunity for SLCD to contribute to women deciding to make and attend a GP appointment was viewed positively, but with the acknowledgement that not all women would engage with the data.

> Certain people might not take any notice, but that is like anything. But there are those who, if they received some information or maybe a bit like a public service announcement associated with their personal buying patterns, might then consider attending a GP appointment sooner. Anyone who gets through the door earlier as a consequence would be a win for the health service.

There is much still to be understood about the impact that SLCD might afford women in their decisions to seek advice from healthcare professionals about ongoing symptoms. However, there is early indication that any data tool that might support earlier attendance by women with those symptoms would be a positive thing in terms of referral rates, successful and earlier diagnosis, patient outcomes and also health economics in terms of treatment interventions.

4.2 Pathway Modifications Due to Implementation of SLCD

The information provided by the SME's indicate that the introduction of SLCD could support improvement of the ovarian cancer diagnosis pathway, extending its remit into community care beyond that of current primary care providers. Figure 1 depicts a breakdown of the typical stages associated with cancer diagnosis, but importantly shows where delays are incurred in that pathway. Whilst there is undoubtedly action that needs to be taken to prevent delays within primary and secondary care systems, a significant theme to come out of the two interviews was the need to bring forward and minimize delays at the point of accessing the first GP appointment. Both SMEs independently suggested how SCLD could be utilized by pharmacists to support women in decision making about seeking health advice and consultation.

> For frequent use—I find pharmacists and pharmacy technicians, they are so good at directing patients……quite often I have people say to me 'I showed this to a pharmacist, and they weren't happy, so they sent me to you.'

It was considered that if SLCD did support earlier identification of ovarian cancer symptoms then this would have most value in the community, to encourage women to access health advice earlier.

> So, if a pharmacist did spot a pattern, if say they did see something in the Boots advantage card and there was a system where it would raise an alert to say this patient has bought X number of pain relief, x no of cystitis medication and also X number of Buscopan…. Maybe have a discussion with them. Then that could be really brilliant, also because patients really trust their pharmacists

Discussion around automated information provision, communication and language were touched upon, but it was felt that much more work would be required on the user interaction with the information and how it might be presented or delivered to ensure engagement and possible adherence with guidance provided.

> In regard to patient decision making and the spread of over the counter and off the shelf products…. if there was opportunity for patients to recognize their frequency of purchase, well that might make them really think about their symptoms and what they are self-medicating. But it's how you are communicating that…it might generate a conversation or even a leaflet. You are buying x, y, and this could be chronic constipation, etc. but it could be something else. It might be useful for you to speak to a GP to just check it out.

Further, it was believed that there was interesting work to be carried out to explore if and how this vital information could be provided to women, both with and without the involvement of a pharmacist or community nurse.

> If we can bring the pharmacist into that conversation or even GP nurses….well they are other professionals trying to support women even before they have spoken to a GP, it might make for earlier dialogue or real consideration of the symptoms…so that could lead to them taking action at a point in time when without that data it might not be possible. You'd also have to think about people who don't want to or might not use those services and how to engage women who don't have much contact and just self-manage for long periods of time.

Variation in service user behavior and understanding types of people was considered a crucial factor in whether or not SLCD could be used in a way that might have positive impact on the early stages of the pathway. This was mentioned in relation to several variables, health anxiety, use of NHS resources, the parameters relating to the Zola's triggers and the relative importance placed on those by individuals.

> Sometimes you get a patient who thinks they are a superhero and sometimes you get ones who just can't face any investigation as they are so anxious. Communication of that data would have to be very sensitively done. Maybe…. flag up in app and then follow up leaflet with suggestion to speak to doctor.

Finally, the interviews reflected on the role of SLCD on their own medical decision making, specifically in terms of 'watch and wait' practices, decisions to undertake accessible tests in primary care and also timely, early referral decisions. It was expressed that most GPs should be thinking of cancer and not prolonging care without considering cancer as an underlying cause of symptoms over a period of time. However as mentioned, the acknowledgement of variation in practice was considered a potential contributor to delayed referral and so the SLCD could help to overcome some barriers to referral by adding additional evidence to the decision-making process.

> Bring any evidence that helps trigger that thought process earlier, whether it be because of experience in the job, people thinking about the cost of tests or even being over worked and what that does to how we think about what to do with patients…well that (SLCD) could be beneficial. Anything that brings attention to it, it can only be useful to them (the patients) and us.

> Certain tests we steer away from as they are non-specific and not as helpful but the CA12 (blood test) is really good, good information and helps. If the shopping data could help add weight to the evidence of the symptoms, how long they've been going on for etc. then I think for most GPs it would help them decide to do that test, and maybe a scan, earlier.

5 Discussion

This formative work is only small scale and very limited in the scope of its enquiry. However, within the interviews conducted some interesting perspectives have been raised that have opened up the dialogue about the implementation of SLCD into primary care practices.

Whilst limited in its applicability it is worth noting that excitement was expressed by the SMEs about the potential value of this kind of data being utilized within the diagnostic pathway and also in regards of empowering women to make better, earlier decisions if they are experiencing long symptoms which might be associated with ovarian cancer. It might be that the novelty of this concept initially prompted largely positive responses from the interviewees. They acknowledged the issue of workload on multiple occasions and there may be bias associated with any proposed intervention that has the potential to improve patient outcomes with minimal addition to workload. This in and of itself needs to be investigated to really understand the

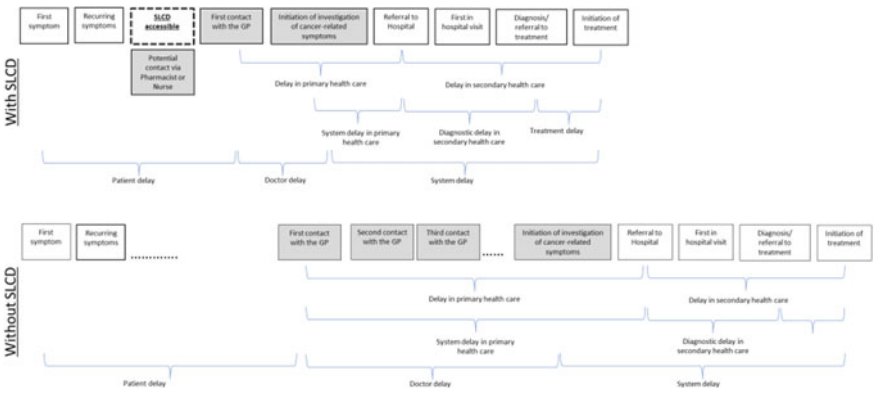

Fig. 2 Comparison perceived diagnostic pathway delays with and without SLCD

integration of new data sets into clinical practice and understand current Work as Done and what might change look like with the introduction of SLCD.

One point to raise specifically is the extension of the diagnostic clinical pathway into the community. Figure 2 represents how the data from these interviews has made suggestion of reduced delays associated with the patient behavior and medical decision making, doctor decision making associated with tests and referral times.

It is evident from this scoping qualitative enquiry that according to GP's there may be a role for SLCD to provide better care of women experiencing symptoms which may be associated with ovarian cancer. It is evident that there are many factors that impact health information seeking behavior and there is

(a) a potential role for SLCD to add understanding about an individual's personal health which could contribute to earlier presentation at a doctor's appointment.
(b) potential for other HCPs to be involved in the use of SLCD and bring them into the pathway to better support women and GPs in encouraging early presentation.
(c) opportunity for more evidence to support more timely tests and referrals for women presenting with those symptoms.

These findings will be crucial in forming the design of future research enquiries into how we examine the use and value of this data set for ovarian cancer and other conditions. There is opportunity for human factors models such as the Systems Engineering Initiative for Patient Safety 2.0 (SEIPS 2.0) model (Holden et al. 2013) to provide a framework for examining the human factors challenges and considerations of service users and HCPs in utilizing this data set within their care pathways and service delivery.

Future research into this topic will look to examine the system of work and requirements of HCPs in further depth, involving not only GPs but other relevant stakeholders, some of whom have been mentioned by the interviewees (pharmacists, community nurses) but also others who may not be clinically trained but who would need to integrate the data set into existing system and service infrastructure. Patient

requirements and perspectives are vital to the success of this, and it would be pertinent to examine those within and between different medical conditions so that the potential implementation of SLCD is not only understood in its application to ovarian cancer.

6 Conclusions

This paper provides an early analysis of the use of shopping loyalty card data (SLCD) in work and interactions associated with medical decision making within the diagnostic pathway for ovarian cancer. There is a universal need to improve cancer detection rates and the UK has prioritised this as a strategic goal for the NHS. Novel data sets such as SLCD have the potential to disrupt current pathways and may offer additional information to support health information seeking behaviours by patients and more evidence to GPs in their clinical decisions. This study provides early evidence to suggest that there could be a role for SLCD in primary care and that further work is required to understand these interactions and the potential value of SLCD more broadly in health and care service delivery.

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Informal Care and Care at Home

Care Partner's Experience with Care Received in the Emergency Department

Peter L. T. Hoonakker, Pascale Carayon, Nicole E. Werner, Paula V. W. Dail, Kathryn L. Wust, Rachel Rutkowski, Hanna J. Barton, Brian W. Patterson, Manish N. Shah, Michael S. Pulia, Sheryl A. Krause, Denise Buckley, Jennifer Hankwitz, Rebecca Schwei, Rebecca K. Green, Ly Hoang, and Barbara J. King

Abstract Patient satisfaction is becoming increasingly viewed as a key component of high-quality care. The literature has shown relationships between high patient satisfaction and improved patient and hospital outcomes, including profitability (Kelley et al. 2014; Richter and Muhlestein 2017). During their journey, patients are often accompanied by a significant other, family member or friend (care partner) when they go to a medical setting to receive care. Although very important in the patient work system, we know relatively little about who these care partners are and how they experience the care the patient receives. In this study, we examine the experience of care partners of older patients who present to the emergency department (ED) with a fall.

Keywords Care partner · Emergency care · Older patients · Falls · Patient safety

P. L. T. Hoonakker (✉) · P. Carayon · N. E. Werner · K. L. Wust · R. Rutkowski · H. J. Barton
Department of Industrial and Systems Engineering, Wisconsin Institute for Healthcare Systems Engineering, University of Wisconsin (UW)-Madison, Madison, WI, USA
e-mail: Peter.Hoonakker@wisc.edu

B. W. Patterson · M. N. Shah · M. S. Pulia · D. Buckley · J. Hankwitz · R. Schwei · R. K. Green · L. Hoang
Berbee Walsh Emergency Department, UW School of Medicine and Public Health, Madison, WI, USA

S. A. Krause · B. J. King
School of Nursing, University of Wisconsin (UW)-Madison, Madison, WI, USA

N. E. Werner
Department of Health and Wellness Design, Indiana University School of Public Health, Bloomington, IN, USA

P. V. W. Dail
UW-Madison School of Medicine and Public Health Patient and Family Advisory Council, Madison, WI, USA

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1 Background

Patients 65 years and older account for nearly 25% of all Emergency Department (ED) visits (Aminzadeh and Dalziel 2002). Older ED patients are more likely to experience adverse outcomes after an ED visit compared with younger patients, including ED readmission, hospitalization and death (Aminzadeh and Dalziel 2002; Schnitker et al. 2011). Twenty percent of patients >65 years old return to the ED within 30 days (McCusker et al. 2000). Older patients have more frequent transitions than others (Arbaje et al. 2014) and are more vulnerable to care transitions (Aminzadeh and Dalziel 2002). Eighteen percent of ED visits for older adults are fall-related. In 2009, people aged 65 + made over 3.6 million fall-related ED visits in the USA (Carpenter et al. 2014).

The ED is often a very busy and hectic setting. This can generate confusion in older adults (≥65 years old), who often suffer from multiple comorbidities, including conditions such as congestive heart failure (CHF), chronic obstructive pulmonary disease (COPD), asthma, diabetes, and Alzheimer's disease. Therefore, even apart from the injury or illness they present with, the ED environment can be overwhelming and induce emotional distress for this vulnerable population.

Care partners are very important as a source of support to the patient, such as informational, instrumental, emotional, and companion support. The informal network of caregiving is the backbone of health systems (Popejoy 2011). The literature shows that care partners have a positive impact on the patient's hospital visit, in particular on the hospital discharge process (Bauer et al. 2009). Involving care partners provides better quality of care, increased patient safety and can delay patient institutionalization. Results of a meta-analysis showed that integration of the care partner in the hospital or skilled nursing facility (SNF) discharge process led to more than 20% reduction in readmission rates of older patients (Rodakowski et al. 2017). A recent study by Wust et al. (2022) has shown that care partners play an important role as information brokers: they often provide key information about the patient to the health care workers and clinicians. However, we know relatively little about these care partners.

The research questions of this study are:

1. Who are the care partners of older adults who present to the emergency department (ED) with a fall?
2. How do they experience the ED visit of the older adult?

2 Methodology

We conducted three surveys, which were adapted from existing literature. The first survey was administered on arrival at the ED, a second survey right before ED discharge, and a third survey 3–4 days after discharge.

The first survey consists of questions about personal characteristics, experienced health, and health literacy (BRIEF) (Haun et al. 2012). The second survey focusses

on experience in the ED as measured with an adapted version of the Consumer Emergency Services Satisfaction Survey (CECSS) (Davis et al. 1997; Hoonakker et al. 2022). It was administered right before the patient left the ED. The CECSS consists of three subscales: caring, teaching and dissatisfaction. The third survey focusses on information received during care transitions, for example from the ED to the hospital (Coleman et al. 2002). This survey was conducted 3–4 days after discharge. The Institutional Review Board of UW-Madison approved the data collection procedure.

We collected data from 66 care partners who came to the ED with an older patient who had fallen. Scores on the CECSS subscales were transformed to a score between 0 (lowest) and 100 (highest). We use descriptive statistics to describe the results and $\chi 2$ to test for differences between groups.

3 Results

Table 1 describes the characteristics of the care partners.

Results show that the vast majority (94%) of care partners are family members: spouse, children or siblings. Nearly half (42.4%) of the care partners are also older

Table 1 Care partner characteristics (n = 66)

Relationship to patient	Spouse: 25 (37.9%) Daughter/Son: 33 (50.0%) Brother/sister: 4 (6.1%) Aunt/Uncle: 0 Cousin: 0 In-law: 1 (1.5%) Neighbor: 0 Friend: 1 (1.5%) Other: 2 (3.0%) Niece and grandson
Gender	Female 71.2%
Age	<25-year-old: 1 (1.5%) 25–34: 2 (3.0%) 35–44: 1 (1.5%) 45–54: 14 (21.2%) 55–64: 20 (30.3%) 65–69: 6 (9.1%) 70–74: 8 (12.1%) >/75: 14 (21.2%)
Living situation	Same house as patient: 29 (43.9%) Same neighborhood: 4 (6.1%) Same village, town, etc.: 18 (27.3%) Same State: 14 (21.2%) Another State: 1 (1.5%)
BRIEF (health literacy)	Inadequate: 4 (6.1%) Marginal: 6 (9.1%) Adequate: 56 (84.8%)

Table 2 ED experiences of care partners

CECSS subscale	Mean (SD)
Caring	94.24 (7.59)
Teaching	87.91 (19.2)
Dissatisfaction	10.13 (16.73)

than 65 years old. The health literacy of most respondents (85%) was in the adequate range of the BRIEF.

Table 2 summarizes data on the ED experience of the care partners.

Results show that overall, satisfaction is high, and dissatisfaction is low on a scale between 0 (lowest) and 100 (highest). There are no significant differences between the different groups of care partners (spouse, child, sibling), age categories, or level of education of the care partners in appreciation of the care they received in the ED.

4 Discussion

Patient care can be considered as embedded in a socio-technical work system, with many actors and settings involved; this is what the patient journey is about (Carayon et al. 2020). Historically, most attention has been given to the patient and the clinicians and staff who take care of the patient. Care partners have received considerably less attention, despite their important role.

In this study, we examined (1) who the care partners of older patients who present to the ED with a fall are, and (2) how they experience the ED stay of the patient. Results show that care partners of these older patients are predominantly members of the family. Ninety-four percent of care partners are spouse, child or sibling. These numbers correspond to those reported in a study by Wolff and Kasper (2006); they also showed that caregiving for older adults was done by children (41%), spouses (38%) or relatives and friends (20%). Results show further that most care partners are local: more than three-quarters live either with the patient, or the direct vicinity of the patient, which makes it easier to take care of the patient. However, results further showed that many care partners (42%) were older than 65 years old, which has implications for the care of their loved ones. For example, these care partners may face their own physical or cognitive impairments.

Results of this study have also shown that overall, care partners are satisfied with the care that older patients who present with a fall to the ED receive. They are very satisfied with the care they receive from health care workers, and satisfied with discharge teaching. Only a small number is dissatisfied with the care patients receive.

5 Recommendations

The literature has shown that care partners can play a very important role; the question is then what can we do to better integrate them into the (work) system and the ED care process. Clinicians and staff should pay more attention to care partners. Care partners play a crucial role before, during, and after the ED stay of patients. These care partners are an important source of information and indispensable when it comes to all types of support.

Especially at discharge, the patient receives an enormous amount of information, and often does not retain this information (Hoek et al. 2020; Mahajan et al. 2020). Care partners can play an important role in the ED discharge process, not only by retaining information, but also by requesting additional information. However, care partners need be better prepared for their "job" and need to receive better education and information about their role. Results of a recent literature review show that overall, care partners are often dissatisfied with the education and skills training provided to them (Carbery et al. 2021). This in turn results in unpreparedness and poor health outcomes for the patient.

Recent developments in the USA have shown more attention for the role of care partners. For example, in 2017 the Caregiver Advise, Record, And Enable (CARE) legislation was adopted and Medicare regulations are proposed that require caregiver integration into the discharge planning process (Rodakowski et al. 2017). One major barrier that care partners face is identification (Friedman and Tong 2020). One possibility would be to add care partner information to the electronic health record (EHR). That would make it easier for clinicians and staff to identify the care partner. Care partners on the other hand, could get easy access to the electronic patient records, for example through the patient portal. Family members can normally access the patient's information, especially if they are the official power of attorney (POA) for the patient.

5.1 Study Limitations

This observational study was limited to a relatively small sample of older patients and their care partners who present with a fall to one ED of an academic hospital in the Midwest US. This limits the generalizability of the survey results to other emergency departments and hospitals, and to other medical conditions or circumstances that require an ED visit.

6 Conclusions

Care partners are very important for the care of older adults, in particular when they go to the ED. However, they have received relatively little attention. We need to better understand the role of these care partners, and how we can better integrate them into the ED care system of the patient.

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The Effect of Psychological Scarcity on Health Decisions of Rural Residents in China: Preliminary Results

Haiou Zhu, E. Liu, Fangzhou You, Cees de Bont, Thorsten Gruber, Hua Dong, and Marijke Melles

Abstract Economic studies have shown that living in poverty may produce a subjective feeling of scarcity, which affects people's cognitive functions and decision-making. Understanding this mechanism could inform healthcare designers on designing inclusive health interventions by considering the psychological scarcity and limited cognitive resources of impoverished individuals. We conducted a psychological experiment to test the impact of psychological scarcity on cognitive function and health decisions of rural residents in China. We randomly assign participants to two financial scenarios (hard vs. easy) with the technique of priming to induce their immediate financial worries. Then we measure cognitive function using Raven's Progressive Matrices and uncover their decision-making priorities with a budget allocation task. 301 participants finished the study and 264 were included in the main analysis. The results show that both immediate financial worries and cumulative poverty have negative effects on participants' cognitive performance. Responses to scarcity could lead to attentional focus on limited resources, thereby neglecting long-term health consequences, particularly for the lower income group. Based on the findings, we suggest a number of human factors design considerations that are critical to successful healthcare design.

Keywords Psychological scarcity · Cognitive function · Health decision-making · Health intervention

H. Zhu (✉) · F. You · C. de Bont · T. Gruber
Loughborough University, Loughborough, UK
e-mail: h.zhu@lboro.ac.uk

E. Liu
Southwest Forestry University, Kunming, China

H. Dong
Brunel University London, London, UK

H. Zhu · M. Melles
Delft University of Technology, Delft, The Netherlands

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1 Background

Suffering from illness is the greatest contributor to individual poverty in rural China (Liu et al. 2017). The lack of financial resources prevents people living in poverty from improving their health and quality of life, leading to a 'poverty-disease' trap they seem unable to escape (Sala-i-Martın 2005, p. 95). A growing body of research in economics investigates the psychological mechanism of poverty and its effects on individuals' decision-making. Mani et al. (2013) define poverty as 'the gap between one's needs and the resources available to fulfill them'. Shafir and Mullainathan (2013, p. 4) highlight the subjective nature of scarcity, defining it as 'having less than you feel you need'. The concept of psychological scarcity depicts that living in poverty itself may produce psychological consequences that lead to short-sighted (present bias) and risk-averse decision-making (Haushofer and Fehr 2014). This mechanism affects individuals' health behaviours and decisions in lower-income settings, such as lower adherence, excessive alcohol consumption and lower adoption of health technology (Dupas and Miguel 2017).

In the field of ergonomics and human factors, the cognitive and psychological mechanisms of user decision-making are critical considerations for successful healthcare design (Lawler et al. 2011). Healthcare designers aiming to design inclusive healthcare could benefit from understanding how low-income individuals make decisions about their health. With the aid of a human factors approach to easing their psychological and cognitive strain, people in poverty may make better health decisions. However, there is a lack of research identifying the scarcity mechanism in design research. As a result, we conducted a psychological experiment to test the effect of psychological scarcity on health-related decisions of the rural population in China. Following previous studies (Carvalho et al. 2016; Mani et al. 2013), we used the technique of priming to induce participants' financial worries and measure their immediate perceptions of scarcity. We then administered questionnaires aimed at eliciting their risk and time preferences. We used Raven's matrix (Raven 2000) tasks to assess their cognitive function, followed by a hypothetical budget allocation to evaluate their decision-making priorities.

The purpose of this experiment is to understand the mechanism of psychological scarcity on health-related decisions and to discuss its implication for designing effective and human-centred health interventions in future research. The paper is structured as follows: we first introduce the design of experiment and the process of data collection and analysis. Then, we present the preliminary results of the study (the remaining results will be presented at a later stage). Next, we discuss the findings and their implications for design research. Based on the findings, we suggest a number of human factors design considerations that are critical to successful healthcare design in lower-income setting. Finally, we highlight limitations and provide directions for future research.

2 Methodology

2.1 Design of Experiment

This study uses an artefactual field experiment (Harrison and List 2004), which is a lab in the field approach, to collect data from rural China. We choose rural China because health disparities between rural and urban regions have been growing despite China's major progress in poverty alleviation (State Council 2015). The lack of financial resources, as well as healthcare infrastructures and services, are the primary obstacles for rural residents in seeking health and making better decisions about their quality of life. Healthcare designers might better design for, with and by these marginalised groups in Chinese society and promote inclusive and equitable healthcare (Fang and Xin 2018) by taking into account both macro level of economic and societal determinants and micro level of psychological mechanism.

The experiment was conducted between May and June 2022 in a town located in Yunnan Province, one of the least developed rural regions in southwestern China. The disposable income per capita in 2021 is ¥14,197 (€1,861) for rural residents, compared to ¥40,905 (€5,361) for urban residents in this province. The town has eight communities and 85 natural villages, with a population of 31,117 people, of whom about 94.8% live in rural areas. The ethnic minorities make up 21.2% of the population. The study was approved by the ethics committee of Loughborough University. A pilot study was conducted to refine the experiment design and to adapt materials and measurements to local contexts. To be eligible for the study, participants needed to be: (i) 18 years old above (ii) living in rural areas (iii) able to comprehend the instruction and perform the tasks accordingly.

The experiment consisted of two treatments, the 'hard' financial scenarios and the 'easy' financial scenarios, which were referred to as the treatment and placebo groups. The method of priming, frequently used in psychology and economics (Cohn and Maréchal 2016), was adopted to induce participants to think about financial circumstances that they might encounter in daily life. Participants were asked how they would handle three different sets of financial shocks: raising money in one week, declining of annual income and increasing of medical costs. The first two sets were adapted from Mani et al. (2013), whereas the third set was primarily about financial shocks brought on by illness. The descriptions and questions are identical in all sets of scenarios for the two groups except that the magnitude of money varies. For example, the 'hard' scenario describes an unforeseen event requiring an immediate ¥20,000 expense, whereas the 'easy' scenario only requires ¥1000 expense. The participants were exposed to each of the three scenarios and were asked to respond both open-ended and closed-ended questions. The open-ended questions asked participants to respond in three sentences on how they would handle the financial shocks to trigger feelings and concerns. The closed-ended questions were coded with five-item Likert scales to measure the levels of worries. Responses to these scales were used to check if the manipulation was successful in inducing increased levels of worries in

the treatment group. The detailed descriptions and all questions for the priming of financial scenarios can be seen in Appendix 1.

The primary variables include cognitive function, risk preference (monetary and health), time preference (monetary and health), and decision-making measurements. In this paper, we only introduce the methods to measure cognitive function and decision-making.

For the measurement of cognitive function, Raven's Progressive Matrices (Raven 2000) were used, with which participants try to match a set of graphic patterns (see an example in Appendix 2). It is one of the most prominent and widely used tools in psychology and economics for measuring fluid intelligence, a core feature of individuals' cognitive capacity to think logically and solve problems in novel situations (Schilbach et al. 2016). Given that our participants have very low levels of literacy (18.56% illiterate), a non-verbal test is more appropriate to administer in the field.

For the measurement of purchase decisions, participants were asked to allocate a hypothetical budget of ¥100 over three categories of goods: (i) daily groceries (ii) medicine and health-related goods (iii) temptation goods. The items selected are popular and well-known in local market and were refined after the pilot study. These product categories represent decision-making priorities of participants: health goods are catered to a long-term priority on health; groceries satisfy immediate family needs while temptation goods cater to short-term utility.

2.2 Data Collection and Analysis

The authors provided training for locally hired research assistants to collect data in the field. The survey questions and research materials were adjusted for the local dialect and culture to ease the participants' burden on answering questions. The research assistants, who are familiar with local environments, travelled to the villages and the weekend market in the town. They approached residents and introduced the study to them. After acquiring their informed consent, participants were randomly assigned to the two financial scenarios to answer the priming questions. When answering the open-ended questions, they were given adequate time to process the information, and were encouraged to imagine and describe what kind of impacts these financial shocks could have in their own lives and how they would handle them. Then they were instructed to answer questions for risk and time preference elicitation, perform the budget allocation task, complete the Raven's Matrices task, and answer demographic questions. After the experiment, participants received a towel (€0.3 worth) as a 'thankyou' gift.

A sample of 301 participants finished the experiment, of which 150 were randomly assigned to the hard scenarios and 151 to the easy scenarios. We used the IBM SPSS Statistics 28 for data analysis. Of the participants, 37 were excluded (20 from hard scenarios and 17 from easy scenarios) as they contain outliers ($Z > 2$ & $Z < -2$) in their annual income, household income or budget allocation amount. The final

sample included in the main analysis is 264, of which 130 were from the group of hard scenarios and 134 from the group of easy scenarios.

Table 1 provides a summary of the participant's demographics, including gender, age, education, and source of income. Males account for 54.26% of the population, while females account for 45.74%. The majority of the participants (76.24%) fall into the 41–50, 51–60 and 60–plus age brackets. This is consistent with the current situation of Chinese society where the older generation stays at home while young adults leave home to study or work in the city. 18.56% of the participants are illiterate and 38.26% only go to primary school. According to the results of the source of income, migrant employment (31.56%) and farming (15.96%) account for roughly half of the participants' income. 13.48% of the participants rely on family support and 3.19% have no income. Those who do not have a source of income would be given government sustenance payments according to the feedback from the research assistants. The mean of annual income is ¥28,462.48 (€3730.34), and the median is ¥20,000 (€2621).

Table 1 Participant demographics

Sample characteristics		Number	Percentage (%)
Gender	Male	140	53.03
	Female	124	46.97
Age	18–30	25	9.47
	31–40	38	14.39
	41–50	59	22.35
	51–60	55	20.83
	60 years above	87	32.95
Education	Illiterate	49	18.56
	Primary school	101	38.26
	Middle school	52	19.70
	High school	31	11.74
	Undergraduate and above	31	11.74
Income sources	Migrant working	84	31.82
	Farming	45	17.05
	Family support	36	13.64
	No income	8	3.03
	Other	91	34.47

3 Results

This section presents balance check for randomisation, manipulation check and treatment effects on cognitive function and decision-making.

3.1 Balance Check

Table 2 shows balance check results, by comparing the characteristics of participants in the 'hard' and 'easy' scenarios. The last column displays the p-value of the t-Test for the two treatment groups. These tests reveal no significant differences between the two groups, indicating that the randomization resulted in a balanced trial group.

3.2 Manipulation Check

The purpose of the manipulation check is to confirm that the priming succeeded in triggering financial worries for the 'hard' scenario group. The responses to the open-ended questions offer qualitative evidence that the scenarios were thought to be challenging. The answers to the closed-ended (yes or no) questions and the Likert scales provide data to quantify the effects of these financial scenarios. Figure 1 presents the response means of the three financial scenarios, which show a clear increase of subjective perceptions of worries and/or difficulties for participants exposed to 'hard' scenarios relative to 'easy' scenarios. According to the results of multivariate regressions (see Appendix 1), the joint p-value is significant at the 1% level ($p < 0.001$), suggesting that the experimental manipulation was successful in inducing immediate financial worries.

3.3 Treatment Effects

Poverty may impede cognitive function directly (Mani et al. 2013). We measured cognitive functioning using the Raven's matrix. To investigate whether cognitive function would be affected by immediate monetary concerns or long-term economic conditions, we compare the differences of correct rate between 'hard' and 'easy' groups, as well as between lower income and higher income split by median annual income (¥20,000). The average correct rate of 'hard' group (54.60%) is lower than the 'easy' group (61.54%), with a mean difference significant at 0.1 level (two-sample t test, two-tailed test: $t = 1.875$, $p = 0.062$*). Individuals with lower incomes (43.02%) performed significantly worse than those with higher incomes (71.10%), with a correct rate fall of 28.08% (two-sample t test, two-tailed test: $t = -8.498$,

Table 2 Balance check

Sample characteristics	Full sample		Means by treatments				Hard–easy
	Mean	SD	Hard scenario		Easy scenario		Differences in means (p value)
	N = 264		n = 130		n = 134		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Gender	1.47	0.500	1.43	0.497	1.51	0.502	0.225
Age	5.49	1.430	5.51	1.347	5.46	1.516	0.762
Education	2.60	1.248	2.67	1.206	2.52	1.289	0.334
Income sources	2.91	1.690	2.88	1.773	2.95	1.606	0.753
Annual income	28,462.48	28,868.232	31,308.97	29,205.851	25,528.40	28,328.927	0.104

Notes Columns (1)–(2) show the means and standard deviation of the full sample. Columns (3)–(6) show the means and standard deviation across treatment arms. Column (7) displays the p-values of differences in means tests using t-tests. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

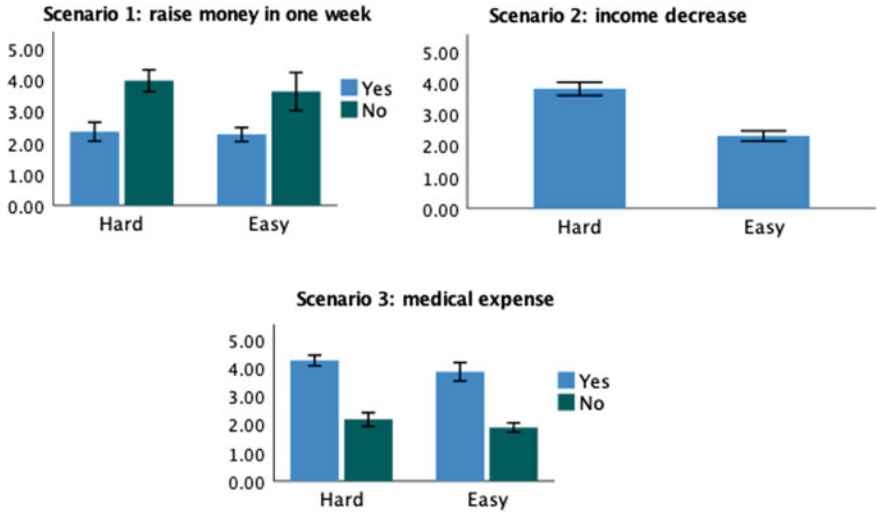

Fig. 1 Impact of Hard versus Easy Scenarios on Financial Worries. *Notes* The bars show hard-easy mean differences for the three financial scenarios: raise money in one week, income decrease and medical expense. Brackets indicate 95% confidence intervals. Scenarios 1 and scenario 3 are split by asking participants 'Are there ways in which you may be able to raise the money in one week?'; and 'Would it be difficult to afford healthcare?'

p 0.001***). Furthermore, within the sample of lower incomes, the correct rate of participants exposed to hard scenarios (34.57%) is lower than that of participants exposed to easy scenarios (49.64%) and the mean difference is significant at 0.05 level (two-sample t test, two-tailed test: $t = 3.156$, $p = 0.002$**). While within the sample of higher incomes, there is no significance (two-sample t test, two-tailed test: $t = 1.541$, $p = 0.126$). The above findings suggest that both immediate financial worries and long-term poverty conditions have an impact on cognitive performance. People with lower income would be affected by both subjective feeling of scarcity and absolute level of resource scarcity, whereas those with higher income appear unaffected by the immediate worries (Fig. 2).

To identify the impact of financial worries on the demand for the three types of household goods (groceries, health and temptation), we designed a budget allocation task (with a budget of ¥100) to measure participants' trade-off thinking and decision-making. Table 3 presents regression results, separately for the 'hard' and 'easy' scenarios and for the lower income and higher income groups. The findings show that compared to the 'easy' group, the 'hard' group spent less on groceries and temptation items, but the differences are not significant. The 'hard' group spent more on health and the difference is significant at 0.1 level ($p = 0.064$). What is remarkable is between the lower income group and the higher income group. The lower income group spent 21.68% more on health but 63.14% less on temptation goods than the higher income group did, and the differences are significant at 0.05 level ($p = 0.015$) and 0.01 level ($p < 0.001$) respectively. It seems that those with

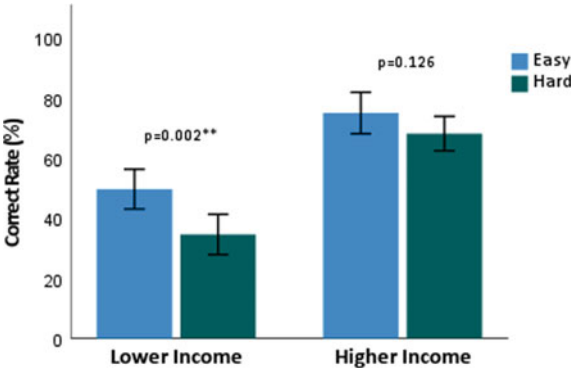

Fig. 2 Correct rate of Raven's matrix. *Notes* The bars indicate the correct rate, and the brackets indicate 95% confidence intervals. Easy (n = 130) and Hard (n = 134) indicates mean correct rate of individuals assigned to easy/hard financial scenarios respectively. Lower income (n = 123) and higher income (n = 141) indicate mean correct rate of individuals split by median annual income (¥20,000). P-values above the bars show statistical significance between 'hard' and 'easy' scenarios or within the lower income group and higher income group. *p < 0.10, **p < 0.05, ***p < 0.01

lower income behave more consistent with rationality, allocating their limited budget more on long term investment such as health rather than impulsive items they might not necessarily need.

4 Discussion

From an ergonomics and human factors perspective, two parts of our findings have direct implications for healthcare design. The first reveals that financial concerns adversely affect participants' cognitive performance, particularly among those with lower incomes (in our sample, individuals earning less than $20,000 annually). This is in line with prior studies (Lichand and Mani 2020; Mani et al. 2013; Ong et al. 2019) that observed worse cognitive performance in financially strained groups.

The field of cognitive ergonomics concerns 'mental processes, such as perception, memory, reasoning, and motor response, as they affect interactions among humans and other elements of a system' (IEA 2022). Our results showcase cognitive limitations in impoverished individuals, which is one of the most critical human factors design considerations. Recognising poverty as the underlying attribute to cognitive function could enrich healthcare designers' understanding of such user group. As an illustration, people living in developing areas may have difficulties in adopting new technologies (Dupas and Miguel 2017). Consider two possible healthcare interventions to improve the adoption of a new digital health information technology. A design that considers users' cognitive load would simplify information structure of the digital health system to alleviate cognitive demands of using the new technology.

Table 3 Purchase decisions on groceries, health goods and temptation goods

	Proportion of money allocated (%)		
	Groceries	Health	Temptation
Hard versus Easy			
{Easy scenario}	1.91	−4.69	2.78
	(2.648)	(2.521)*	(2.051)
Constant	57.73	33.44	8.83
	(1.858)	(1.769)	(1.439)
Lower income versus Higher income			
{Higher income}	−3.00	−6.13	9.13
	(2.650)	(2.515)**	(1.984)***
Constant	60.27	34.41	5.33
	(1.937)	(1.838)	(1.450)
Observations	264	264	264

Notes The dependent variables are the proportion of money allocated to each of the three categories of goods (groceries, health and temptation). The first panel reports results from general linear regression of proportion of money on the 'easy scenario' indicator variable and a constant. The second panel reports results from general linear regression of proportion of money on the 'higher income' indicator variable and a constant. The coefficient on the constant shows the mean for the 'hard' group and the lower income group respectively. Standard errors in brackets. * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

But a design ignores daily life taxing on cognitive capability might design complex versions.

The second finding is that poverty affects decision making both psychologically and financially. In economics study, there are two opposing perspectives on the consequences of scarcity: one is that it could lead to decision-making errors and counterproductive behaviour (Mani et al. 2013), and the other is that it produces a tunnelling effect and draws attentional focus to the task at hand (Zhao and Tomm 2018). Our results appear to support the latter. Participants assigned to 'hard' scenarios experienced greater levels of immediate monetary concerns and spent more on health goods. The effect is more significant when comparing higher income and lower income groups for their choices of health and temptation goods. The lower income spent much more on health goods and much less on temptation goods. A possible explanation is that participants with lower income detect the health-related cues in the task and perform better when making trade-off on limited budgetary resources.

Healthcare designers could greatly benefit from understanding this psychological scarcity mechanism and the trade-off thinking in people's decision-making process when designing potential health interventions. Our research implies that a more successful intervention would involve providing appropriate cues to direct attentional focus as well as guidance for decisions and actions. For instance, health promotion campaigns, like those for getting vaccination and quitting smoking, should place more emphasis on information related to scarcity and offer salient cues to capture

attention. A minor alteration to the user interface or to the feature of a designed object may have a significant impact on individuals' decisions and behaviours.

In addition to the practical human factors design considerations, the study may also shed light on novel approaches to designing inclusive and equitable healthcare targeting these user groups at the systemic and policy level, which would necessitate knowledge of systematic design and policy design. Policies aiming at enhancing the health and quality of life of the poor should consider both the objective and subjective aspects of scarcity to lessen both financial burden and psychological and cognitive load. According to the "World Development Report" (World Bank 2015), there are three promising ways to ensure that poor people have adequate cognitive space to make the best decisions: simplify procedures; target assistance based on cognitive bandwidth; and continue anti-poverty initiatives to reduce income volatility and improve infrastructure. Future studies could look into how design research and practice, with a holistic design approach, could contribute to these solutions and improve the health of impoverished individuals who are struggling in the 'poverty-disease' trap.

To balance the cost and ease of collecting data in the field, we used a relatively simple method to measure the cognitive function. Future research could employ various techniques and improve accuracy. In our upcoming study, we aim at designing tailored health interventions considering the impact of both objective and subjective scarcity and examining their feasibility and effectiveness.

5 Conclusions

In this study, we introduced the concept of psychological scarcity from economics into design research. We presented results from a lab in the field experiment in rural China designed to induce scarcity and examine the impact of financial worries on cognitive function and health-related decisions. Our findings suggest that cognitive performance is negatively impacted by financial worries and that the impact of poverty on decision making is both psychological and financial. It could facilitate academics and practitioners in healthcare design to comprehend the scarcity mechanism and how impoverished individuals make decisions about their health. Furthermore, it has a potential to expand to more contexts and pressing issues that could produce scarcity mindset, such as covid-19 quarantine and refugee aid.

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Appendix 1

See Table 4.

Table 4 Manipulation check

Dependent variable			
N = 264	Mean for		
	Hard scenario	{Easy scenario}	
		Coefficient	P-value
Scenario 1 Raise money in one week Imagine that an unforeseen event requires of you an immediate (¥20,000/¥1000) expense. You need to raise the money in less than a week			
Are there ways in which you may be able to raise the money in one week?	1.43	−0.27	<0.001***
To what extent do you agree with the following statements: (a) 'Coming up with (¥20,000/¥1000) on a very short notice would cause me long-lasting financial hardship.'	2.99	−0.52	0.007**
(b) 'Coming up with (¥20,000/¥1000) on a very short notice would require me to make sacrifices that have long-term consequences.'	3.24	−0.72	<0.001***
Scenario 2 Income decrease shock Imagine that the economy is going through difficult times. The income in your family decreases by (50%/5%). To what extent do you agree with the following statements:			
(a) 'Given my situation, I would be able to maintain roughly the same lifestyle under those new circumstances.'	2.11	1.51	<0.001***
(b) 'The (50%/5%) decrease in our income would strongly impact our daily life.'	3.95	−1.64	<0.001***
Scenario 3 Healthcare increase shock Imaging that due to serve illness, there is an increase in the monthly cost of healthcare by (¥2000/¥100) for your family, which amounts to a total cost increase of (¥24,000/¥1200) a year. This increase is not reimbursable by any government funding scheme			
Would it be difficult to afford healthcare?	1.32	0.44	<0.001***
To what extent do you agree with the following statements: (a) 'Paying additional (¥2000/¥100) a month for healthcare would require difficult budget cuts and sacrifices every month.'	3.87	−1.42	<0.001***
(b) 'Paying additional (¥2000/¥100) a month for healthcare would be too costly and it would probably result in forgoing going to the hospital	3.46	−1.09	<0.001***
Joint test			<0.001***

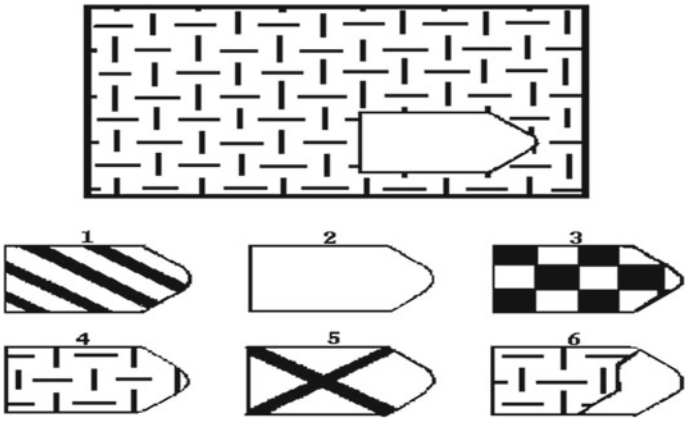

Fig. 3 Example of Raven's progressive matrices

Appendix 2

See Fig. 3.

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Patient Wellbeing, Experience and Empowerment

Patient and Clinician Perspectives on Collaborative Work in the Emergency Department

Kathryn Wust, Hanna Barton, Nicole Werner, Rachel Rutkowski, Peter Hoonakker, Manish Shah, Brian Patterson, Michael Pulia, Denise Buckley, Maureen Smith, Barbara King, Paula Dail, and Pascale Carayon

Abstract Older adults who present to the emergency department (ED) sometimes have a negative patient experience. Collaboration between care partners, patients and ED staff is one way to improve the patient experience in the ED, but patient, care partner, and ED clinician perspectives on collaborative work have yet to be studied. The objective of our exploratory study is to compare patient, care partner and clinician perspectives on collaborative work that occurs in the ED. Using data collected from patients, care partners, and ED clinicians during the design of an ED patient journey map, we identified four instances where patients, care partners, and clinicians expressed their perspectives regarding collaborative work. We found that patients, care partners and ED clinicians often had differing perspectives about

K. Wust (✉) · H. Barton · R. Rutkowski · B. Patterson · M. Pulia · P. Carayon
Department of Industrial and Systems Engineering, University of Wisconsin-Madison, Madison, WI, USA
e-mail: wust@wisc.edu

K. Wust · H. Barton · R. Rutkowski · P. Hoonakker · P. Carayon
Wisconsin Institute for Healthcare Systems Engineering, University of Wisconsin-Madison, Madison, WI, USA

N. Werner
School of Public Health, Indiana University—Bloomington, Bloomington, IN, USA

M. Shah · B. Patterson · M. Pulia · D. Buckley
BerbeeWalsh Department of Emergency Medicine, University of Wisconsin-Madison, Madison, WI, USA

M. Smith
Department of Population Health Sciences and the Health Innovation Program, School of Medicine and Public Health, University of Wisconsin-Madison, Madison, WI, USA

B. King
School of Nursing, University of Wisconsin-Madison, Madison, WI, USA

P. Dail
University of Wisconsin-Madison Health Sciences Patient and Family Advisory Council, Madison, WI, USA

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collaborative work in the ED. For instance, during the intake process, patients report being "checked" by ED clinicians, whereas ED clinicians view this as being "seen". Patients, care partners, and ED clinicians also shared similar perspectives, such as the importance of an ED care team. Older adult patients, care partners and ED clinicians have some similar and some different perspectives of patient-clinician collaboration in the ED that may affect how they interact with each other and the resulting patient experience.

Keywords Patient-clinician collaboration · Multiple perspectives · Emergency department

1 Background

Older adults (≥65) comprised 18.4% (>27 million visits) of emergency department (ED) visits in the U.S. in 2019 (Cairns and Kang 2019). While in the ED, some older adults report having a negative patient experience. For example, 46% of older adults report feelings of spending too long in the ED (Nerney et al. 2001). A qualitative study of 41 older adults and 15 care partners by Goodridge et al. (2018) found that older adults in the ED experienced ageism, poor communication with clinicians, feelings of abandonment, and lack of responsiveness to their unique needs at the time of discharge. These negative experiences may result from a stark contrast between the ED experience and what older adult patients value, specifically, their relationship with ED clinicians. In a systematic review, van Oppen et al. (2019) found that older adults want the following during their ED visit: efficient and effective care, person-centered holistic care, and shared decision making, all of which relate to their relationship with ED clinicians. We conceptualize these interactions that patients and clinicians engage in during an ED visit as collaboration.

Collaboration or collaborative work has been defined by Bedwell and colleagues (2012) as "an evolving process whereby two or more social entities actively engage in joint activities aimed at achieving at least one shared goal." This definition has four key aspects that reflect the interactions between patients and clinicians during ED visits. First, collaboration is an evolving process where relationships, members, and tasks can change over time. While visiting the ED, patients often see multiple different clinicians, their visit may span a shift-change, and the diagnostic process is often being revised based on new information. Second, collaboration occurs between two social entities, such as what occurs in the ED between a patient (i.e., individual) and the ED care team (i.e., team). Third, collaboration requires active and reciprocal, but not necessarily equal, engagement in joint activities. Active and reciprocal engagement includes communicating, coordinating, learning, and shared decision making (Martín-Rodríguez et al. 2005; Patel et al. 2012). Lastly, collaboration is work towards a mutually agreed upon shared goal. In the context of the ED, caring for the patient's urgent care needs and helping them transition to their next care setting may be the mutually agreed upon shared goal. Collaboration is a complex

process that includes multiple perspectives (i.e., patients and clinicians); we need to understand and compare these perspectives regarding the collaborative work process.

Few studies have looked at work processes that involve multiple perspectives using a SEIPS (Carayon et al. 2006, 2014; Holden et al. 2013) approach (Montague and Kleiner 2009; Musuuza et al. 2019; Schultz et al. 2007; Werner et al. 2021). For example, Musuuza et al. (2019), using the perspectives of nurses, physicians, and environmental services personnel, identified common, unique, and conflicting work system barriers and facilitators to implementing a C. difficile prevention bundle in an academic teaching hospital. Montague and Kleiner (2009) evaluated the perspectives of patients and clinicians in the obstetrics unit of a hospital and identified mismatches in role expectations during patient and physician interactions. Werner and colleagues (2021) found that despite being a part of the same care transition process, skilled nursing facility (SNF) and ED clinicians and staff had misaligned mental models, in particular regarding communication during the care transition and organizational capability of the other healthcare setting; these misalignments resulted in different perceptions of the process. Studies have explored multiple perspectives (e.g., patients, clinicians, environmental services personnel) in different contexts (e.g., hospital, outpatient surgery, obstetrics unit). Yet, none of them have evaluated older adult patients' and clinicians' perspectives of collaboration during an ED visit. The objective of our study is to compare patient and clinician perspectives on collaborative work that occurs in the ED.

2 Methods

This study was part of a larger study aimed at improving care transitions for older adults who present to the ED after having experienced a fall. We developed a patient journey map (PJM) (Fig. 1), which represents the ED patient experience. We conducted an exploratory secondary data analysis (Beck 2019) on the feedback that we received during the design process to understand patient and clinician perspectives on collaboration.

Development of the patient journey map (PJM). We developed the PJM using data from: 20 patient-centered observations of older adults (≥65 years old) presenting to the ED, 10 multidisciplinary meetings, and two patient and care partner focus groups. Participants in the 10 multidisciplinary meetings included: ED physicians (n = 3), ED nurses (n = 2), ED leadership (n = 5), ED operations (n = 11), IT (n = 2), patient experience leadership (n = 1), graphic designers (n = 1), and patient care partners (n = 1). The final version of the patient journey map, as seen in Fig. 1, incorporates the feedback from the patient and care partner focus groups. More information on the development of the PJM can be found in another publication (Wust et al. 2022).

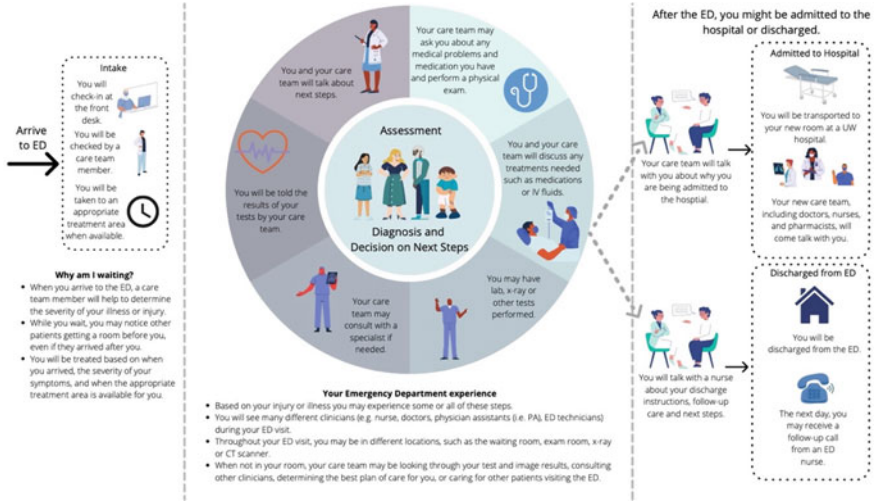

Fig. 1 Emergency Department Patient Journey Map (PJM) Visualization

2.1 Data Collection

Clinician feedback. We collected ED physician and nurse feedback on drafts of the PJM at two separate occasions during the design process. In March 2021, an ED nurse collaborator emailed markups on the PJM, which she had collected by asking ED nurses throughout the department for feedback. In June 2021, two ED physician collaborators and the ED nurse collaborator provided markup feedback on the PJM and the lead author (KW) met with one ED physician collaborator (BP) to review and discuss the feedback.

Patient and care partner feedback. We collected feedback from a care partner collaborator and two patient focus groups. In June and July 2021, the care partner collaborator emailed written feedback on the PJM. We also conducted two 1-h virtual focus groups with patients and care partners. The first group was composed of 1 patient and 2 care partners and the second group 2 patients, for a total of five participants. Before the focus groups, we mailed a printed copy of the PJM to the patients and care partners for them to review and reference during the meeting. Two HFE researchers facilitated the focus groups using a structured focus group guide. We audio-recorded the focus group meetings and a professional transcription service transcribed verbatim the audio-records.

Data analysis. We started analyzing the data using domain and taxonomic coding (Saldaña 2016), dividing the feedback from the patients, care partners, and ED clinicians based on the three overarching processes that occur within the ED: intake and triage (left); assessment, diagnosis, and next steps (middle); and discharge (right) (see Fig. 1). Next, we reviewed the feedback in each segment and identified common ED activities that were discussed by the patient, care partners, and ED clinicians

(e.g., use of the term "care team" to describe the ED clinicians and staff that care of the patient during their ED visit). We then compared how the patients, care partners, and ED clinicians, discussed these ED activities; this allowed us to identify their perspectives on collaborative work in the ED.

3 Results

We identified four instances on the PJM where patients, care partners, and ED clinicians expressed their perspectives regarding collaborative work: (1) arrival to the ED, (2) use of the term "checked" versus the term "seen" to describe the triage process, (3) use of the term "care team", and (4) use of the term "told" versus the term "discussed" to describe the process of receiving test results. Table 1 outlines each of the four instances and the perspectives of the patients, care partners, and ED clinicians as it pertains to collaboration in the ED.

During intake, patients may arrive by ambulance or personal means of transportation (e.g., car, bus). *From the patient and care partner perspective*, as seen in Table 1, one care partner thought including the different modes of arrival was important because it may affect the patient's treatment trajectory once in the ED. The other patients and care partners thought that including the different modes of arrival added unnecessary clutter to the PJM, especially since, depending on the patient's presenting issues, they may experience the same ED trajectory regardless of how they arrived at the ED. *ED clinicians* thought it was important to distinguish the different modes of arrival because they represent different clinician work processes, such as communicating with or collecting paperwork from the ambulance emergency medical staff. Further, mode of arrival may also affect the patient's treatment trajectory in the ED. The final draft of the PJM only includes an arrow labeled "Arrive to ER" (Fig. 1), taking the patient, care partner, and the ED clinician perspectives into account; the two modes of arrival were not included because the patient would not receive the PJM until they had already arrived at the ED, making the mode of arrival less important.

The leftmost side of the PJM (Fig. 1) includes the following activity, "You will be checked by a care team member"; which read "You will be seen by a care team member" in an early version of the PJM. *From the patient and care partner perspective*, the term "seen" was not as familiar to patients. One care partner recommended changing "seen" to "checked" because patients are more accustomed to being "checked" by a clinician than being "seen" (Table 1). *From the ED clinician perspec*tive, saying that the patient will be "seen" by a care team member was an alternative way to describe the triage process; clinicians thought that the term of "triage" may not be clear to patients.

As shown in Fig. 1, there are 10 activities with the title "care team", i.e., ED clinicians and staff caring for the patient in the ED: for example, activities of intake (e.g., being triaged), assessment and diagnosis (e.g., discussing medical history and medications), and discharge (e.g., reviewing the discharge instructions). *From the*

Table 1 Patient, care partner, and ED clinician perspectives around collaborative work

Feature of the PJM	Patient and care partner perspective	ED clinician perspective
Arrival to ED	**Some patients and care partners had differing perspectives on the importance of the mode of arrival to the ED** **Care partner 1:** "'Arrive at the ED' and 'Arrive by Ambulance' need to be separate boxes because arrival outcomes from each are different." **Patient 1:** "If you arrive by ambulance, you may go through the same process as if you arrived on foot." **Care partner 3:** "Yeah. I agree" [in response to patient 1's comment]	• Include all modes of arrival (e.g., ambulance, car) to intake section of PJM
"Seen" versus "checked" by a care team member	**Patients and care partners describe the intake process as being "checked" by ED clinicians rather than being "seen" by ED clinicians** **Care partner 2**: "…you will be seen by a team rather than checked, you know checked out kind of thing…"	• In intake section of PJM, include activity "You will be seen by a care team member"
"Care team"	**Don't view ED clinicians and staff as members of care team** **Patient 1**: "The patient doesn't really see a care team gather. It's one member after another." **Some patients and care partners consider themselves members of the care team while others do not** **Patient 3**: "I wouldn't sort of think of myself really as part of the team" **Patient 1**: "…it kind of depends, [interviewer]. I'd say that it can happen." **Patient 2**: "…Yes, that's part of the team. You're explaining to them and communicating to them what the issue is…" **Conceptualizing ED clinicians and staff as a team is important** **Patient 3**: "In my case, I like the word team." **Patient 1**: "So the idea of a care team, I thought, gee, this would be great to have a sense that people are working as a team because it would, it's really easy to wonder what's keeping this all together	• Consider patient and care partner to be member or care team in addition to ED clinicians and staff • Conceptualizing ED clinicians and staff as a team is important

(continued)

patient perspective and care partner, the term "care team" was indeterminate. Patients and care partners identified various roles for their care team, including ED physician, nurse, pharmacist, and lab staff. Despite consensus around the ED clinicians and staff that compose the care team, patients and care partners had differing perspectives as to whether they were members of the care team. For instance, as shown in Table 1, three patients did not think of themselves as a member of the care team, one patient thought being a member of the care team was a possibility, and two patients

Table 1 (continued)

Feature of the PJM	Patient and care partner perspective	ED clinician perspective
"Discuss" versus "told" test results	**Patients and care partners are told the results of their diagnostic tests, there is no discussion between clinicians, patients, and care partners about test results** **Patient 1**: "in all of the visits with family and myself to the ED over the last 40, 50 years, I've never had a discussion with the care team myself." **Being told rather than discussing test results is a result of the time constrained environment in the ED** **Care partner 2**: "And so, I think probably the nature of the setting is that you don't, you really don't get a lot of specific information" **Patient 1**: "They're [ED clinicians] moving fast. They don't have much time to do much discussing"	• Consider presenting test results to patient and care partner as a discussion

identified as a member of the care team because of their role in communicating with ED clinicians. *ED clinicians* considered themselves as members of the patient's "care team", and thus, they suggested that any instance of "ED clinician" or "ED staff" should be revised to read as "care team" or "care team member". Further, they indicated that the PJM could serve as a tool to help explain the care team to the patient; for example: various roles that compose the care team (e.g., patient, care partner, attending physician, resident physician, nurse). Despite their divergent perspectives, patients, care partners, and clinicians converged around the idea of the importance of the care team. Patients and care partners agreed that it would "be good" to know that the clinicians were part of a team and clinicians emphasized the importance of the team through wanting to be labeled a "care team".

The middle circle of the PJM includes the following activity, "You will be told the results of your tests by your care team". In previous versions of the PJM, this activity read as "You and your care team will discuss your test results." *From the patient and care partner perspective*, they did not view talking with ED clinicians about test results as a discussion but rather they are "told" the test results, as described in Table 1. Further, patients and care partners were able to assume the perspective of ED clinicians and understood that ED clinicians may not have time to discuss the patient's test results because of time constraints in the ED. *ED clinicians and staff* revised this activity but always kept the term "discuss", which may indicate that they view talking with the patient and care partner about test results as a discussion.

4 Discussion

This exploratory qualitative study drew on feedback provided by patients, care partners, and ED clinicians during the design process for an ED PJM. We identified four instances where patients, care partners, and ED clinicians had differing perspectives about ED activities, which allowed us to elicit their views on patient-clinician collaborative work.

Patients and care partners view collaboration in the ED differently than clinicians. Patients and care partners valued simplification, whereas ED clinicians valued a comprehensive description of the activities that occur in the ED. For example, we found that most patients and care partners did not think that including different modes of arrival (e.g., ambulance, car) was valuable, especially because patients may experience the same care trajectory once in the ED regardless of how they arrived. In contrast, ED clinicians and one of our care partners thought that including the different modes of arrival was important because it provided a complete description of the activities that occur in the ED. These findings reveal how each perspective views collaboration differently based on which activities they are engaged in. ED patients' and care partners' perspective reflects the collaborative ED activities that they are actively engaged in; in contrast, ED clinicians' perspective extends beyond the collaborative work that occurs with patients and care partners and includes work that they do separately.

Patients and care partners have different communication needs in collaborative work than ED clinicians. This contrast was seen in our data through different verbs used to describe activities in the ED, such as how patient's felt as if they were "checked" by clinicians during triage rather than "seen" or how they are "told" test results rather than "discuss" results with ED clinicians. While "seen" versus "checked" and "discuss" versus "told" may have inconsequential semantic differences, it reveals the disparate vocabularies held by the different perspectives, which may inhibit collaboration. For example, the use of medical terminology that is unfamiliar to the patient and care partner during interactions with ED clinicians, such as shared decision making, may limit their ability to collaborate. These differences in vocabulary also reveal the inherently disparate communication needs between the different perspectives. This expands upon the work of Werner and colleagues (2021), by revealing that misaligned mental models around communication needs between patients, care partners and ED clinicians can negatively influence collaboration. Aligning the mental models around the communication needs of each perspective during collaborative work is fundamental to improving patient experience in the ED.

Patients and care partners view their collaborative role differently than clinicians. They mainly describe their role in collaboration as that of a passive agent, whereas ED clinicians view patient and care partners as active agents in collaboration. In our data, some patients did not include themselves as members of the care team, whereas ED clinicians viewed patients as members of the care team. Patients and care partners may be willing to assume a passive role because they are aware of the constraints on

time and resources that clinicians work under in the ED. The disparate perspectives on collaborative work between patients, care partners and ED clinicians may show patients' and care partners' understanding of ED constraints while also revealing ED clinicians' willingness to engage with patients and care partners in the ED. There is an opportunity to leverage these disparate perspectives, by helping patients and care partners better understand the ED and by engaging them in collaborative work with ED clinicians; this is likely to further improve their experience in the ED.

Patient, care partner, and clinician perspectives converged around the importance of conceptualizing the ED clinicians, ED staff, the patient, and care partner as a care team. Due to the complexity of the ED environment, patients and care partners are not always aware of the "behind the scenes" work that ED clinicians and staff do to care for patients, which can negatively affect patient experience (Goodridge et al. 2018). From our results, patients and care partners can be brought in on the "behind the scenes" work by conceptualizing the ED clinicians and staff caring for them as a care team. Further, the conceptualization of a care team, rather than individual ED clinicians and staff, presents an opportunity for patients and care partners to be a member of the team and engage in collaboration. Yet, we found that patient and care partner perspectives on whether they were a member of the care team varied. Some patients and care pare partners viewed themselves as members of the team, others thought that being a team member was possible, and others did not consider themselves members of the team. The difference in perspectives among patients and care partners may influence how they engage in collaborative work with ED clinicians. Yet, it presents an opportunity for ED clinicians and staff to invite patients and care partners to be members of the care team. Inviting patients and care partners to be members of the care team can create a safe space for everyone to be engaged in the patient's care, which can help to improve the quality and safety care patients receive and how they perceive their ED experience.

Study limitations and future work. The findings from our study should be considered with respect to several limitations. First, this study was conducted with older adult patients, care partners, and ED clinicians from one academic emergency department, which may limit the transferability of the findings. Future research should examine patient-clinician collaboration in different settings and with different patient populations. Second, demographic information was not collected for patients, care partners, or ED clinicians and the small sample size may limit the generalizability of the results. Third, as an exploratory study, we may not have identified all patient, care partner, or clinician perspectives on collaborative work; instead, the results provide a stepping-off point from which to explore the concept of collaboration further. Future work is needed to build upon our findings and expand our understanding of patient-clinician collaborative work within the ED as well as other health care settings.

5 Conclusions

Patients, care partners, and ED clinicians engage in collaborative work during multiple interactions in the ED, which may affect the patient's ED experience. Analyzing the perspectives of patients, care partners, and ED clinicians on collaborative work in our exploratory study allowed us to elicit how each group perceives collaboration through their contrasting perspectives. Understanding each group's perspective on patient-clinician collaborative work reveals opportunities to align the perspectives, engage patients and care partners, and improve the patient experience in the ED.

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Mapping Contextual Factors Influencing Physical Activity Behavior of People with a Physical Demanding Job

Julia Beckmann, Pieter Coenen, Erwin Speklé, and Jos J. Kraal

Abstract People with a physically demanding job have an unhealthy disbalance in occupational and leisure-time physical activity (PA). We aimed to understand which contextual factors influence this disbalance, and explore opportunities for lifestyle interventions that could restore this disbalance. We applied a contextmapping study with six production workers from a Dutch coating department. Participants filled in a sensitizing booklet with PA-related activities, and were interviewed afterwards. Participants reported reasons for (not) being active in leisure-time using an experience sampling method. Our results indicate that main reasons for being inactive during leisure time were their believes that occupational PA is enough for a healthy lifestyle, and the need to rest after work. Results show that lifestyle interventions should tackle workers inadequate risk perception and over-exhaustion to empower them to shift their PA behavior in a healthier direction. This indicates the need for a holistic approach targeting both home and working environments.

Keywords Holistic approach · Lifestyle intervention · Occupational health · Physical activity paradox · Life-long health · Prevention

J. Beckmann (✉) · J. J. Kraal
Department of Human-Centered Design, Faculty of Industrial Design Engineering, Delft University of Technology, Delft, The Netherlands

J. J. Kraal
e-mail: j.j.kraal@tudelft.nl

P. Coenen · E. Speklé
Department of Public and Occupational Health, Amsterdam UMC, Amsterdam, The Netherlands

E. Speklé
Arbo Unie, utrecht, The Netherlands

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1 Background

People with a physically demanding job tend to have poorer health than people with sedentary jobs, even when adjusted for relevant health, lifestyle, and socioeconomic factors (Li et al. 2013). That is surprising since physical activity (PA) is important to prevent multiple chronic diseases (WHO 2010) and workers with a physically demanding job move the whole day at work. This is called the 'physical activity paradox' and can be explained by the differences in occupational and leisure-time PA (Hallman et al. 2015). Leisure-time PA (LTPA) is usually executed in short moderated or high-intensity bouts of predominantly aerobic activities followed by long recovery periods, whereas occupational PA (OPA) includes tasks like manual handling, repetitive work, and prolonged static postures, over long periods without sufficient recovery (Holtermann et al. 2020). While LTPA improves cardiorespiratory fitness, delivering this kind of strenuous physical work for ≥40 h/week is likely to cause fatigue and thereby inactive (or sedentary) behavior in leisure time (Arias et al. 2015; Bláfoss et al. 2019). This suggests that people with physically demanding jobs are at risk for potentially negative health consequences of OPA and may not benefit from the positive health effects of LTPA. In current occupational health research, interventions for this population typically focus on either the home or work environment. As demonstrated by Prince et al. (2021) these kinds of interventions have limited impact on workers in physically demanding jobs, thus emphasizing the need for new directions for these workers. In a first step to develop a more holistic PA intervention that target the home and work environment, we explored the personal and contextual factors driving PA behavior in people with physically demanding jobs.

2 Methodology

We used two methods in this study: contextmapping to explore which contextual factors influence PA behavior, and an experience sampling method (ESM) to determine which of these factors were most important for our participants. The study was performed in collaboration with a metal processing company. We recruited workers (18–67 years) of the coating department since these have high physical workload during their work.

In pairs, the workers must hang up, take down and carry products such as bars, tubes, and beam sets (20–60 kg), and some products must be coated by hand. They have to finish about 150 rounds in one day, so they must hang up and take down a product every three minutes. Workers with severe physical limitations were excluded. Workers signed an informed consent form before participating.

2.1 Contextmapping

With contextmapping we explored the experiences, needs, motivations and preferences of people with a physically demanding job since peoples ' underlying thoughts, feelings, and desires cannot be explored with standard methods like interviews and observations. Visser et al. (2005) state that contextmapping gives "access to a hidden world of user experience, and thereby build[s] a better understanding of it" (p. 122). Thus, generative methods like contextmapping can be used to explore tacit and latent knowledge, enabling people to express their values and desires in words (Sanders and Stappers 2012) (Fig. 1).

Contextmapping defines that people's current experiences are often influenced by past memories and future dreams. Therefore, we asked participants to first describe their present experiences and recall memories through a sensitizing workbook, and reflect on these experiences and identify future desires through semi-structured interviews.

2.1.1 Sensitizing

Using a workbook to sensitize participants for the topic of interest, increases the quantity and quality of participants' recollection and contributions in a subsequent interview (Visser et al. 2005). In our study, each participant therefore received a workbook with short assignments around the central topic of OPA and LTPA (Fig. 2). The assignments were split over four days and aimed to encourage participants to access, express, and reflect on their experiences, motivations, barriers and preferences. Little stickers with ambiguous pictures and emoticons were added to the package to trigger deeper thoughts and feelings and encourage participants to work on it.

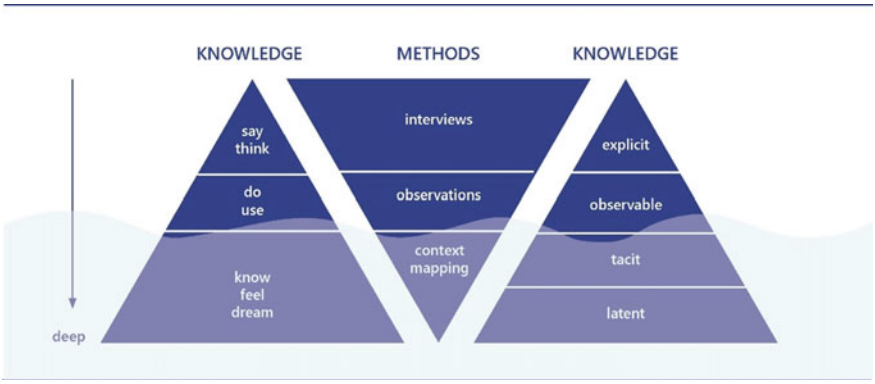

Fig. 1 This illustration shows that generative methods are needed to access deeper knowledge

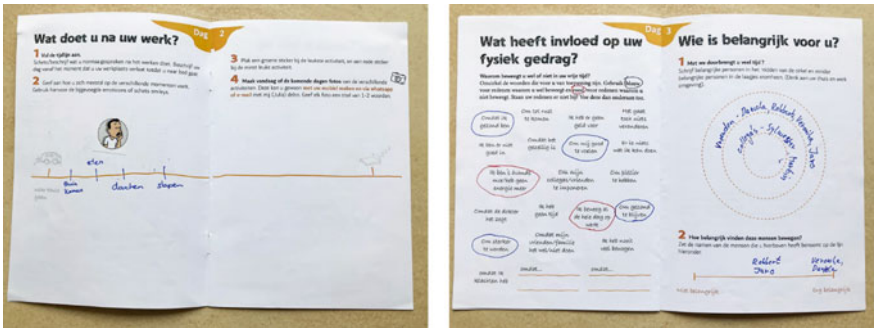

Fig. 2 Filled in examples of the workbook

2.1.2 Interviews

After the workbook was completed, we performed semi-structured interviews with all participants. The script was based on the structure of the sensitizing booklets, and was personalized for each participant depending on their answers from the workbooks. The interviews included questions regarding patient's experiences, needs and motivations for PA behavior, and were executed by JB.

2.2 Experience Sampling Method

ESM was applied to facilitate self-reporting of reasons for being (not) active in the home environment. ESM is a common method for studying what people do, think, and feel during their daily lives (Larson and Csikszentmihalyi 2014). We installed two boxes at the participants' homes for four days (Fig. 3).

Both boxes had seven buttons with labels next to it, describing factors that influence the PA behavior of the participants (Table 1). The factors were based on literature, expert-interviews and the contextmapping study.

The researcher explained to the participants how to use the boxes. The boxes were placed in strategic spots, to trigger the use of the boxes. For example, box 2 was placed near the door so participants were triggered to use it when they were going outside. The boxes were connected to a router, sending data to the researchers. Data were saved on a TU Delft cloud and represented in a dashboard using Grafana. This set up has been developed in Studiolab at TU Delft (Beckmann 2022).

Fig. 3 Left: the router that is connected to the two boxes next to it. Right: the box 2 was placed in a participant's home

Table 1 Labels of the two boxes. Labels describe factors that influence the PA behavior of the participants. Box 1 focused on reasons for being inactive, box 2 provided reasons for being active

Box 1: I am not moving because:	Box 2: I am about to move because:
I don't feel well	It helps me to relax
I want to relax	It makes me feel good
I am exhausted	I want to be fitter/stronger
I don't have time	A friend/family member asked me
I don't know what I should do	I have chores
Nobody is free	I want to go outside/somewhere
Other reasons	Other reasons

2.3 Analysis

Data of the contextmapping study were analyzed according to the six phases approach of Clarke and Braun (2014), using a thematic analysis framework. First, data from the interviews were organized and prepared for the analysis. Field notes were transcribed and written down on post-its using Miro. Quotes were translated to English. Second, relevant quotes and thoughts were noted to familiarize with the data. Lean coding was applied to identify recurrent labels (Creswell 2018). We sorted the data into 10 categories and clustered and labelled the post-its, resulting in 66 codes. Using overlapping codes and categories, 30 initial themes were identified. A diagram was generated that represents relationships among these identified themes. Finally, we used the COM-B model to sort and categorize themes. The COM-B model provides a systemic approach to understand behavior of a person, describing the capability, opportunity and motivation required for behavior (Fig. 4) (Michie et al. 2011; Ellis

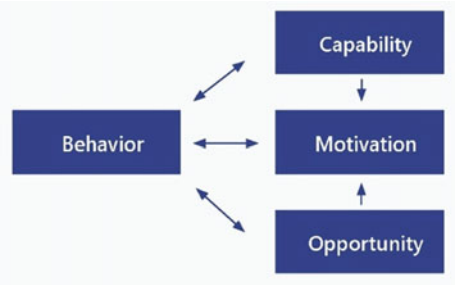

Fig. 4 COM-B model (Michie et al. 2011)

et al. 2019). For ESM, only descriptive statistics (i.e. the relative number each button was pressed) were calculated.

3 Results

Six male workers participated in the context mapping study, aged 31–59 (average 43) years and had the Dutch, Polish, Spanish, Slovakian and Somalian nationality. Four of the six have a partner/family in Netherlands. Identified themes were structured according to the COM-B model, representing factors influencing production workers' capability, opportunity, and motivation for healthy PA behavior (Fig. 5). We labelled each factor with a green (facilitator) or red tag (barrier). Factors that could be a barrier and facilitator received both tags. The most important factors are described below.

3.1 Capabilities

Psychological. All participants knew it is important to perform PA to stay healthy. They could not explain why exactly PA is essential, but they did connect it to better health. However, none of the participants was aware of the differential health effects of occupational OPA and LTPA, indicating an incorrect risk perception as barrier for healthy PA.

> "I have enough sport at work" (male, 53 years old)

Physical. All participants emphasized that they are extremely exhausted after work. Although they would like to be more active during leisure, they spent all of their energy at work.

> "[…],we are working there 10 h, that is the problem why we do nothing after work, because we are tired." (male, 31 years old)

Fig. 5 Overview of the most prevalent factors that influence workers capability, motivation and opportunity for a healthy PA behavior (Green tag = Facilitator; Red tag = barrier)

In addition, some participants reported that they stopped active behaviors due to health complaints or signs of ageing. The physical work is taking toll on their body, limiting LTPA.

3.2 Motivation

Reflective. Because participants believe that their OPA provides enough health benefits, they are not motivated to be active in leisure-time anymore, and feel they deserve time to relax. Furthermore, some participants mentioned that they do not participate in LTPA because they do not want to risk their job.

> "I am watching football. If I would play football, it would be a risk. If I would get injured, I could not go to work tomorrow." (male, 40 years old)

However, the attitude of some workers towards a healthy lifestyle was positive. They reported that they had changed their lifestyle recently, stopped smoking, adopted a healthy diet, and/or started moving in leisure time.

Automatic. Although most participants reported that LTPA energizes them and makes them feel good, many participants developed a habit of inactivity during leisure time. They were aware of the immediate positive effects of PA, but have difficulty

initiating it. Workers had a routine of showering, eating and relaxing after work, and mentioned that they only move if they really have to (e.g. to do groceries or for other chores).

3.3 Opportunities

Physical—work environment. Participants perceived high work pressure in their work, as workers mentioned production goals were increased each year while the number of workers were reduced. Consequently, workers need to work harder, and often skipped breaks and worked overtime. All participants mentioned work load increasing exhaustion and limiting opportunities for LTPA.

> "Like now, I would like to do some sports, but I just don't have time for it." (male, 59 years old)

Workers did not have the autonomy to decide what time they work or take a break, because when the line starts running, they must be present. The team leader does try to take their wishes into account for his planning.

Physical—home environment. Participants mentioned that safe recreational facilities like parks, football places or shops near home facilitate LTPA. They indicated that they prefer moving in nature and that they like cycling because of the well-arranged cycle paths in the Netherlands.

> "Yes I live close to the woods, so we go into the woods for an hour, one-and-a-half." (male, 59 years old)

Social—Working environment. Participants indicated that there is a certain 'macho culture' in their sector, where workers are intended to work hard and do not complain. This macho culture can overstrain workers' body and negatively influence PA behavior.

> "I think the culture is pretty good,… these people go for it and don't complain and you don't even have to tell them to do this or that faster, they understand that very well…" (male, 59 years old)

Social—Home environment. All participants have social roles and responsibilities at home that keep them from being physically active, such as chores, taking care for their family and maintain relationships with friends.

> "Most of the time my wife cleans up, but I have to do something from time to time, otherwise my wife gets angry." (male, 53 years old)

However, social responsibilities can facilitate PA behavior too. Friends that want to meet, children that require playing or a dog that needs to go outside function as facilitators of LTPA.

> "[…] Otherwise the dog is not happy and then I have no rest at home, so I have to." (male, 53 years old)

Fig. 6 The diagram illustrates the relative number the buttons on 'Box1: Not moving' were pressed. Buttons that were pressed most frequently are highlighted in yellow. In total Box 1 was pressed 50 times and Box 2 was pressed 34 times

3.4 Results Experience Sampling Method

The ESM demonstrated which factors influenced the PA behavior of the participants the most. Four of the six workers participated in the ESM study. Three participants pressed multiple buttons each day. One participant used the boxes less frequently, but did press at least one button each day.

Most selected reasons for being inactive were 'I moved at work' and 'I want to relax' (Fig. 6). 'I have chores' and 'I want to go outside' were most frequently indicated reasons for being active (Fig. 7).

4 Discussion

We explored contextual factors influencing PA behavior of people with a physically demanding job, and opportunities for lifestyle interventions. We identified contextual factors of each behavioral component of the COM-B model—capability, motivation, and opportunity, and found that workers mainly do not move because they believe they move enough at work and feel the need to rest. This inadequate risk perception of workers with a physical demanding job was also demonstrated by van den Berge et al. 2020. We also showed that PA could help workers to relax their minds but that they feel too exhausted to get started. This is in line with Bláfoss et al. (2019) who showed that the duration of LTPA gradually decreases with increased work-related fatigue in workers with physically demanding jobs. Facilitators for PA were

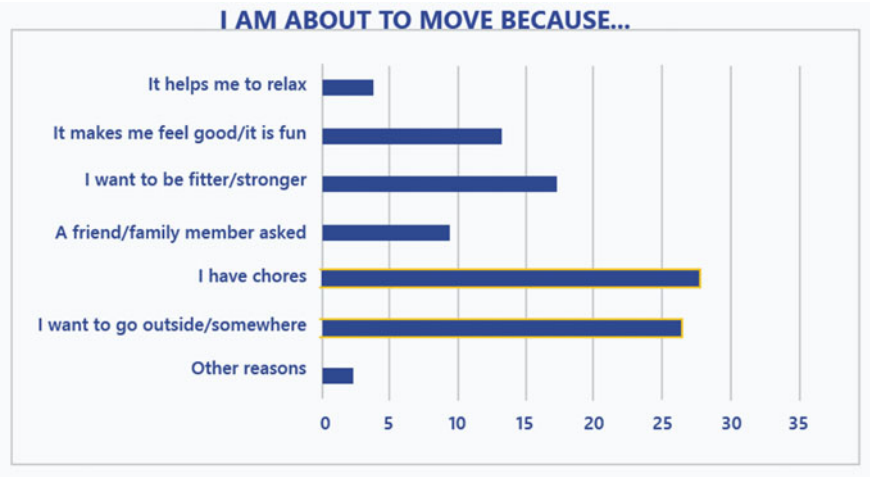

Fig. 7 The diagram illustrates the relative number the buttons on 'Box2: Not moving' were pressed Buttons that were pressed most frequently are highlighted in yellow. In total Box 2 was pressed 34 times

household chores and social or recreational activities. Although workers did not consider household chores as PA, it does elevate energy expenditure. However, the energy expenditure involved in housework is less than that involved in brisk walking or physical exercise (Lawlow et al. 2002). Recreational facilities like nature and social activities (e.g., meeting friends or going to the playground) were important motivators for PA. These findings align with Bauman et al.'s results (2012), which suggest that LTPA is consistently related to the availability and the proximity of recreation facilities and that a pleasant green environment can stimulate people to move. Future interventions should make use of these facilitators to enhance PA behavior.

Our results can be used for interventions for people with a physical demanding job using a holistic approach, including both the home and work environment. We propose an intervention focusing on creating awareness and facilitating change using e.g. an informational campaign and a digital buddy (Beckmann 2022).

The participatory and human-centered method applied in this study increased the depth of our exploration. Combining qualitative and quantitative data on how people experience PA behavior enriched our results and provided clear directions for future interventions. However, our research was performed with a small group of participants, limiting the generalizability of our results. Variety of nationalities of our participants limited clear communication. However, this is a pressing barrier for research projects with people with physical demanding jobs.

5 Conclusions

We showed that leisure-time PA behavior of people with a physically demanding job is limited by inadequate risk perception of the health benefits of occupational PA, and over-exhaustion. Interventions should apply a holistic approach and include home and working environment to promote PA behavior. Our findings are relevant for researchers and practitioners who aim to design preventive interventions to improve PA behavior of people with a physically demanding job.

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From White Paper to Learning Pathway: Progress and Challenges in Professionalizing Human Factors in UK Healthcare

Bringing HFE Education and Training Closer to Healthcare Systems: The Case of a Latin American Network of Practitioners and Academics

Irma Cecilia Landa-Avila and Carlos Aceves-Gonzalez

Abstract Human Factors and Ergonomics (HFE) has been recognised as a critical strategy for improving the quality and safety of healthcare systems and increasing the wellbeing of the different stakeholders. Despite efforts to integrate HFE training into healthcare worldwide, there is an unequal situation in different parts of the world. This is the case in Latin American countries, where the dissemination and implementation of HFE in healthcare systems have been slow despite the urgency to do it. This paper presents the case of a Latin American Network of Ergonomics and Human Factors in Healthcare (RELAESA) in its journey to address the need to develop and deliver HFE training for the healthcare community. The case presents five key milestones and their learnings, from creating the network in 2019 to the ongoing collaboration to adapt the Learning Pathway for a Latin American context. The lessons learned show that significant progress has been made in creating awareness of HFE among healthcare practitioners that are committed to undertaking training. However, it also recognised the urgency of increasing the capacity and capability of HFE specialists in the region. It also evidenced that existing educational/training content generated outside Latin America and translated into Spanish requires a more in-depth adaptation that is culturally aware of the conditions and limitations of the public health systems. Future work includes partnering with existing training organisations to translate, culturally adapt and provide access to existing guidance (HF in Health and Social Care White Paper) and formal training (Healthcare Learning Pathway).

Keywords HFE training · Healthcare ergonomics · Latin America

I. C. Landa-Avila (✉)
Loughborough University, Loughborough, UK
e-mail: i.c.landa-avila@lboro.ac.uk

C. Aceves-Gonzalez
Ergonomics Research Centre, Universidad de Guadalajara, Guadalajara, Mexico

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1 Background

The World Health Organisation (WHO) has recognised in the Global Action Plan for Patient Safety 2021–2030 that Human Factors and Ergonomics (HFE) is a critical strategy for building highly reliable healthcare systems (WHO 2021). Building the capacity of patient safety leaders in HFE and providing all healthcare staff with training in HFE are two of the main strategic actions for accomplishing such a purpose. Academic literature has evidence that HFE is a critical element in improving patient safety across different healthcare services and systems and has contributed to improving areas such as the safe use of medications and the implementation of new technologies (Carayon et al. 2014a, b).

Despite this evidence and the calls and recommendations to integrate HFE training into healthcare worldwide, the level of dissemination and implementation has occurred in different ways across the world. In Latin America, the progress in integrating HFE has been slower, even though there is great urgency for its application, given that the needs and inequalities are greater than in other areas of the world (Aceves-González, Rodríguez et al. 2021a, b; Scott 2008). According to Thatcher and Todd (2019), the application of HFE in Latin America has happened mainly in occupational health in the manufacturing sector, with fewer applications in the (re)design of services and systems.

The Latin American healthcare systems present specific challenges and barriers to accelerating the integration of HFE in their practice. There is poor public infrastructure and insufficient resources to provide equal access to the population and there is limited understanding and evidence of the contributions that HFE has made to improve the quality and safety of Latin American healthcare systems (Aceves-González et al. 2021a, b). In addition, there is little training and education accessible in Latin America. Given this situation, four years ago, a group of HFE academics and healthcare practitioners formed a network to address these challenges and bring HFE to Latin American healthcare systems.

This paper presents the case of a Latin American Network of Ergonomics and Human Factors in Healthcare (RELAESA) in its journey to address the need to develop and deliver EHF training for the healthcare community. The case presents five key milestones and their learnings in chronological order, starting from the creation of the network in 2019 to the ongoing collaboration to adapt the Learning Pathway for a Latin American context.

2 Methodology

This paper describes the case of the Latin American Network RELAESA, which aims to provide access to HFE training to healthcare professionals. The aim of the authors in presenting this case is to reflect on critical moments and milestones of the networks and synthesise learnings that have emerged from them.

2.1 Procedure to Identify the Milestones

For this in-depth case study, we drew on archival documents from the creation of the network in (November 2019) to the present (August 2022). These documents and evidence consist mainly of:

- Minutes from meetings
- Action plans
- Feedback surveys
- Input from network members (recording meetings)
- Stored documents and materials generated

The authors of this paper are founding members and have been participating in all the events and milestones. They also held continuous debriefing sessions after key events, which helped them to synthesise the experiences and reframe and adjust the plans.

3 Results, Milestones and Learnings

Based on the reflection, five key milestones have been identified. These are summarised in Table 1, and each is explained afterwards.

3.1 Formed the RELAESA Network

RELAESA was officially founded in December 2019. The founding members met at academic events and exchanged points of view on the needs of the region. Initially, 18 ergonomists and healthcare professionals began the network; the membership has increased by invitation from members and by the interest of attendees to RELAESA's public webinars. Currently, the network has 40 members from Mexico, Argentina, Colombia, Chile, Costa Rica, Peru, Brazil, Venezuela, España and UK.

Figure 1 show the structure of the network. This structure aimed to communicate a more dynamic relationship between the members rather than a top-down structure.

One of the first actions was to generate a foundation document describing the aims, vision, and objectives of the network. Existing members collectively developed this document over four months. The writing process evidenced the level of understanding of HFE, existing practices (some of which were unconscious), the strengths of the network and what would be the initial action plan. Although it was not initially considered, it was vital to identify healthcare practitioners that could act as HFE champions. These champions have been key in disseminating the importance of HFE in their organisation and helping open doors with other healthcare organisations.

Table 1 Summary of the milestones of RELAESA

Year	Milestone	Description	Learnings	Evidence
2019	Formed the RELAESA network	Define the aim and structure of the network and identify special interest groups	• Need for a lay/ consistent description of HFE • Experiential learning of HFE by healthcare practitioners • Identify healthcare practitioners that act as HFE champions	• Foundation document containing aim, objectives, and structure
2020	Determine a training strategy	Determining a peer-to-peer training and dissemination strategy. The HF in Health and Social Care White Paper and the SIEPS model have guided most of the initial training	• Pharmacovigilance is a strong domain in the region • HFE-led training first to create a common ground • Preference for internal trainers	• Action plan 2020 • Action plan 2021 • Webinars and conversation recordings • Feedback from attendees
2020–2021	Translating existing HFE resources	Translating in Spanish and disseminating existing knowledge from guidance and academic papers in webinars	• Need that translations also adapt recommendations and guidance to the Latin American context	Spanish version of • Overcoming COVID-19: What can human factors and ergonomics offer? • Vaccinating a Nation Guidance (CIEHF)
2021	A systematic review of Latin American literature	Systematically reviewing the Latin American literature to evidence knowledge gaps that support future applications	• Focus on the usability of medical devices and healthcare workers' performance and safety • Patient safety incident analysis, system design and organisational/ system resilience are underexplored in Latin America	• Journal Article (Spanish) (Aceves-González et al. 2021a, b)

(continued)

Table 1 (continued)

Year	Milestone	Description	Learnings	Evidence
2021	Organising a Symposium and Special Issue	Publishing a Special Issue in Spanish that collates HFE practices in healthcare	• High interest in integrating HFE in healthcare systems, but lack of HFE specialists in healthcare settings • Latin American environments include psychological, political and personal safety pressures	• 11 published papers • CIEHF President's award (highly commended)

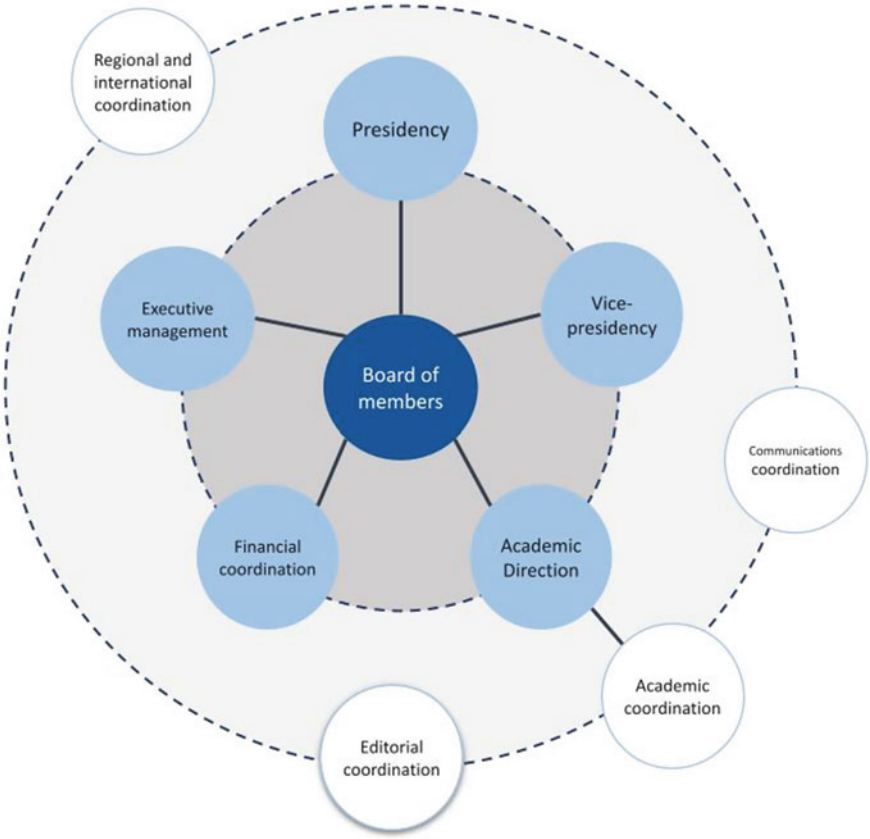

Fig. 1 Organisation chart of RELAESA

3.2 Determine a Training Strategy

The foundation documented highlighted the need to define a training strategy in two directions; first, HFE academics will disseminate HFE knowledge among healthcare professionals and second, health professionals will bring their practical expertise to tackle the knowledge-practice gap. Due to the high number of RELAESA members in the area of pharmacy, this training strategy has been focused on this community and context.

From the early days, RELAESA has unofficially partnered with the Chartered Institute of Ergonomics and Human Factors (CIEHF) of the UK. This has guided us in defining the skills and competencies we should nurture in our members. CIEHF also has a key ally to access and disseminate training resources and connect with international members willing to support the network.

Regarding the content, two main topics have dominated the training agenda. The first one is to promote that the HFE has been recognised by international organisations (i.e., WHO) for its fundamental role in improving patient safety. Secondly, much emphasis has been made on understanding healthcare as a complex system. For the first topic, the Human Factors in Health and Social Care White Paper (CIEHF 2018) has played a critical role. It has provided clear evidence and examples of the role of HFE to investigate incidents and to think about systems. This document also emphasises the importance of ensuring that sufficient and relevant HFE education is included in clinical curricula, which has helped RELAESA to open doors with senior managers in healthcare organisations. In supporting the dissemination of a systems approach, the Safety Engineering Initiative for Patient Safety (SEIPS) model (Carayon et al. 2020; Holden et al. 2013) has been a straightforward resource to explain what is a system, its elements and how each of them are connected. SEIPS has contributed to highlighting the importance of different stakeholders (e.g., patients, family members, healthcare professionals, managers and policymakers) and how they interact with technology, tools and task. It has also helped us explain the different systems levels and what can be considered an environment. Another effective resource for explaining the concept and implications of a systems approach has been the video "Systems Thinking, a new direction in healthcare incident investigation" (Jun 2017). This video has resonated with our members and offered them alternatives to improve patient safety, especially by shifting from a blaming culture to a learning organisation model.

RELAESA has continuously organised online webinars and conversation panels covering different topics from which patient safety and medication errors have gained more interest. From the beginning of 2022, it was decided to separate public and members-only sessions. This was decided as RELAESA members reached a point where they needed more advanced training, while the public sessions still require a basic level and focus on increasing the awareness of HFE.

3.3 Translating Existing HFE Resources

The subsequent action of RELAESA was to translate some key resources to Spanish. This decision was made because a large population does not have a good level of understanding of English. Due to the COVID-19 outbreak, it was decided to centre the efforts on generating material that could help tackle some emerging challenges.

One of the resources was the journal paper "Overcoming COVID-19: What can human factors and ergonomics offer?" by Gurses and colleagues (2020). This paper succinctly exposes the antecedents of HFE in helping to mitigate some problems in previous pandemics and exemplifies actionable recommendations. Another resource was the guidance "Vaccinating a Nation" (Chartered Institute of Ergonomics and Human Factors 2021) which provided ten principles to support a safe rollout of a massive vaccination programme. Following the translation, a webinar was held to present the principles and provide cases from ongoing vaccination services.

Feedback from attendees to the webinar and RELAESA members evidenced that more than translating was needed to create relevant content. The main issue is that these resources were generated considered other healthcare systems (i.e., UK and USA) that are substantially different from Latin American ones. Moreover, some of the recommendations could be considered insensitive to the actual conditions of the healthcare systems. This eye-opening moment changed how RELAESA will make the knowledge accessible. It was recognised that an in-depth exploration of knowledge from/by Latin Americans was needed to responsible curate the training content.

3.4 A Systematic Review of Latin American Literature

A systematic review of the Latin American literature was conducted to evidence existing knowledge and gaps that guide future applications. This review (Aceves-González et al. 2021a, b) included 77 papers and categorised the papers according to the domain applications (Carayon 2014a, b). Research has focused on the performance of healthcare workers (32/77), the usability of technology (26/77), systems design (9/77), system resilience (7/3) and none in patient safety incident analysis; three papers were classified in more than one domain.

These results suggest that most HFE researched domains (i.e., the usability of medical devices and healthcare workers' performance) might study a limited number of systems elements' interactions without a systems perspective. Approaches such as patient safety incident analysis, system design and organisational/system resilience seem to be underexplored in Latin American literature, which may reduce the opportunities to increase safety and wellbeing more sustainably. This review was also critical to illustrate that there has been the implementation of HFE in healthcare that

is normally underappreciated more widely. This might be because most of the literature was written mostly in Portuguese and Spanish, and therefore, it has not been spotted by the community that mostly consults papers written in English.

3.5 Organising Symposium at the IEA Conference and Special Issue

The final milestone included in this case consists in documenting the contributions of HFE in Latin America healthcare systems and defining the challenges that ergonomists and health professionals can tackle together.

A call for papers looked for contributions was published as part of the International Ergonomics Association (Vancouver 2021). Ten papers were selected for the Symposium; these papers covered four topics: (i) role and evolution of ergonomics in Latin American health systems, (ii) medication errors and patient safety, (iii) well-being of healthcare staff and organisational ergonomics and (iv) HFE and COVID-19. The authors were invited to build on these contributions and send a full paper to the subsequent Special Issue published in the Research and Development Journal. An online webinar accompanied the Special Issue to disseminate the selected papers.

Feedback from attendees to the Symposium and webinar reiterated the commitment and willingness of the healthcare community to undertake training and implement HFE-led changes. However, it also demonstrated the lack of educational resources that were created consciously considering the conditions of the Latin American systems.

3.6 Other Significant Milestones

In 2021, the board members were encouraged to apply for the CIEHF President's award. The submission obtained a good response and was highly commended by the judges in the category.

RELAESA members have been actively engaged with other healthcare communities and invited as speakers in health and patient safety conferences to create awareness of the discipline. In addition, healthcare practitioners have increased their involvement in writing academic publications as they have recognised the value of evidence their practice-knowledge experiences.

4 Discussion

This paper presents the case of a Latin American Network of Ergonomics and Human Factors in Healthcare (RELAESA) and its learnings in bringing HFE training and education to healthcare practitioners.

The lessons learned from the milestones show that significant progress has been made in creating awareness of the benefits of HFE among healthcare practitioners. The initial formation of the network evidenced that many healthcare professionals have implicitly received some HFE education. This phenomenon has been identified previously as "experiential learning" and the "hidden curriculum" (Vosper and Hignett 2018). This has helped in recognising HFE as a valuable discipline for improving patient safety. In fact, a strength of RELAESA is the high number of practitioner members committed to undertaking formal training in HFE, giving back their practical knowledge (work-as-done) and documenting the training/implementation progress. This could lead to a robust training plan that delivers theory and practice. Moreover, this could also contribute to generating literature in the area of pharmacy and patient safety that has been identified as lacking (Vosper and Hignett 2018).

The learnings have also identified the relevance in disseminating the systems approach perspective. This has been one of the main challenges of the training for many reasons. First, there are different interpretations of systems, some of which tend to imply a more reductionist approach. A misunderstanding of the systems approach could lead to an inaccurate view of safety (exclusively Safety I) that tend to identify people as the root cause and look for "find and fix" elements of systems (Pickup et al. 2018; Vosper et al. 2018). Therefore, RELAESA training will keep focused on 'healthcare as a complex system. Although this training will include a variety of perspectives, methods, and tools, certain content curation will be made to not send conflicting/confusing messages to members regarding a systems approach. The key will be to offer balanced content that does not mislead our members to (over)rely on one HFE systems approach/method for all their situations. The emphasis will be made on providing the expertise to critically select the method/tool most appropriate to their needs and context (Shorrock and Williams 2016). We will be conscious that our willingness to bring HFE closer to healthcare systems will not create false expectations for practitioners; we will nurture a mindset that embraces small but constant changes rather than believing in "quick gains".

Nevertheless, these three years also led to recognising the urgency of increasing the capacity and capability of HFE specialists in every country in the region. To the best of our knowledge, there is no under or postgraduate education in HFE in healthcare in Latin America; only Master's degrees in Ergonomics exist in the region (e.g., Chile, Brazil, Argentina and Colombia, among others) (Avila-Chaurand et al. 2019) and one Doctoral degree that started this year (Universidad del Valle in Colombia). One strategy to provide formal training is to reach outside Latin America and create partnerships to make that training accessible to our community. However, existing educational/training content generated outside Latin America requires a more in-depth adaptation than just translating the content. A constant demand from

our members is that HFE content and recommendations should be more culturally aware of the conditions and limitations of the public health systems and the staff and patients' behaviours. RELAESA will be looking for the formal training to be recognised by official healthcare regulatory bodies and integrated into health-related education to incentivise more healthcare practitioners to undertake it.

4.1 Future Work

The ongoing actions of RELAESA include collaborating with academics to adapt the Healthcare Learning Pathway (School of Design and Creative Arts & Loughborough University 2021) to Latin American systems. Eventually, documentation and feedback of the training will help to refine and disseminate the content more widely. Furthermore, members undertaking the training will be encouraged to document how they have integrated HFE knowledge into their practice through case studies that guide other healthcare practitioners and HFE specialists.

An additional strategy will be to develop and strengthen collaboration with the Latin American Ergonomics Union (ULAERGO) and ergonomics societies in the region to join efforts in the education and training of healthcare professionals.

5 Conclusions

This paper presents the case of RELAESA, a Latin American network that looks to bring HFE training and education to healthcare practitioners. Throughout the three years, different learnings have been obtained; most of them highlighted the need to recognise the academic work made in the region and develop HFE training that is conscious of the context, political situations, and resource limitations of the healthcare systems. Reasonable future work includes partnering with existing training programmes to translate, culturally adapt and provide access to existing guidance (e.g., Health and Social Care—White Paper) and formal/accredited training.

Although much remains to be done, it is evident that the commitment of RELAESA members and strategic allies will be paramount to tackling future challenges in Latin American systems and consolidating the role of HFE in achieving this aim.

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Workflow, Training and Resilience

Multidisciplinary Clinicians' Perspectives About Barriers and Facilitators to a Team-Based OR-To-ICU Handoff

Bat-Zion Hose, Meghan Lane-Fall, and Ellen J. Bass

Abstract Research about operating room (OR)-to-intensive care unit (ICU) handoffs reports barriers and facilitators to the team-based process, but less is known about role-specific challenges and strategies. Based on a secondary analysis of eight interviews with frontline clinicians from two health systems, we identify seven dimensions of role-specific barriers and facilitators to a team-based OR-to-ICU handoff, also referred to as the team huddle in the patient's ICU room. The seven dimensions are related to three factors: (1) preparing for the patient's arrival to the ICU, (2) providing information at the team huddle, and (3) participating in the co-located, synchronous team huddle. The role-specific barriers and facilitators describe challenges related to the timing of the team huddle in the patient's room, which is dependent on the end of the patient's surgery and therefore cannot be scheduled. Another challenge is that busy clinicians with competing priorities are physically separated across the OR and ICU. Thus, the sending roles from the OR are required to travel with the patient to the ICU while receiving roles prepare for the patient's arrival. Identifying role-specific barriers and facilitators to a team-based process can inform the design, or redesign. When implemented, the handoff process can positively impact care quality by ensuring important information is shared among team members.

Keywords Team-based care · Handoff · Patient safety

B.-Z. Hose (✉) · M. Lane-Fall · E. J. Bass
Department of Anesthesiology and Critical Care at the Perelman School of Medicine, University of Pennsylvania, Philadelphia, PA, USA
e-mail: Bat-Zion.Hose@Pennmedicine.upenn.edu

E. J. Bass
College of Computing and Informatics, Drexel University, Philadelphia, PA, USA

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1 Background

Multidisciplinary, team-based handoffs provide an opportunity for the sending operating room (OR) team and receiving intensive care unit (ICU) team to communicate important, time-sensitive patient information required for providing critical care (Nagpal et al. 2010). The American Heart Association recommends a post-surgical team handoff process, which have shown to improve information exchange, teamwork, and professionalism (Wahr et al. 2013). A recent review by Abraham et al. (2021), reports inconsistent evidence on the effectiveness of OR-to-ICU handoff interventions, e.g., standardized handoff process (Lane-Fall et al. 2020).

Health care systems aiming to design, or redesign, the handoff process can benefit from a multi-site case study reporting barriers and facilitators to a team huddle in the patient's ICU room. Previous studies by McElroy et al. (2015), Lane-Fall et al. (2018), and Wooldridge et al. (2020) included interviews with frontline clinicians involved in the OR-to-ICU handoff for liver transplant patients, two OR-to-ICU pathways (at one health system) caring for a mixed surgical population, and OR-to-pediatric ICU handoff, respectively; in addition to identifying handoff barriers and facilitators, all three studies (Lane-Fall et al. 2018; McElroy et al. 2015; Wooldridge et al. 2020) describe handoff tasks, e.g., physical transfer. Reported barriers and facilitators to OR-to-ICU handoffs include:

- Advanced notification of the handoff (McElroy et al. 2015)
- Time pressure to return to the OR (Lane-Fall et al. 2018)
- Staffing and resources availability (Wooldridge et al. 2020)
- Prioritization of clinical care and handoff communication (McElroy et al. 2015)
- Team member participating during the handoff (McElroy et al. 2015)
- Confusion about other clinician's informational needs (Lane-Fall et al. 2018).

Both Lane-Fall et al. (2018) and Wooldridge et al. (2020) report barriers and facilitators to the handoff process, but do not focus on identifying clinicians' multiple perspectives to OR-to-ICU handoff tasks, like McElroy et al. (2015). Identifying barriers and facilitators for one role or multiple roles can inform the design of a handoff process that ensures team communication of important patient information.

Research in handoff and team-based decision making has shown that having different roles representing multiple perspectives can facilitate team communication (Cooke et al. 2003). However, these different roles can encounter difficulty trying to coordinate their work. Kipps et al. (2020) identified that team-based care like multidisciplinary rounds planned and initiated around one role's schedule (e.g., attending physician) can result in other roles (e.g., family) being unable to participate. Due to differing responsibilities and competing priorities, the timing of team-based care (e.g., OR-to-ICU handoffs) is a role-specific barrier to participation. More recently, the COVID-19 pandemic has brought global attention to the problem of resource-constrained hospitals with staff turnover and shortages impacting participation in team-based care (Office of the Assistant Secretary for Planning and Evaluation 2022). Identifying role-specific barriers and facilitators to team-based OR-to-ICU handoffs

can inform the design of processes that are compatible with clinicians' roles and that clinicians find value in adopting.

Due to limited knowledge about role-specific barriers and facilitators to OR-to-ICU handoffs, we conducted a two-ICU site study to explore the following questions about OR-to-ICU handoffs:

- What are receiving role-specific barriers and facilitators to preparing for the patient's ICU arrival?
- What are role-specific barriers and facilitators to exchanging relevant information?
- What are role-specific barriers and facilitators to participating in a synchronous team huddle?

We identified common dimensions of barriers and facilitators to a team-based OR-to-ICU handoff by characterizing frontline clinicians' perspectives.

2 Methods

2.1 Setting and Participants

As part of an ongoing project to standardize OR-to-ICU handoffs across multiple health care systems (Lane-Fall et al. 2021), we conducted eight 45-min interviews with frontline clinicians. Site 1 has a 20-bed ICU and Site 2 has a 10-bed ICU. Both sites are part of urban academic medical centers. Both sites have surgery, anesthesia, ICU nurse, and ICU provider roles. At Site 1, the interviewees included an anesthetist, ICU nurse, ICU advanced practice providers (APP), and an attending surgeon. At Site 2 the interviewees included the first three roles as Site 1 and a resident surgeon. Data collection occurred between April and September 2021.

Approval for this study was obtained from the institutional review board (IRB) at the University of Pennsylvania (#843,670), which serves as the single IRB of record for the sites participating in this study.

2.2 Data Collection

To understand and represent the current OR-to-ICU handoff process for multiple ICU sites, two human factors (HF) researchers created an interview guide and conducted semi-structured interviews via video conference. Questions addressed current handoff process as well as opportunities and challenges for designing a standard team-based handoff process. The mean interview duration was 42 min (range: 35–52 min).

Interviews were video-recorded, and the audio portions were initially transcribed via software post processing. One researcher cleaned software-produced transcripts and removed identifying information.

2.3 Data Analysis

The two researchers conducted a secondary analysis by applying an analytic expansion approach (Thorne 2013). They asked emerging research questions from primary data collected to develop current state process maps.

One HF researcher identified excerpts where clinicians described barriers and facilitators to conducting a team-based handoff. Excerpts were exported to Microsoft Excel®. Two HF researchers independently coded all excerpts by summarizing the barriers and facilitators. The two researchers reviewed and discussed coded summaries to reach consensus. One HF researcher reviewed final summaries to identify dimensions of barriers and facilitators. Then, the two HF researchers reviewed and agreed on the final list of dimensions. As a form of member checking, barrier and facilitator dimensions were critically reviewed by a clinician on the research team who was not involved in the data analysis (Mays and Pope 2000).

3 Results

Researchers identified seven dimensions of barriers and facilitators and organized them into three categories: (1) preparing for the patient's arrival to the ICU, (2) providing information at the team-based huddle in the patient's ICU room, and (3) participating in the co-located team huddle. Each of the seven dimensions have role-specific barriers and facilitators. The team members comprise of sending roles, including the surgery and anesthesia representatives, and receiving roles, including the ICU provider and nurse.

Table 1 shows the two dimensions related to preparing for the patient's ICU arrival, their definitions, and respective barriers and facilitators. Before the operation ends, a member of the OR team contacts the ICU to provide an estimate time of arrival and information about equipment and medications to prepare. The anesthesia representatives, ICU nurses, and ICU providers were mixed about the notification to prepare and having enough time to ensure the ICU room was ready for the patient arrival.

Table 2 shows the three dimensions of providing information at the team huddle in the patient's room, their definitions, and respective barriers and facilitators. Participants explained that team members' roles and experience with these handoffs influence the information provided at the huddle. Surgeons and ICU nurses explained that multiple people (e.g., attending physician, fellow, resident) can serve as the surgery representative and articulated challenges related to who participates in that role; this

Table 1 Barriers and facilitators to ICU team preparation for patient arrival

Dimension	Definition	Barriers (B) and facilitators (F)
Notification to prepare	Sending role contacts receiving role to provide relevant information for coordinating resources and to provide estimated time of arrival	– B: Lack of procedural knowledge: due to turnover, new staff (e.g., anesthesia representative) unaware of completing notification about patient arrival to ICU – F: Multiple notifications: two anticipatory phone calls from sending role helps receiving role (1) prepare and (2) be ready (e.g., with equipment and/or medications) for patient arrival to ICU – F: ICU team coordinates equipment needed in patient room ahead of arrival to ICU: receiving role (e.g., ICU provider) notifies respiratory therapy to bring a ventilator to patient's ICU room – F: ICU team coordinates additional role members present when patient arrives to ICU: receiving role (i.e., ICU nurse) notifies additional nurses to be available when patient arrives to help transfer monitors
Preparation activities	Receiving role (ICU nurse) must prepare room (e.g., with ventilator) for patient arrival	– B: Lack of preparation: if receiving roles do not prepare, then sending role(s) waits upon patient arrival to ICU as receiving role gathers resources (e.g., ventilator) – F: Preparation: efficient when receiving role (ICU nurse) has ventilator waiting, bed pulled out, and additional ICU nurses ready to transfer monitors and settle patient

is a surgery-related barrier to the team-based huddle. The OR team must travel to the ICU for the handoff, which enhances information exchange between the sending and receiving roles; the ICU providers were positive about being co-located during the team huddle especially to examine the patient together. Such co-location in the ICU is a facilitator of the team-based huddle.

Table 3 shows the two dimensions of arriving to the team huddle in the patient's ICU room, their definitions, and respective barriers and facilitators. Anesthesia representatives, surgery representatives, and ICU nurses expressed mixed feelings about the nurse's competing priorities (managing another patient and settling the patient) that impact whether they can be present and engaged during the team huddle. Alternatively, the surgery representative and ICU nurse reported challenges for the sending roles—compelled to stay in the OR—to be present and fully participating at the team huddle.

Table 2 Barriers and facilitators for providing information at team-based huddle

Dimension	Definition	Barriers (B) and facilitators (F)
Multi-disciplinary team	Sending roles (i.e., anesthesia representative and surgery representative) different than receiving roles (i.e., ICU nurse and ICU provider) and must share role-specific information required for patient care	– F: Transfer of information: sending role (e.g., surgeon) provides information about patient's care needs (e.g., dressing procedures) that is helpful for receiving role (e.g., ICU nurse) – F: Filling in information gaps: sending role (e.g., anesthetist) gives report after other sending role (e.g., surgeon) and can provide information that was not yet mentioned (e.g., a penicillin allergy) – F: Prior receiving role experience: sending role's (e.g., surgeon) prior experience as receiving role (e.g., ICU provider), so shares important information for receiving roles providing post-surgical care
Sending role representation	More than one role representative (e.g., surgeon and/or surgery resident) for sender	– B: Multiple candidates for sending role representative: multiple (potential) sender role representatives completing different tasks during case (due to numerous surgical specialties and anesthesia shift changes) requires selection of role representative – B: Selecting sending role representative with incomplete knowledge of case: surgical specialty (e.g., plastics) who finishes procedure most likely to participate in handoff and unable to answer questions about entire case – B: Sending role representative's lack of experience: varying levels of experience for sender role due to professional title (e.g., surgeon and surgery resident) impacts information shared during handoff
Co-location	Some activities (e.g., physical exam) requires sender (surgeon) and receiver (ICU provider) roles to be physically together	– F: Activities requiring co-location: Sending role (surgeon) points out drains, chest tubes, and may have receiving role (ICU provider) palpate body parts

Table 3 Barriers and facilitators to participating in co-located team-based handoff

Dimension	Definition	Barriers (B) and facilitators (F)
Receiver's workload	Receiving role's (i.e., ICU nurse) competing priorities (e.g., settling patient and transferring monitors) impacts ability to be present at handoff	– B: Competing task: receiving role (i.e., ICU nurse) prioritizes settling the patient and may be delayed to handoff, if secondary nurses are unavailable – B: Multi-tasking: if patient is "crashing", then receiving role (e.g., ICU nurse) is at bedside managing patient and listening to handoff – F: Ensuring team members are engaged: roles (surgery representative, anesthesia representative, and ICU provider) wait for ICU nurse to begin handoff
Sender's workload	Sender's need to manage competing priorities (e.g. OR schedule and handoff)	– B: Lack of presence: sending role (e.g., surgeon) not always present at handoff – B: Partial presence: sending role (i.e., surgery and/or anesthesia representative) needs to go back to OR and leaves after giving report, which may result in 'incomplete handoff' (e.g., not asking about postoperative antibiotic course)

4 Discussion

In this study, we identified role differences for seven dimensions of barriers and facilitators to conducting the team-based handoff. Clinicians noted challenges with preparation to ensure the room is ready when the patient and OR team arrive to the ICU, information provided by different roles, and competing priorities for the sending and receiving roles to be present at the team huddle in the patient's room.

McElroy et al. (2015) explained the importance of providing advanced notice to the receiving ICU team of liver transplant patients—allowing sufficient time for recruiting additional staff and gathering equipment. Similarly, Wooldridge et al. (2020) identified clinician anticipation of future care needs as essential when caring for traumatically injured children. We also identified dimensions of barriers and facilitators related to preparation for the patient's ICU arrival. Our results show that both sending and receiving roles describe the importance of notifying the ICU of the patient's arrival and consequences when the ICU team lacks time to prepare by informing secondary nurses and retrieving equipment. Understanding barriers and facilitators reported by different clinical roles involved in the handoff process can inform the (re)design of a handoff process that fits in the current workflow.

Prior handoff research by McElroy et al. (2015) and Lane-Fall et al. (2018) identified challenges impacting handoff quality, such as a lack of information being communicated due to the operative surgeon missing. Our results also demonstrate difficulties related to information being communicated at the team huddle. We expand upon barriers about role representation at the huddle, specifically for the sending surgical representative whose level of experience impacts information communicated to the receiving roles (e.g., ICU nurse). Team-based handoff protocols are

needed to assign appropriate sending role representatives and ensure that important patient information is communicated to the receiving roles.

Research on handoffs (Lane-Fall et al. 2018; McElroy et al. 2015; Wooldridge et al. 2020) identified barriers and facilitators related to participation in a co-located handoff. Wooldridge et al. (2020) mentioned challenges with staffing and resources. Similar to McElroy et al. (2015), we report consequences of staffing and resource shortages for the ICU nurse prioritizing clinical care over handoff communication. For instance, the ICU nurse may be caring for an unstable patient, resulting in the perceived need to multi-task and listen while the other clinicians begin the handoff. Lane-Fall et al. (2018) identified time pressure for the sending roles (i.e., surgery and anesthesia representative) to return to the OR. Our findings support that the sender's workload requires managing competing priorities and may result in their absence or partial presence at the team huddle, ultimately comprising information communicated to the receiving roles. Participating in the team-based handoff creates challenges for sending roles who must travel to the ICU and receiving roles in the ICU who begin assuming responsibility of patient care.

4.1 Study Strengths and Limitations

Study strengths include that this is the second multi health system case study of OR-to-ICU handoff (Lane-Fall et al. 2020); analyzing barriers and facilitators at two ICU sites allowed us to examine similar barriers and facilitators. Another strength is the inclusion of the four roles participating in the handoff. Results of our analysis highlight role differences for barriers and facilitators to the handoff.

One limitation of this study is that each ICU site was one of several ICUs (e.g., trauma, surgical, burn, neuro, and pediatric) at the two health systems. Thus, we did not study every OR-to-ICU pathway at each respective health system. Still, we found similar barriers and facilitators mentioned by clinicians at both ICU sites. Another limitation is the interview guide was created to understand the current handoff process and develop a process map. We did not directly ask clinicians about barriers and facilitators to conducting the team-based handoff. Finally, we conducted individual interviews. Future research may uncover other barriers and facilitators from group interviews with a sending and receiving role.

5 Conclusions

Identifying role-specific barriers and facilitators can inform the design of OR-to-ICU handoff protocols that are integrated in the workflow, and therefore consistently employed by members of a multidisciplinary team. Such protocols can ensure that important patient information is communicated between the sending OR team and the receiving ICU team.

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Socio-technical Systems Analysis of Medical Ward Rounds in an Acute Teaching Hospital

Marie E. Ward, Barry Kennedy, Cormac Kennedy, Susie O'Callaghan, Declan Byrne, Óisín Galvin, Hannah Kielty, Ellen Flynn, Sharon O'Hara, and Una Geary

Abstract Ward Rounds (WR) are an essential organisational process at the interface between patients, their families/carers and the clinicians who provide their care. WRs are also complex socio-technical systems (STS) involving interactions between people and technology commonly occurring in environments not fit for purpose. This study was undertaken as part of a longitudinal improvement project in relation to WRs taking an STS approach. A STS analysis (STSA) called the Cube was undertaken to understand current 'AS IS' WR practice from a Human Factors and Safety Science perspective. Key findings are broken into the domains of the Cube and include the following: Time constraints on all disciplines make it difficult for shared sense-making; Goals are not always shared in relation to the purpose of WRs; there is variation in practice in relation to pre-rounds, board rounds and handover; Safari WRs make relationship-building, collaboration and trust between disciplines difficult; there is a lack of defined outcome metrics for 'success' in relation to WRs. This initial STSA has helped us to identify areas which we need to

M. E. Ward (✉)
Health Systems Learning and Research, St James's Hospital, Dublin, Ireland
e-mail: maward@stjames.ie

Centre for Innovative Human Systems, School of Psychology, Trinity College, The University of Dublin, Dublin, Ireland

B. Kennedy · C. Kennedy · S. O'Callaghan · D. Byrne · Ó. Galvin · H. Kielty · E. Flynn · S. O'Hara
St James's Hospital, Dublin, Ireland

C. Kennedy
Clinical Research Facility, St James's Hospital, Dublin, Ireland

D. Byrne
Medical Gerontology, School of Medicine, Trinity College, The University of Dublin, Dublin, Ireland

U. Geary
St James's Hospital, Dublin, Ireland

Clinical Medicine, School of Medicine, Trinity College, The University of Dublin, Dublin, Ireland

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improve. Reforming care for patients who require unscheduled care in acute hospitals is a healthcare priority. Given the resources required by WRs and the pivotal role they play, improving WRs will significantly contribute to this reform.

Keywords Socio-technical system analysis · Ward rounds · Acute hospital

1 Background

Ward Rounds (WR) are an essential organisational process at the interface between patients, their families/carers and the clinicians who provide their care. The purpose of WRs includes the planning and delivery of patient care (Swenne and Skytt 2013), providing a link between patients' admission and their discharge (RCP/RCN 2012), and teaching doctors in training (Walton et al. 2016). A recent systematic review reported that, in practice, there is variation in the definition and objectives of WRs, where they take place, who partakes in them and understanding their impact on patient care (Heip et al. 2022). Challenges to efficient and effective WR practice have previously been described from different perspectives. These include medical teams experiencing significant time pressure during WRs (Walton et al. 2019); nurses reporting experiences of not having a 'voice' on WRs (e.g. Liu et al. 2013); patients reporting discussions being rushed or inaccessible, feelings of disempowerment (Swenne and Skytt 2014) and communication barriers due to use of mobile healthcare information technology (HIT) (Rajasoorya 2016). While quality and safety checklists have improved patient perception of care (Read et al. 2021) and patient safety on WRs (Keller et al. 2017), their use is not commonplace. From a multi-disciplinary team (MDT) perspective the following challenges have been noted: ineffective communication, impact of individual personalities on how WRs are conducted, a lack of understanding about roles and responsibilities, and challenges with organisational structure (Walton et al. 2020).

WRs are complex socio-technical systems (STS) involving intra- and interprofessional working, patient and family/career communication, the use of healthcare information technology (HIT) in environments that are often not fit for purpose (Salonen et al. 2013). Many efforts have been made to improve WRs including checklists such as the Considerative Checklist (Herring et al. 2011) and frameworks like the Structured Interdisciplinary Bedside Rounds (SIBR) (Gausvik et al. 2015). While these have improved WRs, barriers to implementation include disconnect between medical and nursing staff, lack of ring-fenced time for nurses to attend WRs, unpreparedness of junior doctors and lack of research into implementation issues (Darbyshire et al. 2015). Carayon et al. (2011) have argued for the need for more research in healthcare taking an STS approach and employing STS analysis (STSA). This study was undertaken as part of a longitudinal improvement project in relation to WRs taking an STS approach. A STS analysis (STSA) called the Cube was undertaken to understand current 'AS IS' WR practice from a Human Factors and Safety Science perspective.

2 Methodology

2.1 Introduction to the Cube STSA

The Cube STSA framework has been developed over several years across numerous programmes of research in aviation safety (e.g. Ward et al. 2010; Ulfvengren and Corrigan 2015) and more recently in healthcare safety (e.g. Corrigan et al. 2018; McDonald et al. 2021; Ward et al. 2022; Geary et al. 2022). The purpose of the Cube is to support a rich understanding of the 'AS IS' situation. STSAs like the Cube are guided by the principles of relevance and leverage—what is most relevant to look at that will give us the most leverage in terms of understanding and changing systems and sustaining change.

The Cube STSA recognises that processes are not linear and cannot be represented as such but rather explores four domains of STS (Culture, System functioning, Action, and Sense-making); and four types of relation within each domain (Goals/outcomes, Process, Social Relations, and Information and Knowledge). These domains are all interconnected and we have tried to capture this complexity in an image of a cube—hence the name of the framework. Please see Fig. 1.

The framework was designed to support an analysis that could span a set of diverse theoretical approaches and perspectives. The four domains of the Cube cover the following:

- Culture represents the pattern of shared basic assumptions and (what is often) a partial shared understanding of the STS and incorporates Schein's (Schein 1984, 2010) and Pigeon and O'Leary's (1994) work on culture.
- System functioning represents how the system actually works and incorporates both formal elements (work-as-imagined), i.e. Policies, Procedures, Protocols, and Guidelines (PPPGs) as well as informal elements (work-as-done or the sequence of activities that normally takes place) (Dekker 2006) and incorporates Perrow's functional focus on complexity and coupling (Perrow 1984).

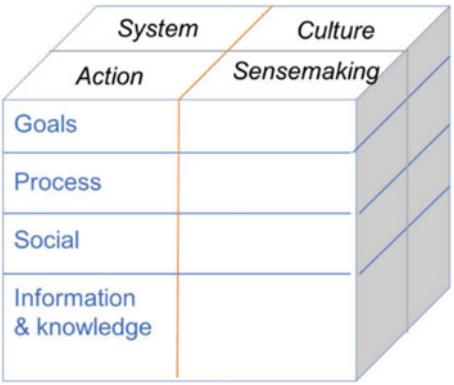

Fig. 1 Pictorial representation of the Cube (from McDonald et al. 2021)

- Action represents how we act within the system, incorporating Turner and Pidgeon's work on the flows of information, knowledge and understanding, and anything that happens in the system that is recordable or measurable (Turner and Pidgeon 1997); this can be analysed at different levels, such as individual actions, team performance against a standard, activity sequences, or key outcome, process, and balancing measures in relation to system performance (Ward et al. 2019).
- Sensemaking represents how we understand and make sense of our world and incorporates Weick's work on how individuals operating within the system make sense of it, often through practical action (Weick 1995).

These dimensions of the CUBE are further broken down in terms of four types of relation: Goals (linked to system objectives and outcomes), Process (sequential relations), Social Relations (reciprocal relations of working with and reporting to others), and Information and Knowledge (exchanges of meaning that link people and processes). A high level set of questions representing these dimensions of the Cube are presented in Table 1. To the best of our knowledge an STSA has not been carried out on WRs. An initial 'rapid' cube was carried out as part of the longitudinal study to inform both the initial 'AS IS' analysis and what would be needed to carry out a more in-depth STSA of WR practices and processes.

Table 1 High-level questions derived from the STSA Cube (a full list of questions can be found in Geary et al. 2022)

	Culture	Functioning system	Action	Sensemaking
Goals	What are the cultural values of people working in the organisation?	What are the system goals?	What are the key outcomes of the current situation and how are they measured?	What are the objectives of key stakeholders?
Process	What are the norms of behaviour and everyday practice?	What are the key tasks and activities, and how effective is the current sequence?	What data and indicators are used to assess performance?	What is the quality of the tasks and activities being carried out?
Social Relations	What different professional groups/ subcultures work together?	What are the key roles and relationships (working with, reporting to)?	How are roles and relationships documented and assessed?	What is the quality of leadership and collaboration?
Information and knowledge	Is there a shared understanding of what to do and how the system works?	Describe the flow of information that links people to their activity	How is the quality of information, knowledge and information flow measured?	What is the quality and flow of information like, with regards to enabling informed action?

2.2 Data Gathering and Analysis

Ethnographic observations took place of pre-WR MDT meetings; post-take clinical handover meetings; medical and surgical WRs (15 h spent over 6-month timeframe from June to Nov 2021). Six focus groups were held with the following staff groups.

(i) junior doctors (September 2021 n = 28)
(ii) senior management (with representation from consultants, nursing, health and social care professionals (HSCP), operations, bed management, patient experience, process improvement) (October 2021 n = 10)
(iii) surgical nurse managers (November 2021 n = 16)
(iv) and medical nurse managers; (November 2021 n = 14)
(v) HSCPs managers (November 2021 n = 8)
(vi) HSCP staff (December 2021 n = 8)

All of the notes from the observations and focus groups were written up by one author (MEW). MEW used the Cube framework high level questions in Table 1 to conduct an initial STSA of the data. This was then validated by all the other authors at the WR improvement project management meetings which were held on 2–3 week basis from June to December 2021. The Cube analysis was developed iteratively through a process of drafting and refining based on new material emerging from the sessions and feedback from the WR improvement project management group.

The final analysis was presented to and validated by a wider WR improvement project advisory group consisting of representation from consultants, nursing, HSCP, quality and safety improvement, patient safety, clinical audit, information technology, person centred care and process improvement (December 2021 n = 18).

3 Results

An initial Cube STSA was completed. The findings are outlined in Table 2 and summarised below.

Sensemaking: WRs involve an extremely complex processes of reviewing medical information, drawing information from different IT systems, clinician decision making, and discussing the patient's progress with them on the WR. The RCP/RCN (2021) guidance sets an expectation that following WRs, clinicians can estimate the patient's date of discharge (EDD). Time constraints on all disciplines make it difficult for shared sensemaking or deep situational awareness (SA) (Endsley 1995) in relation to the care of each patient.

Functional system: Goals are not always shared in relation to the purpose of WRs. Wards are operating at capacity (100% occupancy vs the recommended 85% occupancy rate (IMO, 2017)) resulting in difficulties maintaining speciality co-horting of patients and 'safari' ward rounds where patients are seen across multiple wards. There is variation in practice in relation to pre-rounds, board rounds and handover. There is

a lack of closed loop communication between disciplines using the Electronic Patient Record (EPR) system.

Culture: While patient care is prioritised, challenges with hospital infrastructure inhibit space for MDT shared decision making (SDM). Safari WRs and lack of specialist ward based care make relationship-building, collaboration and trust between disciplines difficult. WRs are not given precedence despite their central role in patient care; separate disciplines often perform different tasks, frequently disrupting each other.

Action: Key parts of progressing action were not always specified, e.g. MDT agreeing clinical criteria for discharge (CCD) and EDD. EPR functionality was not always exploited for collaborative working. There was a lack of defined outcome metrics for 'success' in relation to WRs. Roles and responsibilities of MDT members were not clearly understood by all. In Table 2 below we also have bolded the areas that we believe are most relevant to look at to give us the most leverage in terms of understanding, changing and sustaining changes to ward rounding.

4 Discussion

This study is part of a longer-term project to co-design new ways of carrying out MDT WRs while improving the quality and safety of clinical care. This initial STSA has helped us to identify areas were we need to work on to gain leverage in relation to change.

We have identified the following priorities to focus on. Clarity in relation to goals is a key feature of a high functioning STS and is the single most important predictor of success in healthcare teams (Lyubovnikova and West 2013; Klein et al. 2009). In terms of the process we will focus on gaining a better understanding of how EPR supports shared SA among the MDT of the clinical status of each patient to be seen on the WR. We will focus on the make-up of the clinical teams and how we can better integrate the perspectives of the different stakeholders. Finally, we will focus on understanding how activity on WR maps onto process, outcome and balancing measures.

The limitations of this study include the depth of the analysis; we were time and resource constrained to do a deeper STSA and acknowledge that this is only an initial analysis. We also acknowledge that the patient perspective is missing and we have built this into our next phase of analysis. The Cube STSA is just one type of STSA and is relatively new to healthcare. Its development was predominately informed by psychologists. It would be interesting to also look at a more established STSA in healthcare such as the Systems Engineering Initiative for Patient Safety (SEIPS) (Carayon et al. 2020) and look at how the two STSA approaches would compare in understanding and improving WR practice.

Table 2 Cube STSA analysis of WRs

	Culture	Functional system	Action	Sensemaking
Goals/objectives	Genuine care and concern expressed for each patient Desire expressed by staff to 'go back' to ward based care (had happened during Covid-19 responses); to having all disciplines involved in WRs; to have opportunities to get to know staff from other disciplines At system level variability in having patient voice in planning for WR/Shared Decision Making (SDM) Medical teams are extremely busy, competing for resources (Workstation on Wheels (WOWs); time; space)	**Different goals** were in evidence in relation to WRs Based on the goals of the Royal College of Physicians/Royal College of Nurses (2021) some were shared e.g.: Review patient history & current status and Develop/progress care plan Others were not-shared: reviewing milestones, Clinical Criteria for Discharge (CCD) and Estimated Date of Discharge (EDD); Communicating with MDT and patients/carers; Use of patient quality and safety approach and checklists; Education	Key outcomes from WRs depend on goals Goals are not clearly specified and WR process not clearly documented Goals not clear in relation to patient flow and use of CCD and EDD Senior clinical decision maker not seeing all patients by 12 noon Lack of data on the time and resources spent on 'safari' WRs	Complex process for consultant of reviewing all data on patient—updates from intern/senior house office (SHO)/Reg; from nursing and Health and Social Care Professional (HSPC) notes on Electronic Patient Record (EPR); from diagnostic results and discussion with patient Feedforward from WR process into EPR but not always communicated directly to nursing/HSCP staff who may need to action care plan in timely manner
Process	Consultants would like to model how they would like WRs to be conducted, what type of information they feel is important to review Variation in levels of collaboration and communication across disciplines at pre-WR MDT meetings	'Safari' WRs take place—lasting up to 7 hours Variation in practice around WRs, pre-WR activities Variation in application of evidence-based practice guidelines for WRs (e.g. carrying out quality and patient safety checklists)	Not clear about what data and indicators are used to assess effectiveness of WR Overall measures (outcome, process, balancing) of Value of WR?	Each discipline **makes sense of situation from their perspective**; at pre-WR MDT notes are recorded separately Lack of opportunity/time for detailed sensemaking across professions; notes written in EPR but then not necessarily reviewed by other disciplines in timely manner

(continued)

Table 2 (continued)

	Culture	Functional system	Action	Sensemaking
Social relations/ team	Intra-disciplinary team: some consultants engaged in teaching medical colleagues; SHOs/Reg noted it was extremely important part of their education to verify their clinical decision making **Inter-disciplinary team**: tension over who was/was not present on WR; how info shared pre-WR and decisions shared post-WR Patient and their family not always seen as part of the team	Some, not all, WRs are Consultant led Great intra-disciplinary team working displayed Not clear on how all pre-WR activities (e.g. nursing WR; MDT meetings feed into medical WR) Co-ordination and communication across disciplines unclear	Roles, responsibilities and relationships not always understood Not clear about how the quality of collaboration is measured (e.g. query re data on timeliness of decisions make on WR and prescription changes getting enacted)	Lack of current evidence based practice (EBP) guidelines in relation to leadership and collaboration on WRs Clarity on how and where accountability for care progression in relation to WRs outlined Clarity on SDM with patients and their families/carers
Information and knowledge flow; technology	There is a shared understanding of tasks to be completed, from using EPR within disciplines Patients and their families/ carers not always given adequate time/notice to prepare for WRs Variation in how patient/ family information accessed	Flow of information through EPR; assumption that others will check EPR; lack of closed loop communication Lack of interoperability between EPRs in different parts of the system WOWs in place; differences in whether teams used them Processes for documenting shared MDT decision making could be improved	EPR has greatly improved legibility of notes Not all support functionality in EPR utilised—doctors notes; messaging/ communication tools **Not clear on what measures used** or what they indicate about how information is accessed, transformed or deployed	Each team knows and understands care plan from their perspective WRs are seen an essential tool for educating medical teams especially around clinical decision making Not clear whether there is shared understanding of timeliness of action in EPR

5 Conclusions

This initial STSA has informed our understanding of current WR practices and processes. The richness of STSA is taking a systems perspective to view an issue. This also allows us to understand and appreciate the complexity of the problem. WRs are a pivotal daily process and yet we do not agree on their purpose or fully understand their impact on patient outcomes. Reforming how we care for patients requiring unscheduled care in the acute hospital setting is a healthcare priority (HSE 2021). Given the resources required by WRs and the pivotal role they play, improving WRs will significantly contribute to this reform.

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Patient Vehicle Extrication at the Entry Door of an Emergency Care: An Analysis of Nursing Activity

Angélica Garcia Juns and Clarissa Simões Moreira da Silva

Abstract The research was carried out in the Emergency Room of a private hospital in the city of São Paulo, Brazil. This addressed the activity of mobilizing and removing patients from inside the car, when they arrive at the service. The nursing team presented complaints regarding the lack of standardization and institutional guidelines for practice, which support safety and injury prevention for patients and professionals. The study then sought to carry out an evaluation of the nursing work activity in the vehicular extrication of the patient to identify conditions of the activity, barriers, facilitators and variability. The methodology was an exploratory study with the application of a questionnaire to approach and analyze the characteristics of the population and the vision of the nursing professionals, in complementarity with a structured guided observation of the simulation of the activity by 4 different work teams. As a result, a description of the activities was obtained concerning to: the principle of scene safety, classification of severity according to the patient's assessment, the postures and positioning of the professional's body and the use of equipment. The reflection on this theme points to the need for the development of institutional training and care flows, mentioned as being of importance by the professionals participating in the activity. As a conclusion, it was possible, through concrete data, to dialogue in order to seek new options for modes of operation, as well as to promote future comparisons with other reference centers in the world.

Keywords Vehicle extrication · Emergency nursing · Patient safety · Ergonomics

A. G. Juns (✉)
Syrian-Lebanese Hospital, São Paulo, Brazil
e-mail: angelica.gjuns@hsl.org.br

C. S. M. da Silva
Mobile Emergency Care Service (SAMU), São Paulo, Brazil

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1 Background

The study was developed at the Charitable Association of Ladies Syrian-Libanese Hospital, a private philanthropic hospital, an international reference in health. Specifically at the Emergency Room (ER), located at the Bela Vista Unit, central region of São Paulo in November 2021. This took place as a conclusion work for a Nursing Residency, motivated by complaints from the hospital's ER nursing team, regarding the lack of standardization and institutional guidelines for the practice of mobilization and removal of patients from cars. These mobilizations are required by the patient's reduced mobility demand or even due to the urgency or emergency character characteristic of the profile of the entrance doors of Emergency Care. It was understood that the recognition of barriers and facilitators, the description of the activity as it already happens, would be a primary condition for the discussion of safety and health risks for the patient and for the nursing professionals. Also, given that the existence of flows and protocols contributes to greater visibility of the profession by demonstrating the scientific bases of its care (Sales et al. 2018), this study is understood of relevance for the quality and safety of care in this specific activity of Emergency Services. Therefore, the study aimed to:

(a) Describe the activity to support information for discussion of ergonomic conditions favorable and unfavorable to patient and worker safety;
(b) Describe the current standards of action to support future developments of safe protocols for Nursing Care in the Patient's Vehicular Extrication.

2 Methodology

The study carried out had a quantitative–qualitative approach, an option arising from the need to use exploratory approaches to collect data from a working population with the necessary complementarity to understand the work activity and professional practices.

The application of a Questionnaire was managed through the Research Electronic Data Capture (REDCap) platform and made available to the 161 nursing professionals of the service, and was answered by 75. This was prepared based on the researchers' previous knowledge about the task and in questions of approximation with the theme, having been composed of 12 questions divided into three thematic axes: the first allows characterizing the workers participating in the study; the second extends on the approach of workers with the activity of extrication; and finally the last block is intended to collect data on the perceptions and perspective for the development of the extrication activity.

Descriptive statistical analysis was performed using some summary measures such as absolute and relative frequencies (percentage). Data were entered into Excel 2010 for Windows spreadsheets for adequate information storage and the statistical program used was IBM-SPSS Statistics version 24.

Simulation, as a strategy to approach the activity, became necessary, replacing the observation of the real activity, since this activity is unpredictable and eventual, for not being a routine and not admitting to predict its occurrence to observe scientifically.

The objectives of the simulation were to better analyze the following aspects of the activity:

- Potential risks to patient and worker safety;
- Ergonomic conditions of the activity;
- Knowledge and use of techniques, equipment and human resources for patient care;
- Behavioral skills in the work environment;
- Variability in patient care processes.

The scenario was aligned with the sector's leadership and it was agreed to carry out a simulation for each of the four existing teams in the ER, one for each work shift, totaling 4 Simulations, with an average duration of 6 min each. It was performed by two actors, one playing the patient (an elderly woman who fell at home, hit her head and feels intense pain in her hip and right leg). Each simulation was planned and conducted by the researchers, who only acted as observers during the activity, without interacting with the participants. Only after closing, everyone interacted in a debriefing, for approximately 10 min, guided by a Guide to help the discussion, according to the objectives of the scenario and good practices in realistic simulation (INACSL 2016).

The Guided Observation Script of the simulation scenario was filled in by one of the researchers, during observation of the simulation, on paper on a clipboard. The other researcher performed filming and simple observation. The construction of the Guided Observation Guide was based on protocols expected from the pre-hospital care procedures found in the literature (Brasil 2016).

3 Survey Results

For the surveys, an initial response rate of 75 respondents was obtained. After applying the exclusion criteria, 3 were removed for incorrectly filling in and 5 for never having actively participated in the vehicular extrication activity, in the end, obtaining a total of 67 viable questionnaires.

Initially, the survey results help to understand the profile of the professionals who perform the activity, in relation to the profession, level of education and length of service in the researched hospital.

The study included 31 (46.3%) Nurses, 35 (52.2%) Nursing Technicians and 1 (1.5%) Nursing Assistant, expressed in the following Positions in the Syrian-Lebanese Emergency Department (Table 1).

In Table 2, it can be seen that the average level of education among the participants was 39 (58.2%) Graduates in Nursing, among them, 34 (50.7%) with Graduate Studies and 28 (41.8%) professionals with a Technical Course in Nursing.

Table 1 Characterization of professionals with experience in extrication, 2021

Role	n	%
Nursing Assistant	1	1.5
Nursing technician	35	52.2
Nurse JR	5	7.5
Nurse PL	24	35.8
Nurse SR	2	3.0

Table 2 Professionals' education level

Education level	n	%
Technical course	28	41.8
University education	5	7.5
Postgraduate studies	34	50.7

Regarding the time of work in that ER, there was 6 (9.0%) professionals with less than 1 year of work, 30 (44.8%) professionals with 1–5 years of work, and 31 (46.3%) with more than 5 years of experience in the Syrian-Lebanese Emergency Service, as shown in the Table 3.

Then, seeking an approximation with the experience of these professionals with this activity, the results show the frequency of participation in a patient removal from a vehicle in the last 6 months, the number of professionals who usually perform together, the composition of the teams, their ways to organize themselves collectively, who usually leads patient care and which patients' illnesses they take out of the car.

Regarding the number of times that each professional actively participated in the removal of a patient from a car (private car, taxi/application) at the Entrance Door of the Syrian-Lebanese Emergency Room in the last 6 months, the following result was obtained (Table 4).

Table 3 Working time in the Syrian-Lebanese emergency department

Working time	n	%
Less than 1 year	6	9.0
From 1 to 2 years	7	10.4
From 2 to 5 years	23	34.3
More than 5 years	31	46.3

Table 4 How many times participated in this activity in the last 6 months

Times participated in an extrication in the last 6 months	n	%
1 to 5 times	21	31.3
6 to 10 times	11	16.4
More than 10 times	35	52.2

Table 5 Number of professionals collaborating in the activity

Number of professionals	n	%
1	1	1.5
2	29	43.3
3	14	20.9
4	1	1.5
More than 4	22	32.8

The number of professionals habitually actively collaborating to remove a patient from a car was predominantly identified as: 2, 3 or more than 4 professionals (Table 5).

Regarding which professionals most commonly actively participate in removing a patient from the car, all identified the Nursing Technician as a participant, 82.1% (55) also identified the nurse and 37.3% (25) included the family member/companion of the patient. The other professionals represent less than 15% of the respondents (Table 6).

The predominant professional identified as the leader in the activity of removing the patient from the car (private car, taxi/application) visualized at the Entrance Door of the ER was for 50.7% (34) of the professionals the Nursing Technician and for 43.3% (29) the Nurse (Table 7).

Among the clinical situations of patients who require removal of the car, the conditions of the "Fragile elderly person dependent on assistance for mobilization"

Table 6 People who regularly collaborate

Role	n	%
Gateway security	9	13.4
Concierge	3	4.5
Administrative	0	0
Nursing technician	67	100.0
Nurse	55	82.1
Physician	1	1.5
Receptionist	3	4.5
Relatives/companions	25	37.3
Taxi/app drivers	6	9.0
Others	2	3.0

Table 7 The predominant professional identified as the leader in the activity

Leader	n	%
Nurse	29	43.3
Relatives/companions	4	6.0
Nursing technician	34	50.7

were identified as predominant, with 92.5% (62), followed by the "Patient with movement restriction or motor disability", with 85.1% (57), and the "Patient with a report of disabling referred pain", with 74.6% (50) (Table 8).

Finally, the questionnaire brings the perceptions and perspectives of these professionals, regarding which factors they consider relevant for the safety of the activity and which improvements they believe are necessary for better performance and safety in carrying out the activity.

The ER professionals evaluated as criteria of evaluative importance in the safe development of the activity of removing the patient from the car (Table 9).

Regarding what they perceive as a necessary improvement for the development of the activity, 88.1% (59) indicate a desire to have more Institutional Training (Table 10).

Table 8 Clinical situations most identified in patients

Clinical situations	n	%
Patient in cardiopulmonary arrest	31	46.3
Unconscious patient	43	64.2
Patient with movement restriction or motor impairment	57	85.1
Patient with a report of fall or trauma	46	68.7
Patient with a seizure report	41	61.2
Patient with report of disabling referred pain	50	74.6
Frail elderly dependent on assistance for mobilization	62	92.5
Others	5	7.5

Table 9 Criteria of evaluation for safety

Criteria	n	%
Patient severity	57	85.1
Correct posture to perform the activity	51	76.1
Use of assistive equipment (board, sliding sheet, etc.)	45	67.2
Others	4	6.0

Table 10 Perspective of improving the practice of this activity

What to improve	n	%
No improvement is needed	2	3.0
Use of assistive equipment (board, sliding sheet, etc.)	29	43.3
Institutional training (simulations, workshops, etc.)	59	88.1
Service flow	31	46.3
Others	1	1.5

4 Simulation Results

In all the simulations it was evidenced that the first professional to approach the patient and/or family member, asking about the need for help to get out of the car at the entrance of the ER was the Security professional. As soon as the patient's family member requested assistance, he activated the flow "Help at the ER Gateway".

In all simulations, the patient was informed and guided by the respective professionals about the mobilization actions and conduct of the teams. In most of the simulations, the adoption of body biomechanics of the professionals suitable for patient movement and the use of assistance equipment was evidenced (Table 11).

However, in all of them, body movements with inadequate biomechanics were also evidenced, predominantly related to the adoption of spine flexion instead of hip and leg flexion, for reaching movements in areas below the trunk and for lifting the patient's lever.

It is observed that the low work plane, for visual access and manual reach to the patient, requires professionals to bend the body (Figs. 1, 2, 3, 4 and 5).

Regarding the scene safety assessment, only in Simulation S1(N) it was evident that actions in favor of scene safety occurred, carried out by the main nursing technician. The professional paid attention to the actors' information before touching the vehicle and investigating the vehicle's condition by turning off and removing the ignition key followed by applying the parking brake to ensure a safe approach.

On the other hand, in the other simulations S2(D), S3(N), S4(D) the general situation of the vehicle was not observed nor the information from the actors was heard before approaching the victim and the vehicle.

In the simulations S1(N) and S4(D) the primary assessment of the patient was evident, in both performed by nurses, considering that in S4(D) the assessment was carried out by the professional with the position of nurse in the institution together with the professional with the position of nursing technician, who, however, has a degree in nursing. At the same time in the simulations S2(D) and S3(N) it was not at all evident that a primary assessment of the patient had taken place, as shown in Table 12.

Table 11 Simulation: ergonomics and use of assistive equipment

Simulation	Adoption of proper biomechanics	Assistive equipment
S1(N)	Nothing evident	Backboard stretcher + stretcher
S2(D)	Something evident	Wheelchair
S3(N)	Something evident	Wheelchair
S4(D)	Something evident	Backboard stretcher + stretcher

Fig. 1 S1(N) nurse and nursing technician reaching the patient inside of the car

Fig. 2 S2(D) nursing technicians moving patient from the car to the wheelchair

At none of the simulations was evidenced the explanation of the primary assessment XABCDE mnemonic suggested by Advanced Trauma Life Support (ATLS) (American College of Surgeons 2013) or similar. However, the primary evaluation was empirically demonstrated to the visualization of the patient lucid, oriented, communicative, without bleeding or apparent fractures by the professionals of the simulations S1(N) and S4(D) who still verbalized aloud the investigation of the trauma scene in the residence and the possible injuries that affected the victim. While

Fig. 3 S3(N) nursing technician reaching the patient inside of the car

Fig. 4 S3(N) nursing technician moving patient from the car to the wheelchair

Fig. 5 S4(D) Nursing professionals moving patient with the stretcher

Table 12 Simulação: Avaliação Primária do Paciente

Simulation	Primary assessment of the patient	Professional
S1(N)	Something evident	Nurse
S2(D)	Nothing evident	Not applicable
S3(N)	Nothing evident	Not applicable
S4(D)	Something evident	Nurse + nursing technician

the professionals of the S2(D) and S3(N) simulations only asked what happened and if the victim would be able to get out of the car alone.

The evidence of effective communication and consensus on the activity reaffirmed the findings regarding the aforementioned leadership role: in simulations S1(N), S3(N) and S4(D) "Very evident" and in simulation S2(D) "Nothing evident" verified in the Table 13.

Table 13 Simulation: effective communication and consensus on the activity

Simulation	Effective communication	Consensus on the activity
S1(N)	Very evident	Very evident
S2(D)	Nothing evident	Nothing evident
S3(N)	Very evident	Very evident
S4(D)	Very evident	Very evident

In simulations S1(N) and S3(N) and S4(D) there was clear verbal guidance from their respective leaders or consensus decisions of the teams observed in the face of a harmony of those performed. On the other hand, in simulation S2(D) there was no conversation about the movement to be performed. The nursing technician requested as more experienced assumed and just proceeded without sharing the behaviors with the other members.

5 Discussion

The approximation of professionals with the extrication activity, verified in the survey results, showed that the activity was performed more than ten times in the last semester by at least 52% of nursing professionals from the Sírio-Libanês ER, which demonstrates that the activity is not performed habitually by all, but is present in a moderate frequency for the routine of most professionals. Furthermore, the nursing technician was identified as the performer of the activity by all respondents, followed by the nurse by 82.1% and the family members/companions by 37.3%, identifying the main composition of the extrication team with these three different actors.

It was possible to measure the number of professionals indicated for habitually collaborating in the activity, 43.3% in pairs and 32.8% succeeding with more than four professionals. Notwithstanding what was measured, the extrication activities in the simulated performed demonstrated the active collaboration of at least three professionals, at least two from the health area and one as a security guard who participates without direct interaction with the patient, but minimally provides and stabilizes the instrument to help the nursing professional. Thus, it was observed that the activity demands at least two professionals and the composition is variable, according to the availability of professionals at the time of the occurrence.

According to the respondents of the questionnaire and, as verified in the simulations, both the nursing technician and the nurse actively participated in customer service. The leadership was assumed by a professional with the position of Nurse only in S1(N), however in S4(D) the leader with the position of nursing technician also has a degree as a nurse, and thus it was considered that in two simulations the professional nurse assumed scene leadership. This variability in team composition and leadership by professional nurses directly influenced the approach to the scene, in relation to the assessment of the patient and, consequently, the mobilization technique adopted.

Patient safety is directly related to employee safety. The choice of mobilization technique based on the patient's assessment guarantees patient safety, as well as determining the ideal equipment for the situation, using techniques that prioritize height adjustment and proper positioning; favoring the professional to optimize their body movements and reduce the effort necessary for the execution, which provides greater safety for the patient, preventing falls.

The state of the art of pre-hospital care, for more than 50 years, has been employing the use of a cervical collar and backboard stretchers (with the use of head immobilizers and straps) during extrication, transport and transfer of the patient to the hospital bed, with the justification of the use of this apparatus on the principle that maintaining the spine in a neutral position avoids secondary neurological injuries caused by its instability throughout the process (Brasil 2019). That said, as referenced in the simulations with the presence of the nurse, the method of patient mobilization using the backboard stretcher and stretcher was identified, and in the simulations without nurses the use of a wheelchair was adopted. The conduct performed by nurses corroborates current protocols that recognize the suspicion or criteria for performing restriction of spine movement in blunt trauma in adults: age over 65 years; the sharply altered level of consciousness; the presence of a dangerous mechanism (kinematics); circumstances or injuries that cause distraction (fractures of long bones, extensive burns, etc.) or that reduce the patient's ability to contribute to a reliable examination; focal neurological signs (sensory and motor signs and symptoms); among others, as well as the use of the backboard stretcher only for the extrication function (Brasil 2019).

The choice of posture adopted by the professional proved to be influenced by several variables: the patient's position, the patient's criticality, the model of the car, the opening of the door, the number of people in the scene, etc. The notion that postural care, with body awareness, is the only criterion for defining the ergonomic condition of patient movement is refuted here, while the bodily constraints imposed by the environment (car) are unfavorable for this. However, the adoption of body biomechanics more favorable to the protection of the professional's spine, considering the use of lower limbs, abdomen and hip muscles, is also evident as a practice that is little adopted. Thus, in the result of the questionnaire that shows that most professionals understand that a "correct posture to perform the activity" is an important evaluation criterion for the safety of this activity, it is demonstrated that they are clear about the need to adopt, but, as evidenced in the simulations, they do not know how to perform correct postures (protective for the spine) for the activity.

Although there is no evidence in the literature that suggests a "golden rule" for the extrication activity when it occurs at the entrance door of an ER, the results of this word, in a succinct manner, brings some aspects to be taken into account when performing the activity. Some of them are: the scene safety principle, classification of severity according to the patient's assessment, and the postures and positioning of the professional's body, as well as body biomechanics and the use of equipment, for the elaboration of institutional training and care flows, mentioned as of evaluative importance by the professionals participating in the activity.

6 Conclusions

The innovative character of the present study is related to the analysis of the activity, from the perspective of the worker's experience. Through a better approximation with what has been done, by recognizing the variability of professional practice, it is possible to dialogue in order to seek new options for operating modes, as well as to promote future comparisons with other reference centers in Brazil.

Finally, it is suggested to investigate the extrication activity at the door of the AP with so many different critical conditions presented by the patients. It is also suggested that this entire process be evaluated, as the answer to increasingly apparent questions has not been exhausted, such as the formalization of activity procedures at the door of the ER.

Thus, we will continue to be driven by the desire to innovate, in a sustained way, professional nursing practices, in order to guarantee technical and scientific competence in the execution, structure and process of the activity of extrication of patients at the entrance door of the ER of organizations of health.

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Design Towards a More Sustainable Healthcare System

Towards Greener ICUs: Redesigning the Use of Disposable Gloves

Lisanne van den Berg, Armağan Albayrak, Nicole Hunfeld, and Jan Carel Diehl

Abstract This research and design project is part of the Green ICU initiative and focused on reducing the environmental impact of gloves at the Intensive Care Unit (ICU) of the Erasmus Medical Center (EMC). At the ICU of the EMC around 108 gloves are used per patient per day; to protect the user (healthcare staff) from infections. The high frequency of use and the resource-intensive production define disposable nitrile gloves as one of the 'hotspots' contributing to the environmental impact created by the ICU. This research and design project addressed the problem from three different perspectives: user-centred, product-centred and supply-centred. The extensive research resulted in three design directions on how to reduce the environmental impact of gloves. Subsequently, all insights from the research were brought together into five design building blocks. These design building blocks provided guidance for the design phase of the project. The project resulted in a redesign of the current glove dispensers. The final design is named 'GloVe', a vertical dispense system. By incorporating the five building blocks, the design can provide benefits for multiple stakeholders within the healthcare system. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are dispensed at the cuff, which comes in little contact with the patient. The vertical movement is pleasant to the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. Also, nurses will see at a glance, which size gloves they are dispensing. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible.

Keywords Design for sustainability · Gloves · User-centred · Medisign · Infection prevention · Intensive care unit

L. van den Berg (✉) · A. Albayrak · J. C. Diehl
Delft University of Technology, Delft, The Netherlands

N. Hunfeld
Erasmus Medical Center, Rotterdam, The Netherlands

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1 Background

The healthcare sector provides us access to high-quality care but is also responsible for a severe environmental impact. Currently, the healthcare sector is one of the most carbon-intensive sectors, contributing to 4.4% of global net greenhouse gas emissions and toxic air pollutants (Karliner et al. 2020). In the Netherlands, even 7% of the national footprint is associated with the healthcare sector (De Bruin et al. 2019). The complexity and intensity of care make the ICU one of the most resource-intensive departments of the hospital. Products such as syringes, liquid solutions, dressings, catheters, and personal protective equipment are used in fast quantities to treat patients and save lives (Browne-Wilkinson et al. 2021).

Disposable gloves are used as Personal Protective Equipment (PPE); to protect the user from contamination and radiation and are used for nonsterile activities. The high frequency of use, around 108 gloves per patient per day, and resource-intensive production identified disposable gloves as one of the five hotspots contributing to the negative environmental impact created by the ICU (Browne-Wilkinson et al. 2021). The aggregated weight makes up more than 12% of disposable medical devices' ICU weight. Furthermore, nitrile is highlighted as the material with the highest impact intensity, in the single-use medical devices category, in terms of carbon footprint (9.3 kg CO2-eq/kg nitrile) and water usage (0.5 m^3 water/kg nitrile) (Browne-Wilkinson et al. 2021). Therefore, the main question to be answered during this project was: *How could the environmental impact of gloves in the ICU be reduced, while remaining quality of care?*

2 Methodology

A design thinking process as visualized in Fig. 1 was followed to answer this question. The project has a non-linear approach and the steps contribute to each other.

Research is executed from three different perspectives: a user perspective, a product perspective and a supply chain perspective.

2.1 User-Centred Research

User observation. The observation aimed to understand and interpret the behaviour of the ICU staff during their work shift. The ICU context was entered without certain expectations. To execute the observation, the role of "participant as an observer" was taken on (Mulhall 2003).

Participant as observer. This role was taken on when following one of the ICU nurses for a complete work shift. The focus was on applying hand hygiene and using/

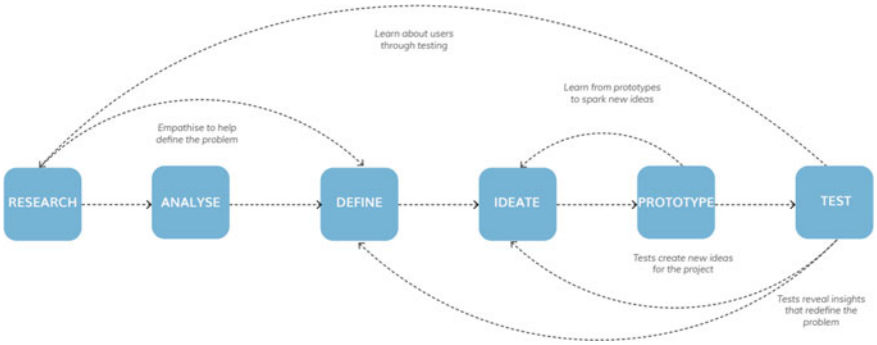

Fig. 1 Adapted model of the design thinking approach (*Source* Interaction Design Foundation Baeck and Gremett 2012)

changing and disposing of the gloves. The ICU nurse was asked to think out loud during her activities.

Product centred research. The goal of this observation was to follow the product through the Intensive Care Unit. For this observation another role was taken on;

Complete observer. This role was mainly adopted when sitting in the ward of the ICU on the fourth floor. It was observed how the different stakeholders distributed, used and disposed of the gloves and glove boxes. The routes were drawn on a floor plan. When an action or role was not clear it was asked after their activity.

Product analysis. The product was analyzed on variables. The dimensions of the box and opening were measured. To test the functionality of the product, gloves were taken out one by one.

2.2 Supply Centred Research

Expert interview. An experienced employee of the procurement team of the Erasmus MC was interviewed. A structured interview was used to answer questions about quantities and the market of gloves.

PICU waste observation. The previously obtained quantities from the Material Flow Analysis from Metabolic by Browne-Wilkinson, et al. (2021) at the ICU did not mention anything about the extent to which these gloves were used. The Paediatric Intensive Care UNIT (PICU) waste observation was done to map the waste created by this department. It was also used to define the ratio between used and unused products in the waste disposal.

3 Results

Product Analysis. The product analysis resulted in a photo series where the gloves were dispensed step by step (see Fig. 2) The gloves are packed so tightly and intertwined that it is almost impossible to remove one glove at a time.

Material Flow model. The Material Flow indicates how many gloves are used in the ICU compared to the bigger context, see Fig. 3. The number of gloves used in the ICU is relatively small compared to the worldwide production and distribution. Despite this, it can be seen that some of the gloves in the ICU are disposed unused. During the PICU waste observation, the number of unused gloves was determined to be 6% of the total used gloves. However, it was not possible to tell whether the gloves had been used properly, whether they had been used unnecessarily or whether they were overused.

3.1 Hospital Flow Model

The Hospital Flow model zooms in on two ICU rooms, see Fig. 4. The care assistant distributes the gloves in the ICU. The nurses and other medical staff use gloves. The care assistant will dispose of the gloves and waste workers collect the waste. The following problem situations do occur:

- The glove dispenser at the back corner is difficult to reach (position of dispenser).
- During care, a lot of unexpected materials are needed. The nurse should have bare hands when picking something from the storage on the counter. So, it is needed to take off the gloves (use protocols).
- The order of the sizes is not clear for every care assistant. Furthermore, it is difficult to read the size of the gloves on the box (not clear which size is in which box).

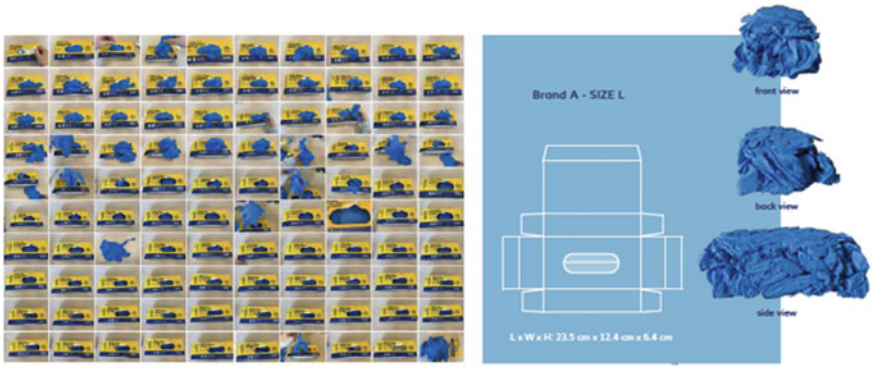

Fig. 2 Results of the glove box product analysis

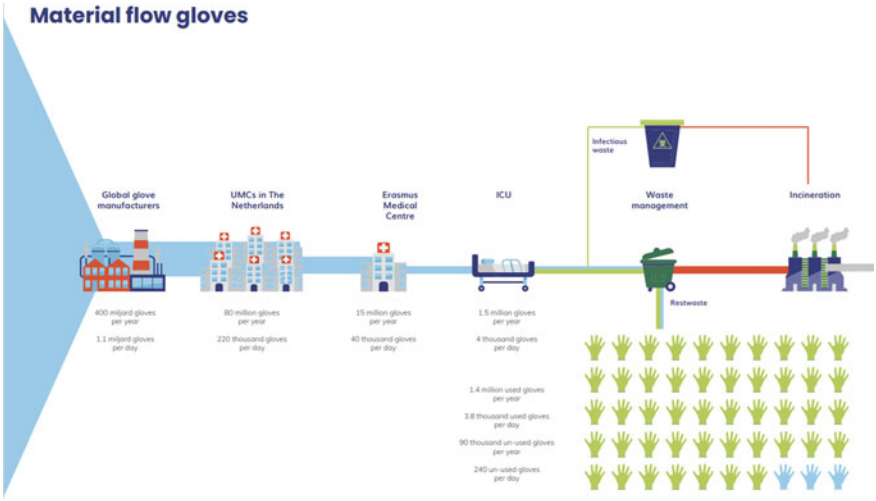

Fig. 3 Material flow model gloves

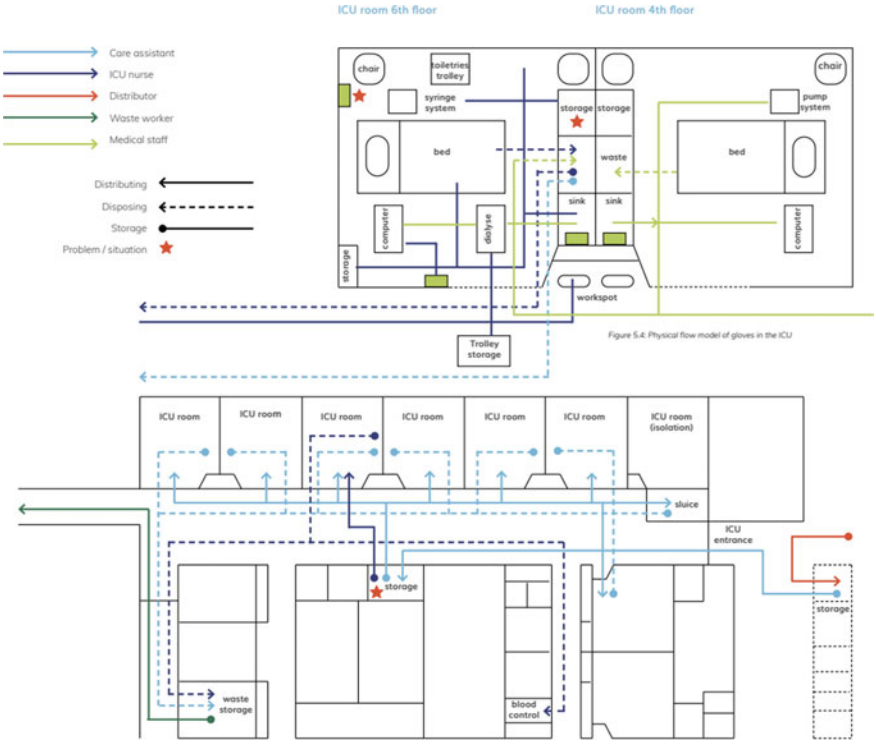

Fig. 4 Hospital Flow model gloves

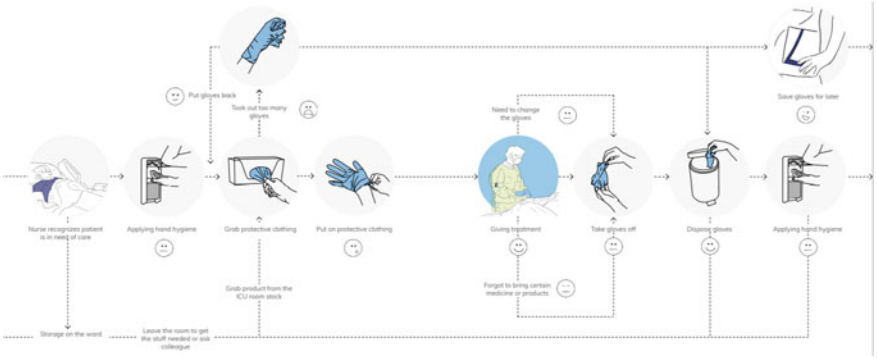

Fig. 5 User journey of ICU nurse using gloves

3.2 User Journey

The user journey illustrates the activities and tasks performed while interacting with the product, see Fig. 5.

The field research including observations and interviews gave an understanding of different perspectives and system levels. The main insights can be listed and divided into three design directions. The design directions are substantiated by the drivers.

1. Rethink the (unnecessary) use
2. Reduce the number of unused gloves
3. Reduce the number of glove changes.

In consultation with the ICU staff, it was decided to reduce the number of unused gloves in the design part of the project.

3.3 Building Blocks for Design

The different steps of the research and design process resulted in a better understanding of the problem. The sustainability impact of disposable gloves is a difficult problem. Various properties and factors are intertwined. Also, the stakeholders have different interests in a new design. Altogether, 12 main insights were listed, divided into five building blocks that should be incorporated into the new design.

3.4 Ease of Use

- **Sizes should be visible:** Both the ICU nurse and care assistants would like to see at a glance which size of gloves a box contains. Having difficulties reading the

size or placing the box into the wrong holder can result in dispensing the gloves in the wrong size.
- **Fixed place:** The glove boxes should have a fixed place. The order of the sizes must always be the same.
- **Ready to use:** When a glove comes out of the package, it should be ready to use right away. It should not be necessary to unfold the glove first.

3.5 Infection Prevention

- **Touch only one glove at a time:** Contamination of gloves can be prevented if only the glove that will be used is touched. Also, only one glove should be opened to the environment.
- **Dispense by the cuff:** The fingers and the middle part of the glove are mostly in contact with the patient. Therefore, it is preferred to dispense the gloves, by touching the cuff. The cuff is less in contact with the patient.
- **Prevent undesirable behaviour:** It is unwanted that gloves are pushed back into a package. The opening in the current glove boxes is big enough to place gloves back. Contamination of gloves can be reduced when this undesirable behaviour is prevented.
- **Cleanable:** Hygiene is an important topic in the ICU. The patients in the ICU often have a malfunctioning immune system and infections can be life-threatening. That is why the design must be cleanable.

3.6 Zero Risk

- **Procurement:** Because the functioning of the hospital is of vital importance, a zero-risk approach is applied in the hospital. This also applies to buying gloves. In the current high-demand market, it is not beneficial to be dependent on one supplier. This should certainly be included in the solution.

3.7 Technology

- **Manufacturing in Malaysia:** Gloves are currently produced in Malaysia. The factories are producing at full capacity. Setting up and or changing a glove factory is a big investment. It would be beneficial if the solution could be made in with the technologies available in the current factories.

3.8 *Efficiency*

- **Time;** Many gloves are used every day in the ICU. The design should not require more time from the users.
- **Quality:** Quality over quantity. Presenting gloves of good quality is important for the user. Also from a sustainable perspective, good quality gloves can reduce the number of gloves used. Bad quality gloves need to be changed more often or are overused.
- **Space:** The ICU boxes have limited space for a lot of equipment and supplies. The product must deal well with the available space.

3.9 *Final Design*

The final design is GloVe, a vertical dispense system. By incorporating the five building blocks, the design can provide benefits for multiple stakeholders. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are dispensed at the cuff, which comes in little contact with the patient. The vertical movement is pleasant to the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. Also, nurses will see at a glance, which size gloves they are dispensing. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible (Fig. 6).

Fig. 6 Final design GloVe

4 Discussion

This project was focused on the research phase of the design process. There was not much information available in the literature on sustainability-related issues of disposable gloves. Furthermore, there were no resources that combined information. Research with a broad scope was applied to investigate the problem from multiple perspectives and system levels. The research and prototyping phase revealed the complex and intertwining factors on the functioning of the product. The extensive research resulted in less time in the design phase. Having more time in the design phase or being closer to the manufacturing phase could have resulted in an even more detailed understanding of the physical factors influencing the functioning of the product; resistance, material properties etc. Furthermore, the scope of this project was to apply a product or system in the ICU in the short term. Since manufacturers are bound to the general shape of the product, this general shape was used as a basis for the design. Applying a completely different shape to the box can't be applied in the short term. But, letting go of the general shape of the box could have led to more inventive designs.

5 Conclusions

The main question to be answered during this project was: *How could the environmental impact of gloves in the ICU be reduced, while remaining quality of care?*

To answer this question, remote research was executed, fieldwork with different focuses was done, and concepts were developed into prototypes. The prototypes were evaluated with the ICU team. As the final step of the project, the GloVe dispensing system was designed.

The research on the existing state of the art of disposable gloves revealed paint points. The market for disposable gloves is a difficult one; only a few manufacturers are producing at maximum capacity for the high demand worldwide. Disposable gloves are produced in worrisome circumstances. More transparency on the production circumstances could influence the choice between alternatives.

The gloves are packed so tightly and intertwined that it is almost impossible to remove one glove at a time. Technologies to stack the gloves without intertwining are available. But, manufacturers are less likely to change the production process, due to the high demand on the market and the high investment costs.

The field research resulted in three design directions to reduce the environmental impact of the use of disposable gloves. Two out of three design directions are focused on human behaviour and protocols. ICU nurses need to do a lot of activities around the patient, which include the use of a lot of glove changes. Potentially, the number of glove changes can be decreased by changing the protocols. Furthermore, the research demonstrated that gloves are not always used as intended. Revising the protocols

and having sustainable alternatives for certain activities can decrease the number of gloves. Also, the field research showed that the product itself can be improved. The product dispenser does not function as desired and does not dispense the gloves one by one.

Because of an Integrated Product Design background, it was decided to reduce the number of unused gloves in the short term and focus on the glove box. The design building blocks provided a foundation for the design process. The concepts showed it is not possible to judge ideas based on just drawings. For this reason, prototyping and testing at the ICU with healthcare staff were used to evaluate the ideas. The prototyping and testing revealed even more complex factors behind the functioning of the product.

The final design is GloVe, a vertical dispensing system. It reduces the environmental impact of gloves in the ICU by dispensing one glove at a time. Furthermore, the gloves are touched at the non-critical part, at the cuff. The vertical dispensing movement is pleasant for the user. The use of colour for different sizes makes it clear to the care assistant which box should go in which holder. The small V-shaped opening makes the undesirable behaviour, of placing gloves back, almost impossible.

All in all, there is not one way to answer the main question. The research with different perspectives on the product of a disposable glove box revealed overall intertwined complexity. Answering the question and creating a solution is challenging, since the different stages of the product, production, purchasing and use, are so far apart and do influence each other. The research showed the importance of including the user (and other stakeholders) in the design- and procurement process.

The design project was not a linear process, but with this project, the complex problem could be defined better. Resulting in a concept design and a lot of recommendations to transform towards a greener ICU.

The final report of this research (Berg 2022) can be found at https://repository.tudelft.nl/islandora/object/uuid%3A1732b9db-6795-4990-ae56-c02fb6d7c81a?collection=education.

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Reducing the Environmental Impact of Syringes at the Intensive Care Unit

Margot Honkoop, Armagan Albayrak, Ruud Balkenende, Nicole Hunfeld, and Jan Carel Diehl

Abstract This research project, part of the Green Intensive Care Unit (ICU) initiative at the Erasmus University Medical Center (EMC), is focused on reducing the environmental impact of syringes at the ICU by designing solutions based on circular economy principles. Based on a Material Flow Analysis of the EMC ICU, syringes and their packaging have been identified as one of the main environmental impact hotspots. Therefore, this project aimed to redesign the syringes, their packaging, and their use, according to circular design strategies suitable for medical products to decrease their environmental impact, while remaining convenient and safe in use for the healthcare staff and patients. Research was executed to understand the context from multiple perspectives. The outcomes demonstrated that decreasing the impact of syringes is not only related to the design of the syringe itself. Manufacturing, preparation, use and disposal, all contribute to the environmental impact of the syringe. Various possible interventions were derived to reduce its impact:

1. Adapting the infection prevention protocol and behaviour of the staff;
2. Separating infectious waste from general hospital waste;
3. Redesigning the syringe itself;
4. Optimising the filling process of syringes.

The final design is an optimised filling process for prefilled sterilised syringes (PFSs), based on circular strategies such as reduce, reuse, rethink and repurpose. Interventions include: eliminating a redundant sterilisation phase, reducing residual medication and changing from steam to gamma sterilisation. This resulted in decreasing the amount of waste, material, energy and water consumption, while offering similar convenience and safety for the staff and patients of the ICU.

Keywords Circular healthcare · Syringe · Environmental impact · Design

M. Honkoop (✉) · A. Albayrak · R. Balkenende
Delft University of Technology, Delft, The Netherlands
e-mail: margothonkoop@hotmail.com

N. Hunfeld · J. C. Diehl
Erasmus University Medical Center, Rotterdam, The Netherlands
e-mail: J.C.Diehl@tudelft.nl

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1 Background

The healthcare sector has a high environmental impact, contributing to 4.4% of the global net greenhouse gas emissions and toxic air pollutants (Karliner et al. 2020). In the Netherlands, 5.9% of the national ecological footprint is associated with the healthcare sector. The majority (71%) of these emissions come from the production, use, transport, and disposal of medical products used in the hospital (Browne-Wilkinson et al. 2021). Single-use and disposable products are commonly used in the healthcare sector as a procedure to reduce (cross-)infections and have resulted in better health outcomes (Kane et al. 2017).

The ICU of EMC produces an excessive amount of waste. In the existing situation, to a large extent, the products used are disposables. After one time use, they are disposed of and incinerated. The current state of the ICU is therefore not sustainable nor circular since it is based on single-use devices, disposables, and a linear economy. The reason for this is the fact that safety, sterility, and infection prevention have been prioritised above sustainability.

Based upon the Material Flow Analysis (MFA) of the ICU at EMC, syringes and their packaging have been defined as an environmental impact hotspot. Meaning that it is a product group causing significant environmental impacts, due to the product properties, extensive use (24 syringes per patient per day), and the fact that it is a single-use disposable product (Browne-Wilkinson et al. 2021). The syringes (50 ml) are used to administer medication to the patient. They are connected to the patient via an extension line and placed in an infusion pump for automated administration of the fluid. After single-use, the syringe is disposed of. Some syringes are even disposed of unused, due to limited shelf life or due to the infection prevention protocol. Furthermore, the syringe is an assembly of components made of different materials (polypropylene (PP) and bromobutyl). The packaging, to keep the syringe sterile, is made of a laminate of two plastic (namely polyamide 6 (PA6) and low-density polyethylene (LDPE)) which is hard to separate at the disposal stage (for recycling). This packaging laminate contributes significantly to the carbon footprint of the syringe.

The main underlying problem of the relatively high environmental impact of syringes is that the current life cycle is "linear". The impact at the end-of-life of a syringe and its packaging has not been taken into account in the design. This results in syringes being used only once (or not even), disposed of afterwards and being incinerated. To limit the amount of waste and reduce the use of natural resources, the current linear system needs to be transformed into a "circular" one (Ellen MacArthur Foundation 2019). Design can play an important role here, since designing products from a circular economy perspective prevents the production of waste and pollution in the first place. The materials and products used can be designed to be circulated back into the loop instead of ending up in incineration.

Therefore, this project aimed to redesign the syringes, their packaging, and their use, according to circular design strategies suitable for medical products to decrease

their environmental impact. Precondition is the fact that the use of syringes should remain convenient and safe for the healthcare staff and patients.

2 Methodology

The research project is divided into four phases: discover (understanding the problem), define (scoping of the project), develop (idea finding and developing concepts) and deliver (design conceptualisation). This is an iterative process, in which different methods are used per phase and each phase can be performed multiple times. Research questions are answered using different methods (as stated in Table 1) and are executed from three different perspectives: a user perspective, a product perspective and an end-of-life perspective. Results from these analyses will identify starting points for design solutions and interventions.

3 Results

3.1 User Perspective

The main users are the staff of the ICU, a team of medical specialists. Four nurses, two care assistants and one pharmacy technician were interviewed. The observations involved all of the staff members of the ICU. A use scenario, user journey and a workflow analysis are made to process the insights.

- **The workflow** analysis visualised the interaction between staff members using syringes. The staff members interact with the syringes in different ways. The intensivists only communicate about the syringe by prescribing the order. The pharmacy technician (PT 1) checks the order and arranges the logistics. Next, a second PT (PT 2) prepares the syringes if needed. Thereafter, PT 1 ensures that the syringe is placed in the drawer of the patient. The nurses interact with the syringes and the patient, and the care assistant only interacts with the syringe before use and the cleaners after use.
- **The use scenario** showed that filling a syringe with medication at the ICU and connecting it to the patient requires several other products in addition to the syringe itself. All these additional products needed to fill the syringe are single-use disposable items, such as gauze pads, gloves, needles, stoppers and packaging. These are needed per syringe since each syringe is filled one by one per specific patient.
- **The flow model** showed that there are different storage locations to store new syringes. One of these locations is the patient's room where strict infection prevention protocols are in place. This means that when a patient leaves after a stay that exceeded 24 h, the entire inventory, including unused syringes in the room needs to

Table 1 Research questions and accompanying methods used

Research question	Method	Explanation method
How much waste is disposed (differentiating between used and unused) on the paediatric intensive care (PICU), and what does it consist of? How many syringes are disposed of (unused)?	Waste audit	General hospital waste of the PICU is collected for four consecutive days. The PICU consists of four units; each day one unit is analysed. Waste is collected per unit for 24 h. The next morning, all bags of one unit are weighed and opened, and next all items are sorted and counted. Each item is classified as 'used' or 'unused' and sorted into one of the 14 product categories. All the categories are weighed separately at the end. One of these categories is "syringes". Besides the general hospital waste, there are also containers for specific hospital waste (SZA). These containers are left out, due to safety reasons and available time. They are only weighed and opened to see what is generally in there
How are syringes used by the staff in the ICU?	User analysis	Use scenario: observe all the steps of using a syringe in the user environment and interview the users about the use process
		User journey (user-centred design): observe different users and their emotions and frustrations during the use process. Afterwards, ask questions about the frustration and general use of the syringe
		A workflow analysis is performed to understand the human context of using a syringe. Two traditional contextual design models are used: the flow model and the physical model. The contextual design models help to understand the workflow of the users. The flow model shows the interaction between the different users. The physical model shows where and by who the products are used (Holtzblatt and Beyer 2017)
What are the product specifications of a syringe?	Product analysis	Analyse the product on materials, different parts, and weight. The weight of the different parts is measured using a KERN & SOHN GmbH 572 Precision balance. The material specifications are retrieved from the technical datasheet of BD Medical, the manufacturer, and by doing desk research

(continued)

be disposed of. These are disposed of without being used and end up being incinerated (Browne-Wilkinson et al. 2021). Furthermore, the user journey showed that certain nurses have the habit of picking up multiple syringes when they only need one.

The main barriers to decreasing the impact of syringes are the infection prevention protocol and behaviour of the staff, causing syringes to be disposed of unused.

Table 1 (continued)

Research question	Method	Explanation method
What process does the syringe go through during its life cycle?	Life cycle analysis and product journey mapping	Product journey: map the journey of the product from beginning to end with accompanying stakeholders
		The life cycle of the product is mapped in a flow chart. All materials and consumables needed to produce and fill a syringe are included. Impact hotspots in the process are determined by looking at energy consumption and materials needed per step A single score indicator, the ReCiPe Endpoint, is used to assess the impact of the (material) hotspots. This indicator combines 18 different impact categories concerning damage to human health, resource scarcity, and ecosystems (Huijbregts et al. 2020). The values of the endpoints can be found in the EcoInvent V3 database. The specific values of the hotspots have been identified by calculations. When the values of specific processes are not present in the database, existing information from comparable situations in scientific papers is used to determine a value
What are alternative life cycle scenarios for a syringe to reduce its impact?	Comparing life cycles	Comparing different life cycle scenarios by doing a literature study. This is done to investigate to see what possible interventions could be of interest

3.2 End-of-Life Perspective

A waste audit at the Paediatric Intensive Care Unit (PICU) of the Erasmus MC was done to quantify the waste. The analysis was not performed at the adult ICU, due to logistic reasons. During four days, a total of 570 syringes were collected from the waste bags. There were 5–6 children in each unit, so on average, approximately 27 syringes were used per child per day. Around 2% of the syringes were disposed of unused, most of the time because they were out of date. All syringes were disposed of in the general hospital waste bins, some still containing fluids like blood or medication. This was remarkable since these are supposed to be disposed of in the specific hospital waste containers dedicated to infectious waste.

3.3 Product Perspective

The life cycle of the 50 ml Luer-Lok syringes, the type of syringes that are used most in the ICU, was analysed resulting in the following environmental impact hotspots:

The sterilisation process (ethylene oxide): ethylene oxide sterilisation has a significant impact on the environment, but sterilisation is required to deliver sterile syringes to the hospital.

Additional products needed per syringe during the filling process. All the protective products needed at the ICU pharmacy (alcohol swab, sterile gloves, tip cover) are there for preserving the sterility of the syringes. Each syringe is filled one by one per specific patient. Cooled storage (fridge) at the ICU pharmacy until use.

Comparing the life cycle of the original manually filled syringe to new possible life cycle scenarios showed various possibilities to adapt the linear product life cycle towards a more circular life cycle:

- Using prefilled sterilised syringes (PFSs).
- Changing the end of life from incineration to recycling.
- Sterilise the syringes after use for reuse.
- Using other materials; change the material from petroleum-based PP to recycled or bio-based PP or another more sustainable material.

This study looked further into the scenario of PFSs since PFSs are assumed to have a lower impact than manually filled syringes (Cheetham and Johnson 2013). PFSs are prefilled sterilised syringes that are filled and sterilised in large batches by an external provider, in our case Apotheek A15. Comparing the life cycle scenario of PFSs to manually filled syringes showed the following:

- The filling process of PFSs saves a lot of products and materials during the filling process compared to manually filled syringes, as PFSs are produced in large batches (5000 per batch). Needing fewer additional products to prepare a syringe reduces the environmental impact.
- PFSs do not need to be stored in a fridge, as manually filled syringes do.
- Prefilled syringes have a higher impact on a product material level since the syringe is made of materials with a higher ReCiPe endpoint than the manually filled syringe.
- The production process of PFSs involves an energy and water-consuming sterilisation process after filling, which is not the case for manually filled syringes.

4 Discussion

User and product research demonstrated that decreasing the environmental impact of syringes is not only about the product itself. Manufacturing, preparing, using and disposing of the syringe all contribute to the environmental impact. The following possible interventions were identified based on the results:

- The flow model and user journey showed that the storage of new syringes in the ICU rooms could be revised, as well as the infection prevention protocol. Decreasing the stock inside the ICU rooms of the patient would lead to a decrease in unused disposed items. The user journey presented that the amount of disposed

of unused syringes could be decreased by changing the habits of staff. Teaching the staff to only pick the amount you are going to use could decrease the disposal of unused syringes.

- From the waste audit, it can be concluded that the separation of general and specific hospital waste is not always done correctly. This makes mechanical recycling of general waste impossible since infectious waste cannot be mechanically recycled. However, the bags from the pharmacy and the bags which only contained food-related waste showed that separating regular waste from (infectious) specific hospital waste is certainly possible in specific areas of the hospital. This creates an opportunity for recycling general hospital waste. Lastly, it was observed that there is no separation of waste based on materials. Changing the environment by placing different waste bins, in for example the pharmacy, to separate waste.
- The system of the syringe was investigated and different lifecycle scenarios were analysed. It turned out that prefilled sterilised syringes (PFSs) require fewer additional products for filling, and are therefore assumed to be more environmentally friendly. However, an impact hotspot analysis of PFSs showed that the materials used, sterilisation and leftover products contribute significantly to the environmental impact. This makes it less environmentally friendly than existing studies assumed. In conclusion, the PFSs are more sustainable than manually filled syringes in terms of less waste. But the PFSs impact hotspots such as the sterilisation process, leftover medication and materials are points of improvement to make the PFSs an actual sustainable alternative for manually filled syringes.
- A cause of these environmental product hotspots is the need for safety and sterility. Sterility and preventing infections during the production and the filling process are the main barriers to decreasing the environmental impact of the production and filling process of syringes.

4.1 Final Design

The final design, therefore, is focused on optimising the entire filling process of PFSs to reduce the environmental impact of these impact hotspots. All steps in the filling process of PFSs have been reviewed and 10 different interventions based on circular design strategies have been proposed (see Fig. 1), resulting in:

- Reduction of waste (interventions number 4. deliver from stock, 5. decrease the amount of drug solution, 6. improve stopper machine, 7. repurpose packaging, 8. reuse plungers and 10. reuse syringes).
- Reduction of energy and water usage (interventions number 1. double sterilisation and 8. steam to gamma).
- Reduction of material impact (intervention number 2. change to a sustainable material).

The proposed interventions have been evaluated with the relevant stakeholders.

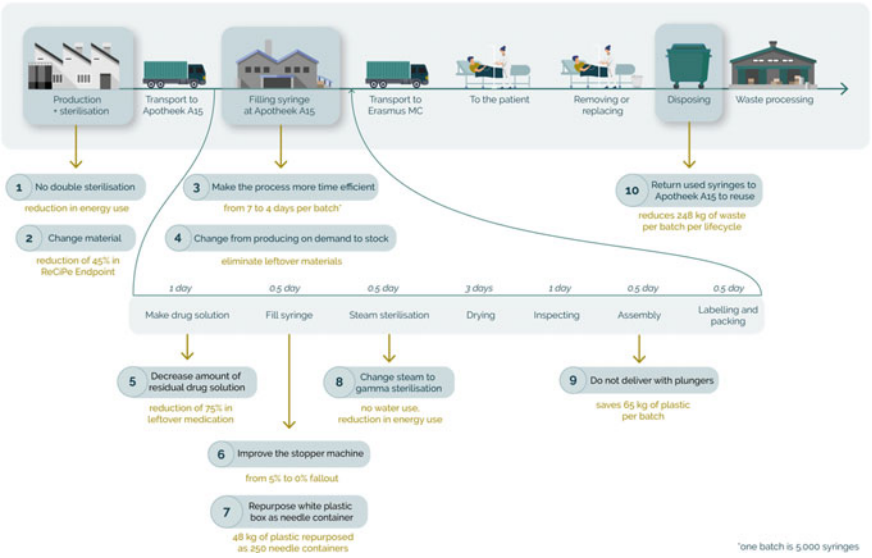

Fig. 1 Overview of interventions to decrease the impact of the filling process of PFSs, visualised on the product journey

This resulted in a holistic concept based on circular design strategies that reduces the environmental impact of syringes without increasing the workflow of the staff in the ICU. Compared to the original manual filling process in the ICU, the concept has an added value by decreasing the workload of the staff in the pharmacy. The workflow of the nurses, care assistants, intensivists, and cleaners will remain the same. The environmental impact of syringes is therefore reduced by optimising the filling process of syringes.

The final design is not the only answer to the main research question and is not the only valuable contribution of this project. The research from different perspectives has revealed a range of pain points and possible solutions that could further decrease the impact of syringes. These insights from the analysis are also valuable for Erasmus MC and the transition to a circular ICU.

5 Conclusions

This project aimed to redesign the syringes, their packaging, and their use, according to circular design strategies suitable for medical products to decrease their environmental impact, while remaining convenient and safe for the healthcare staff and patients.

The outcomes of the research demonstrated that decreasing the impact of syringes is not only related to the design of the syringe itself. Manufacturing, preparation,

use and disposal, all contribute to the environmental impact of the syringe. Various possible interventions were derived from this research:

1. Adapting the infection prevention protocol and behaviour of the nursing staff could lead to a decrease in unused disposed syringes.
2. Separating infectious waste from general hospital waste in a proper way could result in opportunities for recycling.
3. The syringe itself can be redesigned to reduce its impact by changing the material to a sustainable alternative and redesigning the shape for (partial) reuse.
4. The impact of the filling process could be reduced. Research concluded that prefilled sterilised syringes (PFSs) are more environmentally sound than manually filled syringes since they are produced in large batches and, therefore, have fewer by-products per syringe. However, a life cycle analysis of the filling process of PFSs showed various impact hotspots in this filling process, such as the sterilisation phase, materials used, and residual medication. The final design is a process optimisation for batch-produced PFSs, based on circular strategies such as reduce, reuse, rethink and repurpose. Interventions include: eliminating the first sterilisation phase, reduction of residual medication and changing from steam to gamma sterilisation.

In conclusion, this study showed how the environmental impact of syringes can be reduced. Replacing manually filled syringes with PFSs saves additional products, and thus saves waste (see Fig. 2). However, the PFSs come with new significant impact hotspots, such as double sterilisation, materials used and left-over medicine. The impact of these hotspots is decreased by the final design, a process optimisation of the PFSs. In the end, the optimised process reduces the amount of waste, energy and water usage and material impact per syringe.

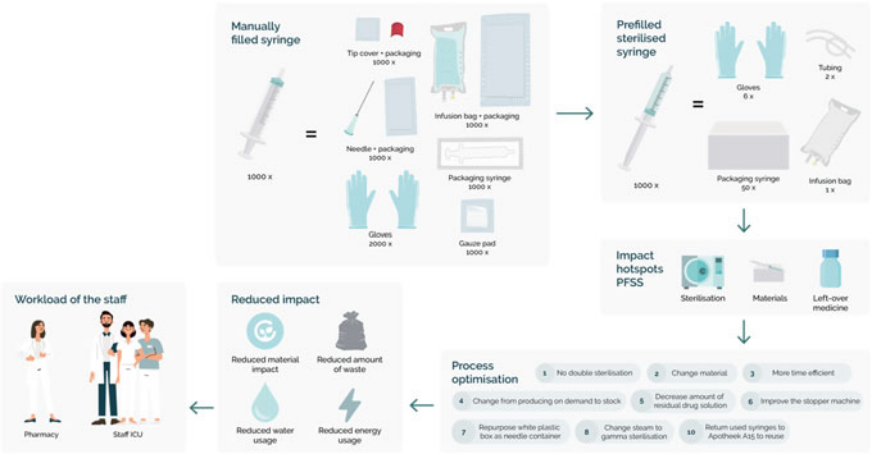

Fig. 2 Visualization of the conclusion of the project

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Towards Circular ICUs: Circular Intubations as a Catalyser for Systemic Change

Alicia Ville, Nicole Hunfeld, Conny Bakker, Baptiste Sene, and Jan Carel Diehl

Abstract This project aims to reduce the environmental impact of the Intensive Care Unit (ICU) of the Erasmus Medical Center (EMC). Systemic design research was executed to map the current waste flow created by the ICU. Literature review, interviews and observations were performed to gather information about the healthcare protocols, hospital procurement process, intubation practices and used devices and consumables. This resulted in a set of challenges which were used to ideate from different perspectives to improve the sustainability of the ICU. A set of opportunities to introduce circularity within the ICU were defined. These opportunities ranged from waste separation to the reduction of the disposal of unused products. The selected circular opportunity was intubation, needed when patients cannot breathe by themselves. For this, a video laryngoscope, which is composed of various plastics, a video camera, and a led light, is used for only a few minutes and disposed of (and incinerated) directly afterwards. The aim of the second part of this research project was: Can we design a circular intubation procedure as a catalyzer for systemic change towards circular ICUs? One of the proposed circular strategies for the video laryngoscope is the reprocessing of intubation devices used at the ICU itself. A transition model toward reprocessing using UV-C radiation technique was further developed. Compared to current reprocessing procedures, UV-C disinfection consumes no water and less electricity and offers the possibility of decentralized reprocessing within the ICU department itself. This project aims to provoke conversations between the hospital, manufacturers and other stakeholders about how the healthcare sector could start reprocessing valuable medical devices towards a circular ICU.

Keywords Circular healthcare · Systemic design · Intensive Care Unit · Intubation

A. Ville (✉) · C. Bakker · J. C. Diehl
Delft University of Technology, Delft, The Netherlands
e-mail: aliciavilleghetti@gmail.com

N. Hunfeld
Erasmus Medical Center, Rotterdam, The Netherlands

B. Sene
Van Berlo, Eindhoven, The Netherlands

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1 Background

The healthcare sector presents the paradox of being responsible for saving lives while simultaneously contributing to climate change. Healthcare itself has been referred to as the greatest health threat of the 21st century (Karliner et al. 2020), contributing in the Netherlands to 5.9% of the national ecological footprint (Browne-Wilkinson et al. 2021). 71% of the emissions generated by the healthcare sector in the Netherlands are related to the production, use, transport, and disposal of medical products used in the hospital (Browne-Wilkinson et al., 2021).

An ICU is a special facility within a hospital that provides intensive supervision, monitoring and life support to critically ill patients. Due to its intense nature, it is one of the areas of the hospitals where a relatively high amount of waste per patient is produced. The EMC ICU produces 50.000 kg of waste annually (Browne-Wilkinson et al., 2021). A wide range of products is being used at the ICU like electronic devices, sophisticated invasive devices, and single-use devices, which currently are all disposed of by incineration.

Despite the intensive use of single-use and disposable products enhanced by regulation to reduce (cross-) infections (Kane et al. 2018), alternative sustainable health practices are increasingly considered across the sector. In fact, transitioning from a linear to circular economy is crucial to prevent depletion of finite natural resources and the associated negative environmental and social impacts. The circular economy is regenerative and restorative by design and would enable hospitals to capture and retain value for longer, thus being less harmful to the environment.

To explore how the ICU of EMC could start envisioning a more circular future, we will focus on one of the more frequent ICU procedures: intubation. Patients get intubated if they cannot maintain their airway or breathe independently without assistance. As it entails a critical condition with constant observation and care, intubated patients are usually placed in the ICU. The purpose of this project was to redesign the intubation process through the use of circular strategies to reduce its environmental impact. A set of different objectives were set: (1) understanding what are the main challenges that the current system of intubation to detubation presents from a sustainability perspective and (2) designing a pilot system which initiates the ICU transition towards fully circular intubation system.

2 Methodology

This project was approached from a systemic design perspective since not only the product itself but also the system within which a product is manufactured, used and disposed of (Browne-Wilkinson et al. 2021) needs to be taken into account to create impactful change.

First, a context research was done to better understand the current waste created by the ICU and answer the question: What are the main challenges that the current

intubation to detubation system present from a sustainability perspective? A literature review, a waste audit, interviews and observations (further described in Table 1) were performed to gather information about the healthcare context, intubation procedures and devices procurement.

The takeaways of this research were summarized in three system maps used to hotspot the challenges the ICU faces from a sustainable perspective. Based on the identified challenges, we first ideated on a set of proposals that could improve the ICU sustainability, next one specific proposal was selected and further detailed. A specific product used throughout intubation was selected, around which the detailing of the selected proposal could be articulated into a tangible pilot.

Table 1 Research methods

Literature review	Base literature concerning the current wastefulness stage of ICUs. A set of four research questions were identified before conducting literature review: What are the laws, regulations and policies guiding procurement and waste management in EU hospitals? – Which current practices make ICUs a non-circular environment and their consequent impact? – Are there already some pilot projects showing potential areas where circular strategies could be applied in ICUs and hospitals? – What are the effects of climate change and COVID on healthcare systems?
Interviews and observations at Erasmus MC	A set of observations were performed at the ICU of: – A nurse setting up a room for intubation – An intensivist performing his daily assessment of intubated patients – Nurses' general workflow by observing corridor workflows – Two nurses cleaning a room after an intubated patient stay Finally, several interviews were made. Nurses, a medical device designer, an IC physician, a device procurement advisor, a strategic buyer and a physician were interviewed
Waste audit	General hospital waste from the pediatric ICU of Erasmus MC was collected for four consecutive days. The waste generated during 24 h by each of the units of the pediatric ICU were analyzed consecutively: Bags were weighted, opened and the items within the bags were then sorted and counted. Items were then classified as 'used' or 'unused' and sorted depending on their product category. Product categories were eventually weighted and photographed once all bags from the unit were analyzed

3 Results

Based on the observations and interviews, a set of three maps were developed: An overview of the intubation steps is provided in Fig. 1, indicating stakeholders involved, tasks and times they are performed. The wastefulness of each stage is illustrated as well at the bottom of the visual. Figure 2 maps non exhaustively the devices used in regular intubation. It visualizes how these devices are used (and disposed of) and in which quantity. Finally, Fig. 3 shows the general journey from raw material extraction until their end of life of intubation devices.

All three maps highlight in red the different challenges that were detected throughout the research, and that will be listed and discussed next.

3.1 Single Use Predilection

The large majority of devices used throughout an intubation are disposable. Even devices of relatively high value (Kane et al. 2018) such as bronchoscopes or video laryngoscopes, are disposed of and incinerated. We observed through interviews that some of the high-value devices were previously reused. Reusable devices must undergo reprocessing, to clean and then disinfect or sterilize them to eliminate microorganisms from previous patients (Food and drugs administration 2019). The

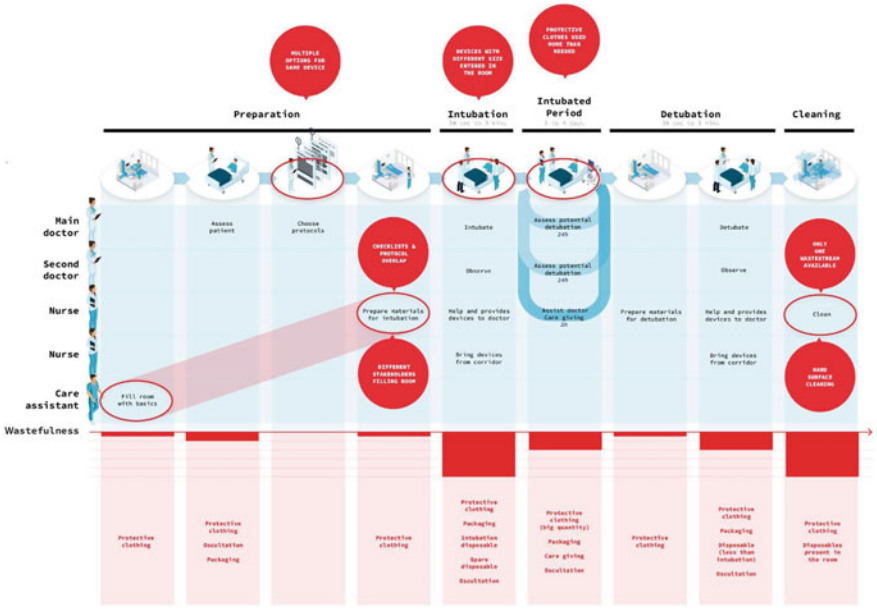

Fig. 1 Intubation steps and actions, and stakeholders required for each of them

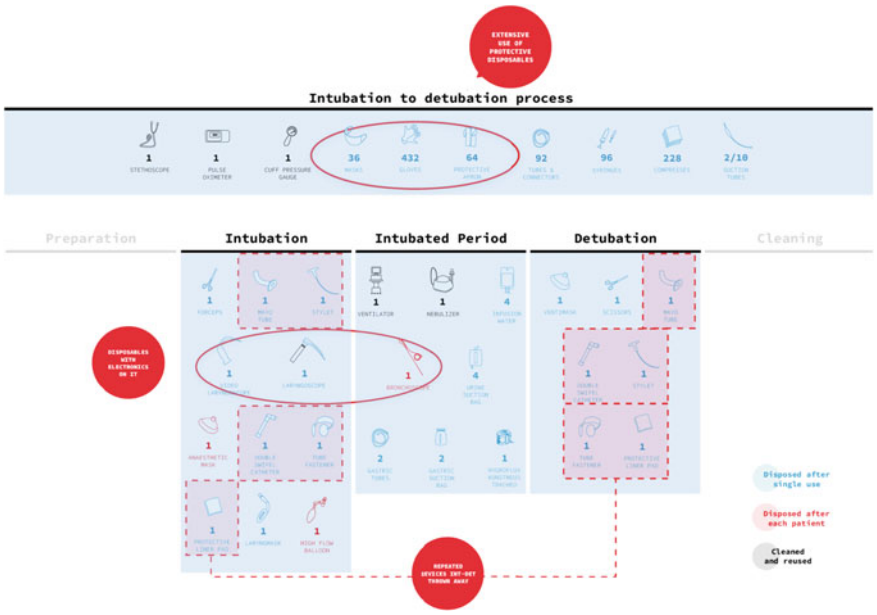

Fig. 2 Map of devices used throughout intubation

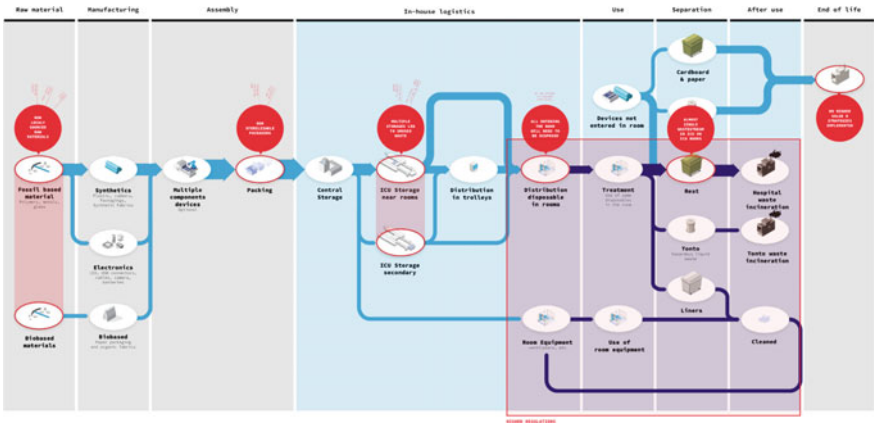

Fig. 3 Devices journey map

previous reprocessing model implemented at EMC ICU became obsolete due to the following non-exhaustive reasons:

1. **Technological innovation jeopardizes the reprocessing of devices**

Technological innovation is always sought in the healthcare environment as it provides higher quality, thus more safety. For instance, the inclusion of a camera in the

video laryngoscope, increases the rates of successful intubations (Baek et al. 2018). It also increases the devices' complexity (in shapes and components requirements), reducing the efficiency of the cleaning methods (Moses et al. 2021).

2. **An inefficient reprocessing system and technology**

The technique used to reprocess ICU devices at EMC was largely based on chemical and steam technology. Both these techniques have a relatively high environmental impact which makes the reuse of devices less attractive from an environmental standpoint. On top of this, the ICU experienced some in-house logistical hiccups. Receiving back the devices from the reprocessing department was taking in some cases too long, which caused a lack of availability of these devices at the ICU. Disposables were as such considered as a better alternative as their stock is not dependent on the performance of other departments.

3. **Safety**

Moreover, single-use devices eliminate infection risk management. This is welcomed both by the hospital administration and the staff that had to perform manually part of the reprocessing, thus having responsibility for its correct disinfection. It is also enhanced by manufacturers for their own economical benefits.

3.2 Limited Waste Separation

Most waste generated throughout intubation is disposed of together and incinerated as hospital waste. The current end-of-life solutions mostly rely on the incineration of goods and rarely on giving back the ownership of products to manufacturers.

3.3 Some Devices Get Disposed Unused

Based on a waste audit performed at EMC Pediatric ICU, the unused waste was estimated at 6%. Disposables are required to be disposed of, even unused, if entered into the ICU room due to infection prevention protocol. This means that the entire room inventory must be disposed of when a patient leaves after a stay that exceeds 24 h. The ICU has multiple storage spaces, most located outside of the patient room. Currently, more devices than required are placed in the ICU rooms during intubation procedures. This is due to doctors' decision-making and overlapping protocols. Many different stakeholders are involved in preparing the rooms, enhancing the entrance of the same device twice into the room. Also, some identical devices are available in multiple locations, jeopardizing their use before the expiration date of less regularly checked ones.

4 Discussion

4.1 Interpretation Results

A set of opportunities for EMC ICU to reduce its environmental impact were detected from the research and summarized in a booklet, as listed in Table 2.

We were able to conclude from the research that one of the main causes for unsustainability at the ICU was the systematic use of disposables. Consequently, a system that allows the reprocessing of intubation devices is explored.

Reprocessing involves a change in the ICU infrastructure, protocols and workflows. Each device requires a specific reprocessing procedure. These procedures are dependent on requirements stipulated by manufacturers, the technologies available for reprocessing, European and national regulations. Due to its inherent complexity, reusing devices requires a transitional design approach. As part of this approach, this paper proposes a pilot that could enable EMC ICU to explore a specific reuse scenario. This pilot is articulated around a specific product, the video laryngoscope. The latter is used to intubate patients. It is composed of various plastics and electronics, and has a relatively high procurement cost. Nevertheless, it is a single-use device, disposed of and incinerated after a few minutes of use.

Table 2 Opportunities deducted from the research

Packaging separation	It can be envisioned to separate device's packaging, mostly made from the same range of materials (paper, laminated PA, LDPE, HDPE, etc.), for recycling
Tools for conscious procurement	Taking into consideration the total cost of ownership of devices and their supply chain impact (CO2, land, water, toxicity, child labour, etc.) during procurement could increase hospital sustainability and the use of reusable devices
Educate doctors for conscious choices	Raising the awareness of ICU staff on these decisions could avoid nonessential use of resources and reduce waste
Enable external storages	Adding an external storage in front of the ICU room allows devices easily accessible, still out of the room. This saves unused devices from incineration
Cleanable packaging	Erasmus MC could explore collaboration with manufacturers to redesign cleanable packaging or alternative cleaning technologies. Cleaning of unused devices still packed could enable them to be saved from disposal
Reuse of high value devices	Allowing the reprocessing of high value devices
Avoid redundant devices	Reducing redundant versions of the same device avoids less known versions going unused until expiration
Redesign overlapping protocols	A redesign of protocols that allows nurses to know which devices can be potentially already in the room can be envisioned. Protocols could also distinguish better optional devices

Ideation on a system enabling a safe and hassle-free reuse of the video laryngoscope at the ICU with a lower environmental impact was done. We first explored which technologies could be used to reprocess video laryngoscopes and similar high-value devices at the lowest environmental impact possible. UV-C disinfection has environmental benefits compared to steam disinfection since less energy and no water is required (Leiden et al. 2020). UV-C radiation is a radiation of a specific wavelength. Lamps emitting this radiation can be used to disinfect surfaces. Indeed, UV-C radiation has been used for decades to reduce the spread of bacteria, and its use during the COVID-19 pandemic has allowed this technology to be recently certified for use in hospitals. UV-C radiation technology can be used to clean non-critical and semi-critical devices which require disinfection only on their external surfaces, such as video laryngoscopes. With UV-C technology, cleaning of non-critical medical devices can be fully automated, avoiding any additional device cleaning workload for ICU nurses. The disinfection of semi-critical devices could also be done through UV-C when previously cleaned with wipes. This reduces the workload for nurses compared to previous reuse scenarios.

A conceptual design of a system for reprocessing laryngoscopes at the ICU itself using different technology available in the market was developed. Two pilots, one using the current video laryngoscope used at the ICU and a second one using a hybrid one were generated. In Fig. 4, future scaleup of the reuse system to other devices is envisioned, as well as replicating it into other Erasmus MC departments.

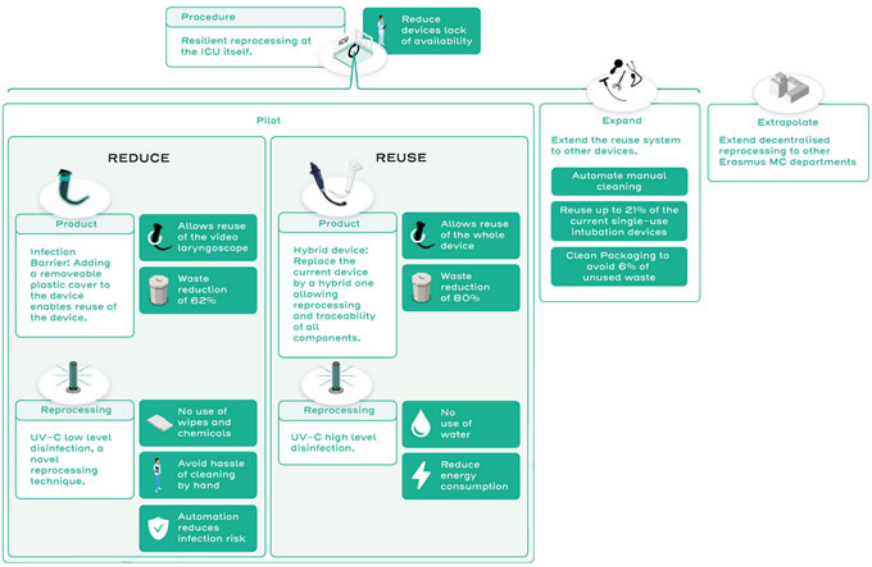

Fig. 4 Transition roadmap

4.2 Limitations

These pilots are conceptual, their feasibility must still be explored before implementation. For instance, testing of the UV-C resistance of the laryngoscope materials would be required. Also, these pilots consider video laryngoscopes as semi-critical devices, thus could not be applied to video laryngoscope entering in contact with blood.

4.3 Strengths and Next Steps

Individual patient safety-centered design limits the radical changes needed to make healthcare sustainable. Current hospital risk management focuses mostly on individual patient safety, leading to an excessive avoidance of specific risks, at the wider expense of unsustainable practices. As such, to catalyze systemic change in healthcare, a reframing of risk management is needed. Reuse practices would not make the EMC a less safe hospital but one that places more attention on their impact at an environmental and societal level instead of only searching for safety at a short-term and individual level.

These transition proposals as well as the pilot exploration aim to provoke conversations between the hospital, manufacturers and other stakeholders around how the healthcare sector could start reprocessing valuable medical devices towards a circular ICU.

5 Conclusion

This paper explores different directions in which EMC ICU could reduce its environmental impact of intubation through circular strategies. It explores the reuse of medical devices through the design of a pilot system on video laryngoscope reuse through an ICU based reprocessing and the use of UV-C radiation. This will result in decreased environmental impact. Even if the infection risk is low and compliant to regulation, tensions arise that can be leading us to the core of health wastefulness. A major takeaway from this project is that most unsustainable ICU practices are closely related with the reduction of safety risks to an absolute minimum. With sustainability acting on spatio-temporal scales that are not directly apparent, it becomes challenging to make decisions now that may have directly visible drawbacks (increased risk), while only offering invisible future benefits (mitigate climate change). Healthcare cannot be free of risks, and a better understanding of the value of sustainable health by organizations and society would allow for innovations toward a circular future.

The full story of this research can be found at: https://repository.tudelft.nl/islandora/object/uuid%3A0ff435ae-4f59-4196-b52c-92a528de3041?collection=education.

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Better In–Better Out: (P)rehabilitation with Patients Preparing for and Recovering from Elective (Oncological) Surgery

Effect of Preoperative Multimodal Lifestyle Interventions on Functional Capacity in Colorectal Cancer Patients and the Importance of Personalization

Sander Kerstens, Jolieke Warmer, Canan Ziylan, and Lottie Kuijt-Evers

Abstract In recent years the preoperative phase of a patient undergoing colorectal cancer surgery is increasingly studied, due to the increasing evidence of "better in, better out" prehabilitation programs, as a means to improve patient outcomes in recovery after surgery. Multimodal programs seem to be of additional benefit to these patient outcomes. Questions remain however which interventions are best suited for improving patient outcomes and to what extent these are tailored to personal capabilities and personal preferences. This systematic literature review analysed, after a thorough search through four different databases, six studies of which four randomized clinical trials. Results showed that most patients benefited from participating in a multimodal prehabilitation program, increasing their functional capacities before and after surgery. Yet frail elderly seemed to benefit less from a prehabilitation program while inactive patients showed greater improvements compared to the more active patients. Furthermore, adherence was higher in the prehabilitation program compared to rehabilitation and personalization of the program appeared to improve adherence. It seems to be of importance to identify which colorectal cancer patients benefit most from a prehabilitation program and how personalization can further increase the benefits of prehabilitation.

Keywords Colorectal cancer · Lifestyle intervention · Prehabilitation · Functional capacity · Personalization

S. Kerstens (✉) · L. Kuijt-Evers
Knowledge Centre Health Innovation, The Hague University of Applied Sciences, The Hague, The Netherlands
e-mail: S.Kerstens@hhs.nl

S. Kerstens · J. Warmer · C. Ziylan · L. Kuijt-Evers
Medical Delta Living Lab Better in—Better out, Delft, The Netherlands

C. Ziylan
Rotterdam University of Applied Sciences, Rotterdam, The Netherlands

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1 Background

With more than 1.9 million new cases, colorectal cancer (CRC) was the third most common cancer worldwide in 2020. In the same year, the Netherlands ranked five in the global list of countries with the highest colorectal cancer incidence rate (WCRF, n.d.). Due to early diagnosis and improved medical treatments, survival rates have increased, resulting in a growing number of cancer survivors (Rawla et al. 2019). In 2021, 80.000 people in the Netherlands were diagnosed with colorectal cancer in the last 10 years (IKNL n.d.). Cancer survivors face unique health and daily functioning challenges as a result of their cancer or treatment, like complications and physical and psychosocial symptoms (Hidding et al. 2014; Schmidt et al. 2018). This could result in reduced quality of life and social participation, in both work and leisure (Han et al. 2020).

In order to reduce treatment side effects and improve quality of life in cancer survivors, several studies investigated the effects of rehabilitation after cancer treatment. A multimodal rehabilitation program consisting of lifestyle interventions (e.g. physical therapy, psychosocial support and diet therapy (Inoue-Choi et al. 2013; Van Blarigan et al. 2018) have shown to reduce mortality and treatment side effects, and improve quality of life in cancer patients (Olsson Möller et al. 2019). In recent years, the effects of lifestyle interventions in the preoperative phase (so called prehabilitation) have been studied. Several systematic reviews have shown that prehabilitation could result in faster recovery and improvement in exercise capabilities before and after surgery (Hoogeboom et al. 2014; Lau and Chamberlain 2019). A recent systematic review of randomized controlled trials (RCTs) by Molenaar et al. (2022), found improved functional capacity and reduced complication rates postoperatively in colorectal cancer patients as a result of multimodal prehabilitation programs.

High adherence to prehabilitation programs for colorectal cancer patients is of importance to gain the best results (Scheede-Bergdahl et al. 2019). Most investigated prehabilitation programs focused on exercise and/or nutrition interventions (Bruns et al. 2016; van Rooijen et al. 2017). However, patients seem to struggle with adhering to these lifestyle changes (Breedveld-Peters et al. 2018; Inoue-Choi et al. 2013; Winkels et al. 2016). This is not because they are unwilling to change their behavior according to Anderson et al. (2013), but they have a need for an evidence-based program that is tailored to their needs. Anderson et al. (2013) showed for example that participants who actively sought lifestyle advice, experienced confusion, mixed messages, culturally inappropriate guidance and uncertainty about the accuracy of the provided advice from health care professionals. Based on these findings, one could argue that a non-personalized program might result in less motivation to adhere to a program and on the other hand that personalizing prehabilitation programs could aid in achieving higher adherence rates. It is important to be aware that personalization can occur on a person's capabilities, but also on a person's preferences (i.e. in activities).

Therefore, the aim of the current review is to investigate which interventions regarding physical activity and dietary advice of the current prehabilitation programs

contribute to improved postoperative outcomes in people suffering from colorectal cancer and to what extent these interventions are tailored to personal physical capacity and personal preferences of the participants.

This study is part of a broader systematic literature research that aims to provide insight in the latest research on which multimodal lifestyle interventions contribute to a faster physical recovery, maintenance of physical performance and functional status, and improved quality of life of people suffering from colorectal cancer during and after cancer treatment. This study focuses on which multimodal lifestyle intervention improve functional outcomes after surgery and if the need for personalization is addressed by these programs. Additionally, this study aims to identify different types of preoperative interventions that are commonly used, so healthcare providers can choose an intervention type that suits their patients' needs.

2 Methodology

A systematic literature review was conducted, according to the PRISMA Guidelines (Moher et al. 2009), to identify studies that examined multimodal lifestyle interventions for colorectal cancer patients during and after their treatment. As this study is part of a broader study, for clarity the method of the broader study will be described.

2.1 Search strategy

The databases PubMed, CINAHL, Medline and Psychology and Behavioral Sciences Collection were systematically searched from March until September 2021 to identify relevant studies. The following search terms were (mainly) used in combination with each other: colorectal neoplasms, lifestyle change, physical activity, nutrition(al) intervention, enhanced recovery, physical performance, functional status, quality of life. During the search, no restrictive filter on language or date of publication was used. If identified studies did not describe the effectiveness of an intervention (e.g. a study protocol), the main study was searched and, if available, added to the identified studies. All findings were imported in the research tool Rayyan (Ouzzani et al. 2016) and duplicates were removed by this tool.

2.2 Eligibility Criteria

Studies on multimodal lifestyle interventions aimed at colorectal cancer patients aged 18 or older were eligible for inclusion. Lifestyle interventions should at least focus on both physical activity and nutrition. Interventions primarily focussing on supplementation of nutrients, without changing participants' habitual diet (e.g. calcium

from supplements), were excluded. Only studies published between 2011 and 2021 were included. Studies in languages other than English or Dutch as well as studies in patients with cognitive impairment were excluded.

2.3 Study Selection

All studies were independently screened on title and abstract by two reviewers based on the eligibility criteria. Any reviewing disagreements were resolved by discussion or by asking a third reviewer. Next, two researchers (SK and JW) screened the full texts on the eligibility criteria. Differences in opinions about inclusion of a study were resolved and concluded through discussion with two other researchers (LK and CZ).

2.4 Quality Assessment

The methodological quality of the studies that met the inclusion criteria were independently assessed by two researchers (SK and JW) using the Cochrane risk of Bias tool (RoB) (Higgins et al. 2019) for RCTs and the Mixed Methods Appraisal Tool for observational studies (Hong et al. 2018). The RoB consists of a series of signalling questions within several domains of bias. Based on the answers, an algorithm will generate a judgement about the risk of bias: 'low', 'high' or 'some concerns'. The MMAT consists of two screening questions and five quality criteria. Each criterium should be rated 'yes', 'no' or 'can't tell'. A total score for every study was calculated, ranging from 0% (none of the criteria met) to 100% (all criteria met). Disagreements between researchers were resolved by discussion or by consulting two other researchers (LK and CZ).

2.5 Data synthesis

Data were collected independently by two researchers (SK and JW). Information on study population and size, intervention, outcome measures and effect estimates were collected. Interventions, outcomes and main results are presented in Table 1.

Table 1 Characteristics of included studies on prehabilitation programs in colorectal cancer patients

	Intervention	Outcomes	Main results
Bousquet-Dion (RCT)	I-group (4 week prehab + 8 week rehab): – Supervised exercise sessions (in-lab, pre) – Individualized exercise (at home, post) – 1x nutrition counselling + whey protein (if needed) (pre) – Anxiety reduction strategies (at home) C-group (8 week rehab only): – Same as I-group, but no in-lab supervised exercise	Physical/functional: – FWC (6MWT) – Energy expenditure (CHAMPS) – Body composition (baseline only) – Grip strength (baseline only) QoL/psychological: – Anxiety and depression (HADS, baseline only) Complications: – 30-day complications – Length of stay – ER visits – Hospital readmission Feasibility: – Adherence	(1) PREHAB + did not further enhance postoperative walking capacity (2) Previously inactive patients were more likely to improve functional capacity due to PREHAB+
Carli (RCT)	I-group (4 week prehab): – Exercise onsite + at home – Personalized dietary advice + whey protein (if needed) – Personalized coping strategies – Smoking/alcohol cessation counselling C-group (4 week rehab): – Same as I-group, but only after surgery	Physical/functional: – FWC (6MWT) – Energy expenditure (CHAMPS) QoL/psychological: – Generic health status (SF-36) – Anxiety and depression (HADS) Complications: – 30-day complications – Length of stay – Readmissions – ER visits Feasibility: – Adherence	No effect on postoperative outcomes

(continued)

3 Results

As shown in Table 1, six articles have been included for further examination after applying the in- and exclusion criteria of the original 698 found articles. Four out of six studies were randomized trials, all scoring at least a medium risk of bias on the RoB scale or MMAT. All included studies performed a prehabilitation program

Table 1 (continued)

	Intervention	Outcomes	Main results
Chen (reanalysis of preoperative data from two RCTs)	I-group (4 week prehab): – Individualized exercise (at home) – Individualized nutritional care plan + whey protein – Anxiety reduction strategies C-group: – Hospital booklet	– Physical/functional – Energy expenditure (CHAMPS) – FWC (6MWT)	(1) PREHAB sign. increased amount of moderate- and vigorous intensity PA (2) PREHAB greater improvement in 6MWT
Gillis (RCT)	I-group (4 week prehab + 8 week rehab): – Individualized exercise (at home) – Individualized nutritional care plan + whey protein – Anxiety reduction strategies C-group (8 week rehab): – Same as I-group, but only after surgery	Physical/functional: – FWC (6MWT) – Energy expenditure (CHAMPS) QoL/psychological: – Generic hrQoL (SF-36) – Anxiety and depression (HADS) Complications: – Postoperative complication rates (Dindo-Clavien classification) Feasibility: – (Compliance)	(1) Higher proportion of the PREHAB group improved 6MWT presurgery (2) At 8 wks PREHAB improved more on 6MWT (3) At 8 wks higher proportion of PREHAB to/above baseline 6MWT (4) No differences in complications rates + hospital stay
Li (pre- and postinterv. study, observational)	I-group (~4 week prehab): – Individualized exercise (at home) – 1x nutrition counselling + whey protein – Anxiety reduction strategies C-group: – No intervention (cohort)	Physical/functional: – FWC (6MWT) – Energy expenditure (CHAMPS) QoL/psychological: – HrQoL (SF-36) – Emotional health (HADS) Complications: – Complication rates (Dindo-Clavien classification) Feasibility: – (Compliance)	(1) At 4 and 8 wks PREHAB better 6MWT (2) PREHAB sign. improved 6MWT during preoper. period (3) At 8 wks higher proportion of PREHAB recovered to baseline 6MWT (4) No differences in complications rates + hospital stay

(continued)

which roughly consisted of a 4-week program prior to surgery and assessed functional capacity using the 6-min walk test (6MWT). Only Chen et al. (2016) did not report post-surgery outcomes. First, the interventions will be compared, split between physical, dietary and other interventions, and secondly the main outcomes will be reported.

Table 1 (continued)

	Intervention	Outcomes	Main results
Van Rooijen (observational cohort study)	I-group (4 week prehab): – Supervised exercise sessions (in-hospital) – Personalized dietary advice + protein supplements and multivitamins – Min. 1x psychological counselling + weekly phone calls C-group: – Standard care	Physical/functional: – FWC (6MWT) – Muscle strength QoL/psychological: / Complications: – Adverse events – Feasibility: – Adherence – Program satisfaction – Drop outs	(1) High attendance rate (90%) + high patient satisfaction (2) No adverse events (3) Endurance and/or strength improved (4) Higher proportion of PREHAB recovered to baseline 6MWT compared to control

Abbreviations: 6MWT, 6-minute walk test; C-group, control group; CHAMPS, Community Healthy Activity Model Programme for Seniors; FWC, functional walking capacity; HADS, Hospital Anxiety and Depression Scale; (hr)QoL, (health-related) quality of life; I-group, intervention group; prehab, prehabilitation; RCT, randomized controlled trial; rehab, rehabilitation

3.1 Physical Interventions

All programs provided their clients with a training program, yet not all in the same manner. All interventions consisted of 3–4 times a week exercising. All programs consisted of strength exercises, and most used an elastic band to train the major muscle groups of the patients. In these exercises patients were assessed before exercise and instructed to train at a percentage of their maximum 1RM (e.g. 8–12 repetitions). Only van Rooijen et al. (2019) performed a high intensity interval (HIT) exercise program targeting the major muscle groups using weight lifting equipment. Most endurance interventions lasted at least 20 min and patients had to experience mild exertion (measured by either the Borg rating scale and/or measuring heartrate). Some studies instructed patients to be active (e.g. walking) for 60 min between sessions. All programs adjusted their exercises based upon the patients physical capabilities, yet not all gave options on personal preferences. Li et al. (2012) let their patients chose to either use an aerobic exercise machine or walk. Gillis et al. (2014) and Chen et al. (2016) had their patients chose their preferred option of aerobic exercise.

3.2 Nutritional Interventions

The nutrition component in the programs usually consisted of a one-time nutritional counselling session with a registered dietitian or nutritionist. Macronutrient intake and/or nutritional status was assessed using a 3-day food diary or subjective

global assessment (SGA) respectively. Protein was the macronutrient considered most important and target protein intake was set at 1.2 or 1.5 g per kg (adjusted) body weight per day. In three of the six studies nutritional counseling also included bowel movement regularity, glycemic control, optimization of body composition or management of cancer-related symptoms. Protein supplements were provided in all programs and were recommended to be ingested within one hour of exercise training to maximize muscle protein synthesis. Two studies provided protein supplements only to patients who did not meet protein requirements through diet alone.

3.3 Psychological Interventions

All studies included a one-time session with a trained psychologist or a psychology-trained nurse/member of the research team. During the session, personalized coping strategies to reduce anxiety were provided. Patients were often instructed to practice the strategies at home 2–3 times a week, sometimes with the help of an instructional compact disk. Two studies explicitly described that enhancing patients' motivation to comply to the physical and nutritional component was an additional goal of the psychological intervention.

3.4 Other Interventions

Van Rooijen et al. (2019) offered a 4-week smoke cessation program to all smokers, comprising weekly intensive counselling sessions and nicotine replacement therapy. Besides smoking cessation, Carli et al. (2020) also included counselling regarding alcohol cessation.

3.5 Outcomes

The main outcome discussed is functional capacity, which all studies showed through the 6MWT.

3.5.1 Functional Capacity

The main outcome in functional capacity reported by all preoperative studies was the 6MWT. Out of these six studies five reported postoperative results. Three out of five studies showed statistically significant improvements in the 6MWT compared to the rehabilitation group before and after surgery. Chen et al. (2016) also showed this improvement preoperatively, but did not report postoperative results. It is important

to note that this improvement in 6MWT in the reported studies was not only statistically significant, but also clinically relevant. Bousquet-Dion et al. (2018) reported no further increase in postoperative walking capacity of the prehabilitation group compared to the rehabilitation group, however they did report that previously inactive patients were more likely to have improved their functional capacity due to their prehabilitation program. Carli et al. (2020) found no effect on postoperative outcomes in their prehabilitation program involving frail elderly patients. Chen et al. (2016) only reported preoperative outcomes and showed that their program significantly improved the preoperative 6MWT functional walking capacity during the preoperative period compared to the start of the prehabilitation program. In general, the studies showed the benefit of a prehabilitation program regarding the functional outcome (6MWT) of the patient after surgery, yet for frail older patients it did not show any improvement.

3.5.2 Complications

All the five studies that performed postoperative measurements, investigated the occurrence/severity of postoperative complications using the The Clavien–Dindo Classification of Surgical Complications (Clavien et al. 2009). This classification system is used to objectively report complications after a surgical procedure. All studies showed no significant difference between the prehabilitation group and control group regarding postoperative complications.

3.5.3 Adherence

All studies that reported postoperative outcomes also reported adherence to the prehabilitation and rehabilitation/control programs. Gillis et al. (2014) found that patients in the prehabilitation program showed greater compliance than patients in the postoperative program. Bousquet-Dion et al. (2018) showed that compliance prior to surgery was 98%, whilst this dropped to 70% after surgery in both groups. Self-reported overall compliance in Carli et al. (2020) was 80% in the prehabilitation group compared to 30% in the postoperative group showing a much higher adherence to the prehabilitation program compared to the rehabilitation group. Li et al. (2013) reported no drop outs during the prehabilitation program. Van Rooijen et al. (2019) showed that 88% of the training program was completed by the prehabilitation group while also showing a high satisfaction score (4.6 out of 5 points). Chen et al. (2016) reported that Individualized programs for their patients supported adherence to their program. They reported that when a training program was too intense, patients were less likely to complete the program and suggest the individualization of training programs to counter this.

4 Discussion

Even though the included studies were all multimodal programs focusing on at least exercise and nutrition, all studies had a major focus on the exercise component. All included studies aimed to improve muscle strength through medium to high impact strength exercises. This should be taken into consideration when preparing a patient for colorectal surgery. Most nutritional components often consisted of one counselling session and the intake of protein after exercise. The aim of the nutritional component in these studies seems to be improving short-term protein intake in order to improve functional outcomes. However, given that most programs do not include follow-up dietary counseling sessions, no attention is paid to improving patients' dietary habits in the long-term, which could benefit CRC patients' quality of life in the long term (Balhareth et al. 2019). Additionally, Robinson et al. (2020) suggest that the period prior to surgery could be a strong teachable moment where patients could be (individually) motivated to change their lifestyle for the future.

It has been shown that it is difficult to set up a double blind randomized controlled trial (RCT) in a multimodal intervention, such as a prehabilitation program. Many systematic reviews, such as Molenaar et al. (2022) suggest improving the design of the studies to decrease the risk of bias. When considering the benefit of person-centered care and personalization of intervention to improve adherence and thereby its outcomes (Chen et al. 2016), one could wonder whether a RCT is the best fitted study design when evaluating a personalized prehabilitation program. Arguments against the use of RCTs for this purpose have been described in earlier publications (Sanson-Fisher et al. 2007; Stephenson and Imrie 1998; Zeilstra et al. 2018). In The Netherlands, The Council of Public Health & Society also stated that context of healthcare situation should be considered when looking at evidence (No evidence without context 2017). In this regard Wynter-Blyth and Moorthy (2017) compared preparing for surgery to preparing for a marathon: both require high effort and motivation and moreover a personalized approach. It seems almost impossible to take this into account when using the RCT design. An alternative research method for future research could for instance be the multiple baseline design, since it allows to demonstrate the change of the patient's behavior, if the change is a result of the intervention and if the change is significant (Hawkins et al. 2007).

Chen et al. (2016) describes the importance of psychological care to help patients cope with anxiety problems which are common in cancer patients and could lead to a reduced quality of life. Tsimopoulou et al. (2015) describe the benefit of psychological care before surgery to reduce after surgery anxiety and depression and improve quality of life. It therefore seems beneficial to not only focus on the physical and nutritional status of the patient, but also on their psychological needs.

The main consensus between the different studies is an improved functional capacity of patients participating in prehabilitation programs and there seem to be no extra complications when looking at the Clavien–Dindo Classification of Surgical Complications scale. However, it seems that not all patients benefit equally from such a prehabilitation program. Bousquet-Dion et al. (2018), for instance, showed

that patients who were previously inactive had better results from the prehabilitation program whereas Carli et al. (2020) showed no improved postoperative outcomes in frail elder patients. This indicates the need to carefully select patients in a preoperative program, to achieve the best results. Furthermore Chen et al. (2016) suggested a greater adherence to their preoperative program when the program is more individualized for patients. A person-centered approach seems to be beneficial for patients with bladder (Nahon et al. 2020) and prostate cancer (Paterson et al. 2020) and seems to increase patient adherence (Ferreira et al. 2018). It therefore seems interesting to explore the possibilities of a more person-centered preoperative programs and its effect on postoperative functional capacity in CRC patients.

5 Conclusions

Prehabilitation seems to improve functional capacity before and after surgery whilst not negatively affecting postoperative complications. Individual differences are seen: frail elderly do not seem to benefit as much from an prehabilitation program while inactive patients seem to benefit more. Adherence is higher in the prehabilitation programs compared to rehabilitation programs and is further enhanced in programs focusing on individual preferences. Future research should focus on identifying which patients benefit the most of a more personalized approach in prehabilitative care.

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Better in—Better Out: What About the Hospital Stay?

Lottie Kuijt-Evers and Sander Kerstens

Abstract Early mobilisation after abdominal surgery is necessary to avoid complications and increase recovery. However, due to a variety of factors, failure of early mobilisation is seen in clinical practice. The aim of this study is to investigate the perspectives of nurses and patients of the Haaglanden Medical Center (HMC) how to increase mobilisation frequency after colorectal surgery in the oncological surgery ward. This explorative study employed qualitative data collection and analysis by means of semi-structured interviews with patients and nurses. Patients were included when they had a colorectal resection, were older than 18 years and spoke Dutch. The interviews were audiotaped and verbatum transcribed. A thematic content analysis was performed. It was concluded that mobilisation can be increased when it is incorporated in daily care activities and family support during visiting hours. Appropriate information about mobilisation and physical activity is needed for nurses, patients and family and the hospital environment should stimulate mobilisation.

Keywords Mobilisation · Hospitalisation · Colorectal surgery · Nurses · Patients

1 Background

Colorectal cancer is the 3rd most common cancer worldwide, with an incidence 1.9 million in 2020, accounting for 10.7% of all new cases of cancer worldwide in 2020 (www.wcrf.org). In the Netherlands, the incidence of colorectal cancer was about 13,000 in 2021 (www.iknl.nl). The most common treatment of colorectal cancer is either open or laparoscopic resection of the tumor and a part of the surrounding healthy colon and associated lymph nodes. Complications in colorectal surgery occur in almost 50% of the cases. Often reported complications are adhesions, thrombosis,

L. Kuijt-Evers (✉) · S. Kerstens
The Hague University of Applied Sciences, The Hague, The Netherlands
e-mail: l.f.m.kuijt-evers@hhs.nl

Medical Delta Living Lab Better in—Better out, Delft, The Netherlands

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postoperative infections, anastomotic leakage and ileus (Kirchhoff et al. 2010). These complications can lead to morbidities, prolonged hospitalisation, unplanned readmissions and mortality (Pak et al. 2020). Despite the risk of complications, major surgery also reduces the physiological and functional capacity of patients (Chen et al. 2017).

In order to prevent for these adverse effects of colorectal surgery, the "Enhanced Recovery After Surgery" (ERAS) approach has been applied since the early 1990s (Kehlet 1997). The approach includes multimodal interventions (containing pre-, intra, and postoperative items) in order to decrease the stress response to surgery and accelerate recovery. This peri-operative approach has improved patient outcome, by reducing physiological stress response and maintaining or rapidly restoring baseline function (Ljungqvist et al. 2017), which results in reducing length of hospital stay and improving short term morbidity (Greco et al. 2014) as well as lower healthcare cost (Stone et al. 2019).

Gustafsson et al. (2019) presented an updated consensus review of perioperative care in which they described evidence based recommendations for all perioperative care items of the ERAS approach, including postoperative mobilisation. They argue that while there is strong evidence regarding harmful effects of immobilisation, evidence is more limited regarding benefits of early mobilisation. However, they conclude that bedrest should be discouraged in favour of early mobilisation and that therefore, early mobilisation is an important component of enhanced recovery after surgery programs, as prolonged immobilisation is associated with a variety of adverse effects (Gustafsson et al. 2019). This was confirmed in several studies, which show that a better compliance to the ERAS program in different countries was associated with better 30 days outcomes in terms of complications, time to discharge and recovery (Ljungqvist et al. 2017) and even long-term survival (Gustafsson et al. 2016).

However, compliance to the ERAS program by health care professionals seems to be difficult in clinical practice. Overall adherence in de pre- and intraoperative period remained almost equal 3–5 years after the implementation activities had been ended, but post-operative adherence dropped considerably (Gillissen et al. 2015). One of the ERAS items for which adherence dropped enormously was postoperative mobilisation, decreasing from 90% adherence during implementation phase, to 38% 3–5 years after implementation (Gillissen et al. 2015).

Gustafsson (2019) state that more qualitative research is necessary to better understand ERAS from nurse perspective, as nurses are mainly responsible for mobilisation of patients in the ward. Klein et al. (2021) studied de perspectives of health care professionals and patients of the geriatrics and gastroenterology ward of a Dutch university hospital. They found that low physical activity levels were mostly caused by a poor physical status, patients' expectations during hospitalisation and lack of knowledge of the importance of mobilisation. Lack of time was indicated as the main barrier for health-care professionals to promote physical activity (Klein et al. 2021).

However, it is unknown whether these factors are the same for the surgical oncology ward of the HMC (Haaglanden Medical Center; a top-clinical hospital on colorectal surgery). Moreover, the possible solutions to improve mobilisation and physical activity may differ between hospitals. Therefore, the purpose of this study

is to investigate the perspectives of both nurses and patients of the HMC on how to increase mobilisation of patients after colorectal resection in the surgical oncology ward and identify factors that influence mobilisation of patients during hospital stay.

2 Methodology

This explorative study employed qualitative data collection and analysis by means of semi-structured interviews with patients and nurses of the surgical oncology ward of HMC.

2.1 Sample and Recruitment

Purposive sampling by student nurses was used to include patients (older than 18 years, Dutch speaking) who had a colorectal resection. Patients of the surgical oncology ward were face-to-face invited to participate in an interview. When a patient agreed, they received an information letter and the interview was scheduled (at least 24 h later, hence the patient could overthink their participation). Nurses of the ward were approached by email and face-to-face by student nurses. Nurses with different level of experience of the surgical oncology ward were included. When a nurse agreed to participate, they received an information letter and the interview was scheduled. Before the interview started, nurses and patients gave their written informed consent.

2.2 Data Collection

Semi-structured interviews with patients (10) were performed by student nurses AS en YW and semi-structured interviews with nurses (10) were held by student nurses DO and JA between November 2020 and January 2021. The interviews were audiotaped with permission of the participants. The interviews with patients took place in single hospital rooms and the interviews with nurses in a meeting room in the hospital. Student nurses made their own interview protocol, which was pilot tested in class by interviewing peers.

2.3 Data Analyses

All interviews were transcribed verbatum. A thematic content analysis was performed consisting of next steps: (1) The transcriptions were read and the researcher became familiar with the content of the transcriptions (2) relevant parts of the transcriptions

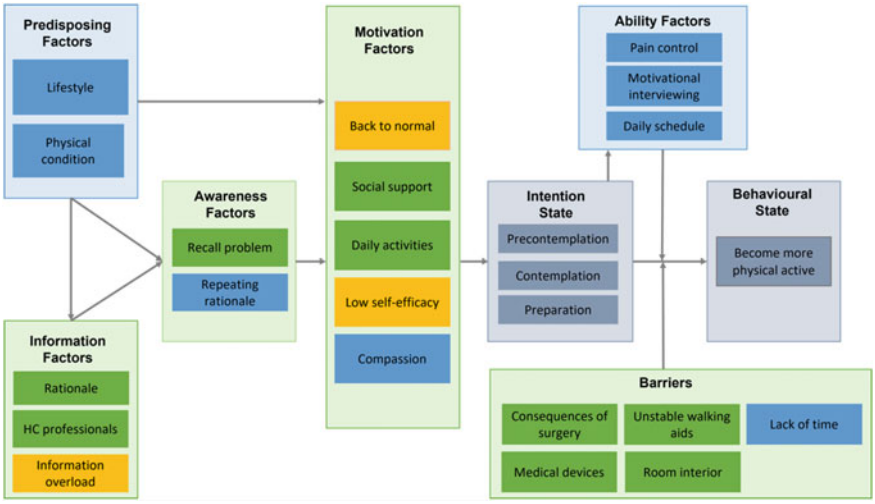

Fig. 1 The I-change model (Adapted from De Vries et al. 2003) containing the determinants of becoming more physical active during hospitalisation according to nurses (blue), patients (yellow) and both nurses and patients (green)

regarding the research question were selected (3) the selected parts of transcripts were mostly deductively coded using a code scheme based on the I-change model (Vries et al. 2003) and inductively coded when a new code emerged (4) a qualitative description of the results was made.

The I-Change model (Fig. 1) is an integrated model explaining motivational and behavioral change based on elements from different behavior theories, like the Theory of Reasoned Action, Social Cognitive Theory, The Transtheoretical Model and the Precaution Adoption Model (Vries et al. 2003). The rationale for choosing this model was that mobilisation after surgery can be seen as a health behavior and from that point of view it can be studied with this model. The I-Change model states that behavior is the result of a person's intentions. Whether the intentions will be realized depends on the person's abilities and the environmental barriers. A person's motivation determines their intention and motivation is based on predisposing factors, information factors and awareness factors (Vries et al. 2003).

3 Results

The results of the interviews with nurses and patients are summarized in Fig. 1.

3.1 Predisposing Factors

The most important predisposing factor that was mentioned by nurses was the pre-operative lifestyle and condition of patients. People who were feeling ill and weak before surgery (e.g., due to less food intake by colorectal obstruction), will have difficulties with mobilising after surgery. Furthermore, lifestyle before illness plays a role. People with an active lifestyle, will be more motivated to start exercising again after surgery than people who had an inactive lifestyle.

> Q1 on effect of pre-operative lifestyle (nurse): "How is someone before surgery? Are they in good condition; walking the dog 5 km every day? […] or is it an emergency surgery, because of a colon obstruction by a tumor which is discovered accidentally. You have to take that into account, the one patient is not the other."

3.2 Information Factors

Information about mobilisation and physical exercises is given by several health care professionals during hospitalisation: physiotherapist, nurses and medical specialists. One nurse said that some patients take the advice of a medical specialist more seriously. Therefore, it is helpful that they also mention the importance of mobilisation during their patient visits. Furthermore, nurses mention that they are responsible for repeating the information about the importance of mobilisation as patients do not think of it.

> Q2 on repeating relevance of mobilisation (nurse): "…patients are busy with themselves and with being ill. They are sick, weak and ill. And it's your [nurses'] task to let them think of something else and to repeat. Why? Why are we doing this [mobilisation]?"

The first information about mobilisation is already given to patients before surgery as part of the pre-operative information. Patients receive a booklet with information about the operation. Nurses indicate that patients do not seem to receive this information or have forgotten it. Patients mention that they receive lots of (written) information and that it was too much to read or to remember. They only read what seems to be important at the moment (preparation before surgery).

> Q3 on information overload (patient <70 y): "I received a lot of information before the surgery, I couldn't read it all. It was too much. [...] Many booklets and information. The surgery was exciting, I could not read that much, so I have only read the parts that I thought that were important".

3.3 Awareness Factors

Most of the patients indicated they know that mobilisation is important after surgery and they subscribe that this is important for their motivation to start mobilising.

However, it is not enough to be only aware of the importance of mobilising. Most patients said that they are exercising with the physiotherapist once a day and that they receive verbal information from the physiotherapist about excises they have to do during the day. However, they have difficulties recalling this information. Therefore, they feel insecure about what to do and finally do nothing. Nurses also observed that patients have difficulties remembering the instruction of the physiotherapist. These findings indicate that patients do not only need to know why they have to mobilise, but that they also need to know how they should mobilise and how often a day.

> Q4 on recall problem (patient > 70 y): "I am not sure. The exercises are not written down. Everyday, new exercises are added, and I cannot recall them all."

3.4 Motivation Factors

Motivation of both nurses and patients is needed to increase mobilisation during hospital stay. In general, nurses say they should do more to stimulate patients to mobilise. Not only by convincing patients that mobilisation is important, but actually go walk with them. Although time pressure is experienced, most of them say that they could and should do better.

> Q5 Nurse's attitude towards mobilisation (nurse): "In general, we can do better, much better. The physiotherapist is coming in the morning [...] but I think that we as nurses have to do more. Not only stimulating the patients, but also mobilising with them."

The most important intrinsic motivation that patients have to start mobilising after surgery is that they want go "back to normal" as quickly as possible. The meaning of "back to normal" is different depending on the situation and physical functioning before surgery. For some people this means going home without homecare and for other people this means walking to the playground with grandchildren or walking the dog.

> Q6 internal motivation (patient >70 Y): "Once a week, I look after my grandchildren, sometimes more often. I want to walk with my grandchildren to the child's farm again. That makes that I want to be up and running soon. That is why I am exercising."

Furthermore, social support is very important. Nurses indicate that they have to motivate patients to go out of bed and patients subscribe that support of nurses is very important to motivate them. Sometimes nurses use social norms, like telling patients that they do not eat in bed at home or that they do not receive visitors lying in bed, to convince them to come out of bed. Communication skills (like motivational interviewing) of nurses are important in motivating patients, especially when patients are not willing to mobilise.

Nurses experience that family can also play an important role. They can for instance motivate the patient to go for a little walk in the hospital together. Most nurses stimulate this by informing the family about the importance of mobilisation. They propose the family member(s) to take their loved one to the living room or garden. Patients say that they enjoy these moments with family.

Q7 on social support (patient >70y) "My wife is really involved. When she visits me, she wants to walk around immediately. That is nice. Then I keep coming out of bed and there is some daily structure."

Patients and nurses both consider that mobilising is easier when it is part op daily activities, like daily personal care moments (in the bathroom instead of in bed), eating, watching television etc. Nurses indicated that there was a project (before the pandemic) that patients went to the living room in the ward to have lunch together. Furthermore, some patients said, they would like to have some more social activities in the ward, because they are bored during the day.

Then, there are factors mentioned by nurses and patients regarding motivation, that are counterproductive. Some patients say they do not want to mobilise. They feel too weak, and think it is too soon after surgery. Their self-efficacy is low. These are mostly frail elderly patients. Nurses on the other hand, show compassion with these patients and although they know it would be better to support these patients to sit in bed or mobilise, they do not put effort in motivating these patients and let them lie in bed.

Q8 on compassion with frail patient (nurse): "I think that nurses often think: "ah, you know, these are older, let them for now. Let go."

3.5 Barriers

Physical and psychological consequences of surgery are the most important barriers that patients indicate, which prevent them to mobilise. People experience physical side effects of the anesthesia, like feeling drowsy, weak or tired. Furthermore, they suffer from pain. Next to that, people are lacking in confidence in their own body. They feel insecure and are afraid to fall down and they are afraid of pain or complications. For these reasons, most patients do not dare to go out of bed on their own. They need support from health care professionals or family members. Lack of time for supporting mobilisation in patients is a barrier that is often mentioned by nurses. Although, some of them see it as lack of priority.

Q9 on physical consequences of surgery (patient >70 y): "Well, I just had a surgery and uh, I feel a bit weak. Of course I am suffering from pain and I am scared to mobilise. I have to trust myself and my body again. I lost my confidence. I am scared to do exercises on my own."

Furthermore, medical devices are mentioned as a barrier to go out of bed. Although infusion bags can hang on the mobylizer (an infusionpole with handles which offers a little support), this is a solution for only a part of the patients. People who are used to a rollator, do not have the support they need. The mobylizer has no brakes and is not suitable for walking on a steep floor (bathroom) nor is it suitable for pulling oneself up from sitting to standing position.

Q10 on unsuitable walking aids (patient >70y): "That pole (mobilyzer) I have to walk with is really dangerous. It is not stable, you can't design a thing like this. It rolls and rolls and

doesn't stop rolling by those wheels. There is no brake on it. The handles are nice, but there is no brake."

At last, the room interior prevent patients from mobilising. The bed is in the middle of the room, with the television in front of the bed. There is a table and seat in the room, but almost all patients say that the seat is very uncomfortable. Therefore, they prefer to sit in bed while eating. This is also stimulated by the kitchen personnel as food is served on the bedside table.

Q11 on staying in bed (patient >70Y) "There is nothing to do. Today, I sat overthere [points to the chair], but the seat is really hard. I can't sit on it all day and then, there is only the bed. And the tv is above the bed, so that's the best place to watch television."

3.6 Ability Factors

Three ability factors were indicated from the interviews with nurses. Based on the interviews with patients, adequate pain control by nurses seems the most important factor. Then motivational interviewing skills are really important to convince patients to start mobilising. Next to that, this can be used to encourage self-management. Two nurses emphasized the relevance of stimulating patients to do things by themselves (like washing themselves, making sandwiches). In that way, people become more active than just lying down.

Q12 about stimulating self-management (nurse): "Washing a patient: it is easy for me to wipe over a washcloth. But, stimulate that they wash their face themselves. Stimulate it, because then they are moving their arms, and their muscles are activated, instead of lying down and let it be done."

The third factor is a combination of needs that are mentioned before. Nurses should provide some daily structure to patients and themselves, in which physical activities are incorporated in daily activities, like personal care, eating, receiving visitors etc.

Q13 about a daily structure (nurse): "Yeah, it has to be structured within the work. So, a little bit of structure, that they [patients] are going to mobilise at some moments. And a little bit of structure within our work, so we'll just do it at fixed times."

4 Discussion

The aim of this study was to investigate the perspectives of both nurses and patients of the HMC how to increase the mobilisation of patients after colorectal resection in the surgical oncology ward and to identify factors that influence patients' physical activity during hospital stay. The results of this study can be compared to the results of Klein et al. (2021), although they interviewed different health care professionals and the current study focused on the perspective of nurses. Moreover, the current study

focused on postoperative mobilisation according to the ERAS-protocol and not on physical activity during hospital stay in general. The last may be an explanation for the difference that was found between stimulating patients to mobilise. In the current study, nurses indicated that they explain to patients why mobilisation is important after surgery and that they stimulate patients in several ways, in contrary to the study of Klein et al. (2021) in which healthcare professionals said they were aware of the importance of physical activity, but they did not stimulate patients to become more active. Furthermore, Klein et al. (2021) found that lifestyle before hospitalization did not influence the physical activity during hospitalization. In our study, we did find that people who were physical active before hospitalization were more motivated to exercise during hospitalization, as they wanted to go "back to normal" as soon as possible. Whether this also resulted in more physical activity during hospitalization cannot be said based on the results of the current study. Next to differences between these studies, some similarities were found. Physical status, in our study mainly referred to consequences of surgery, were found to be a major barrier to mobilise. This was indicated by the nurses as well as the patients in our study. Besides, lack of time was found as barrier in both studies. This was supported by Pearsall et al. (2015), who studied the possible barriers and enablers for implementation of ERAS before implementation of ERAS in 7 University of Toronto-affiliated hospitals. They found that nurses felt that lack of manpower (nurses as well as physiotherapist) and time would be barriers to implement early mobilisation. Moreover, educating and reminding patients about the program would also be time-consuming according to them.

Although lack of time was found as one of the major barriers to stimulate physical activity in the current study, the attitude of the nurses was positive towards supporting mobilisation of patients. Most of the nurses said that they think physical activity is important and that they do not only have to inform patients about the importance of physical activity, but also have to act more to support physical activity, like going for a walk with patients. Besides, some solutions were given to overcome the lack of time barrier. Firstly, moments of physical activity should be incorporated in daily care moments, like personal care in the bathroom and eating at the table during breakfast, lunch and dinner. Eating together in the living room during lunch, will also provide in social support. Once these activities become the social norm, it will be easier for nurses to convince patients to join. Moreover, it gives patients some structure during the day, which some of them were asking for.

Secondly, patient's family or visitors can support physical activity of their loved ones. This may lead to one or two moments a day of physical activity during the visiting hours. Most patients indicated they would like to go for a little walk with their family to the garden or the living room. The social support of family is really important to motivate people and can be used by nurses to convince people to become more active. Thirdly, some patients said that the days last long in hospital and that they would like to have some activities to do together with other patients. Nurses cited that group lessons were given by the physiotherapist geriatrician and before.

The main barrier for patients to become more physical active, are the consequences of the surgery. Firstly, this is the result of the anesthesia. They feel drowsy and

weak. Therefore, the day of the surgery and the day after surgery, support of care professionals is needed to start with early mobilisation. Secondly, patients mostly feel insecure and are afraid to mobilise (afraid to fall and afraid of pain) and they do not dare to go for a walk on their own. Adequate pain control by the nurses is a precondition for becoming physical active. In the interviews nurses said that they are aware of the importance of pain control and that they give pain medication in advance of physical activity.

Some patients experience an information overload in the pre-operative phase. They can only remember the most important information according to them for that moment. Not all information from the leaflet is read. This is endorsed by nurses as they have to repeat information about the importance of mobilisation, once the patient is in the ward. As a consequence, patients are aware of the importance of mobilisation. However, they cannot recall what kind of physical activities they can do. Therefore, they are afraid to do something wrong and stay safely in bed. This situation calls for appropriate information on the right moment. Some hospitals in the Netherlands use a mobilisation information board to inform nurses, patient and family about what kind of physical activities a patient can do, which assistance is needed, and the intensity of the activity (see e.g. https://info.mumc.nl/pub-1090#index-11923). This may be a solution for the HMC as well.

One enabler for behavior change regarding mobilisation in the hospital, which is not mentioned in the I-change model (De Vries et al. 2013), is the influence of a stimulating environment. Both nurses and patients mentioned physical, organisational and social environment factors, that may positively affect mobilisation. The interior of the patient room could be adapted in a way that the bed is no longer the center of the room. A more comfortable chair and the television in front of the chair will stimulate the patient to sit in the chair instead of lying in bed. A more comfortable chair will also stimulate to eat at the table according to patients. Furthermore, simple fitness equipment in the ward can stimulate people to cycle a bit and remind them of the importance of physical activity.

From organisational perspective, it would help patients to know when, how and with who they are going to mobilise. Such a day schedule incorporates mobilisation in daily care activities and exercise moments. This would also be helpful for nurses, as mobilisation is incorporated in their daily care activities. Finally, the social environment within the hospital can stimulate mobilisation. Organising activities for groups of patients will stimulate people to join. Mobilising and being as much physical active as possible should become the standard during hospitalisation.

5 Conclusions

In order to increase mobilisation after colorectal surgery in the HMC, it is recommended that mobilisation and physical activity are incorporated into daily care activities and is supported by family during visiting hours. The hospital environment should invite patients to become physical active. Information about mobilisation should be

provided by the physiotherapist to nurses, patients and their family in a way that they can recall this information anytime. Of course, adequate pain control is a requirement.

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Use-Related Risk Management for Medical Devices and Combination Products

Design of an Evidence-Based Checklist to Help Prevent Use Errors with Auto-Injector Pens

Jessica Schiro, Sylvia Pelayo, Louise Heyndels, and Romaric Marcilly

Abstract Auto-injector pens (AIPs) can improve a patient's quality of life. However, some human factors problems in AIP design can prompt the occurrence of use errors with sometimes dramatic consequences. AIP manufacturers are required to identify characteristics of the user interface that might lead to use errors. This identification can be time-consuming and fastidious. Here, we report on the initial steps in the design of a checklist for identifying AIP use errors (CAPU). The checklist is intended to help professionals in charge of the design and risk management of disposable AIPs to determine the likelihood of use errors more easily. A review of the literature (57 publications) enabled us to identify 341 semantic units that were representative of use errors. These errors were grouped into 50 categories and covered all the steps in AIP use (i.e. from storage to injection and disposal). Initial feedback on CAPU from human factors engineers enabled us to clarify the list's content and the way in which the use errors were listed. CAPU is intended to simplify certain tasks for risk management professionals working on AIPs. It is not intended to replace the involvement of human factors experts in AIP design, evaluation and risk management. The next steps in the project consist in developing a software version of the checklist and extending the volume and type of data underpinning it. Lastly, the checklist's usefulness and psychometric qualities should be evaluated with risk management professionals working on AIPs.

Keywords Human factors engineering · Errors · Design · Injector pen · Checklist · Risk management

J. Schiro (✉) · S. Pelayo · L. Heyndels · R. Marcilly
Univ. Lille, CHU Lille, ULR 2694—METRICS: Évaluation Des Technologies de Santé Et Des Pratiques Médicales, 59000 Lille, France
e-mail: jessica.schiro@univ-lille.fr

Inserm, CIC-IT 1403, 59000 Lille, France

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1 Background

Injector pens (AIPs) are used in many therapeutic indications (diabetes, multiple sclerosis, poisoning, etc.) and many contexts (the patient's home, medical units, the classroom, etc.) by healthcare professionals, non-professional careers (e.g., family members, friends, teachers, and even strangers in an emergency) and patients themselves. In comparison with a syringe, this medical device provides patients with significant advantages and enables them to self-inject their treatment more easily (Thompson and Lange 2013). AIPs help to reduce pain levels at the injection site (Graff and McClanahan 1998; Kadiri et al. 1998; Molife et al. 2009) and improve treatment adherence (Buysman et al. 2011; Molife et al. 2009) and dose accuracy (Clarke and Spollett 2007; Kadiri et al. 1998; Keith et al. 2004). Overall, use of an AIP improves the patient's quality of life (Graff and McClanahan 1998; Molife et al. 2009; Rubin and Peyrot 2004).

People who use an AIP in an emergency (e.g., injecting epinephrine into someone with anaphylactic shock in the street) are not trained in their use. Furthermore, many patients and non-professional careers receive little or no training. The effects of disease or handicap can considerably impair a patient's ability to handle an AIP and thus to inject the treatment correctly: for example, rheumatoid arthritis and multiple sclerosis can make it very difficult and painful to hold and actuate an AIP. Accordingly, AIPs must be as simple and easy to use as possible (Stauder et al. 2014)—especially when the device might have to be used in a medical emergency (e.g. anaphylactic shock).

In general, these medical devices are considered to be "simple" to use because they have few functions and require only a small number of steps for use. Despite this apparent simplicity, human factor problems in the AIP design process can lead to use errors, such as injection of an inappropriate dose (either too low or too high), injection at the wrong site, or the total absence of product injection (Weinhold et al. 2018). A use error has been defined as "a user action or lack of user action while using the medical device that leads to a different result than that intended by the manufacturer or expected by the user" (International Electrotechnical Commission 2015). Use errors that are avoided in time by the user are referred to as "close calls" (International Electrotechnical Commission 2015). AIP use errors can have a broad variety of consequences, depending on the therapeutic intention and the context of use. For example, not immediately administering adrenaline to a person in anaphylactic shock while waiting for the emergency services leads to a major loss of chance, whereas injecting insulin for hyperglycaemia is generally less urgent and can wait for help to arrive. It is therefore essential to prevent the occurrence of errors during the use of AIPs.

Consequently, medical device manufacturers are required to identify the characteristics of the user interface that might affect the safety of patients/users (International Electrotechnical Commission 2015). The identification of potential use errors related to a medical device must be performed iteratively and throughout the device's life cycle. There are various ways of identifying characteristics of the user interface

related to safety of use and use errors: these notably include the identification and analysis of problems described in the scientific literature, user feedback, and incident reports (such as those in the Manufacturer and User Facility Device Experience (MAUDE) database curated by the US Food and Drug Administration (FDA)) (International Electrotechnical Commission 2016).

This iterative identification can be time-consuming, tiring and fastidious. We suspected that an evidence-based tool for rapidly identifying AIP use errors would make this iterative identification easier and make the results more reliable. It has been shown that checklists of key points are of relevance in the field of technology usability (Pierotti 1995). Hence, we reasoned that a checklist might also facilitate the identification of AIP use errors.

The present article describes the initial steps in the design of a checklist for identifying AIP use errors (CAPU). This checklist is intended to help people designing or evaluating s disposable AIPs (including multidose disposable AIPs) to identify use errors more easily.

2 Methodology

CAPU was developed in three phases: (i) collection of evidence-based literature data, (ii) organisation of this information into a checklist, and (iii) initial pretests by human factors engineers with experience of evaluating AIP use errors.

2.1 Data Collection

In 2018, Weinhold et al. systematically reviewed publications on known use errors for disposable AIPs (Weinhold et al. 2018). The review was updated in March 2020 and covered original research on the usability and/or the use of AIPs published in English or French in peer-reviewed journals and conference proceedings referenced in the PubMed or Scopus databases. The main inclusion criteria were (i) studies of disposable AIPs (publications on pumps, pre-filled syringes and rechargeable AIPs were excluded), (ii) objective data on use errors (studies reporting on user or expert perceptions or opinions were excluded). The reference lists of included publications were also assessed. Three sets of keywords ("auto-injector", "usability" and "safety/error" sets) were used in the literature search. In each set, the keywords were linked with the Boolean operator "OR". The three sets were then linked with the operator "AND".

The details of the publication selection process were given in the original review (Weinhold et al. 2018). The 2020 search and analyses were updated by human factors engineers with experience of studying AIPs. A human factors engineer excluded duplicate publications, non-original studies, and publications that had not been peer-reviewed. The researcher screened the publication titles, excluded publications that

clearly fell outside the scope of the review (e.g. animal studies), and then examined the abstracts of the included publications. If the publication lacked an abstract (n = 2), the full text was examined directly. The publications selected on the basis of the abstract were checked by a second human factors engineer (Cohen's kappa for inter-rater agreement = 0.9); any disagreements were resolved by consensus. Lastly, these two reviewers and a third human factors engineer all read the full texts of 6 of the 34 remaining publications, in order to confirm the inclusion criteria and extract the data. The level of agreement between the three human factors engineers was high, and so the 28 remaining publications were shared between them.

Two types of data were extracted from the publications and (if present) their appendices: (i) data on the study and the technology evaluated, and (ii) semantic units that were representative of the descriptions of use errors or close calls. Only the second type of data was used to design CAPU. Descriptions that were not formulated clearly enough for an unambiguous understanding of the problem were not selected; only those that were understandable without having to make inferences were retained.

2.2 Analysis and Organization of the Study Data

The semantic units extracted from the reviewed publications were assessed by two human factors engineers. They grouped together the units to form categories with a good level of internal coherence and that differed from each other. In the event of disagreement, a third human factors engineer helped to form a consensus. Each error category was given a title and a description and featured a prototypic example from the literature. The number of publications reporting on each error category was determined.

Next, an analysis of the error categories enabled us to infer the correct uses of the AIP. Lastly, the use errors were ordered according to the main steps in the use of an AIP (i.e., from preparation to injection and then disposal).

A paper version of CAPU brought together all the correct uses, the associated use errors, the descriptions, and the number of publications in which the errors were observed, for each step in AIP use.

2.3 Pre-tests

Three human factors engineers who had not been involved in the study data extraction and organization but who had experience in AIP evaluation independently assessed the paper version of CAPU. They were asked whether the correct uses and error categories were comprehensible and whether they were organized in an appropriate way, and were invited to comment on CAPU's usability and anticipated uses. Lastly, the two human factors engineers who had designed CAPU met with the three having

performed the pretests, in order to discuss the feedback and come up with ways of optimizing CAPU's use and usefulness.

3 Results

3.1 The CAPU Design Process

Nineteen publications were identified during the 2020 update and were added to the 38 publications included in the initial systematic review. A total of 341 semantic units representative of use errors or close calls were extracted from these 57 publications (232 from the initial review and 109 from the update). These units were grouped into 50 error categories. The error categories were coupled to 42 correct uses (because correct use could fail in different ways) and divided into 19 steps in AIP use.

On average, each error category was mentioned in 5.62 publications (median: 3; range: 1–43). Seven categories were mentioned in at least 10 publications: incorrect injection duration (n = 43), failure to remove the cap or incorrect removal (n = 30), holding the device upside down (n = 19), failure to hold the device against the injection site or to hold it with sufficient pressure (n = 16), the incorrect injection site (n = 16), incorrect dose selection (n = 13), and incorrect attachment of the needle (n = 10).

3.2 Feedback from the Pre-Tests

Other than comments on sometimes ambiguous descriptions of use errors, the main comments on the list concerned the need to contextualize the presentation of errors according to the type of AIP studied. AIPs can be operated in different ways (e.g., with or without priming) and can have different user interfaces (e.g., with or without a window showing the AIP's contents) and contexts of use (e.g. emergency vs. scheduled injections). According to the human factors engineers, it would be more efficient to show only relevant error categories for the AIP being studied. For example, the error "failure to disinfect the injection site" should be shown for AIPs used for scheduled injections but not for AIPs used in an emergency.

The human factors engineers also suggested that the presentation of the errors should depend on the user profile. For example, human factors engineers and quality engineers need different levels of detail for the description of errors.

4 Discussion

The first (paper) version of CAPU was based on a review of the literature on known use errors. Feedback from human factors engineers with experience in the evaluation of AIPs enabled a first round of improvements for CAPU. Firstly, to avoid ambiguity, certain elements of CAPU were reformulated or specified during the conciliation meeting. Secondly, to present only use error categories of relevance for the AIP studied, the two human factors engineers who had developed the first version of CAPU identified various characteristics of the interface, operation, and context of use. They identify 24 application conditions and linked them to the correct uses and error categories.

Following this initial feedback, a new paper version was drawn up to incorporate the error categories' conditions of application (see Table 1 for a number of extracts; the complete version is available at https://forms.office.com/r/bMwswtpggT or with the QR code in Appendix).

In its current state, CAPU can be used to screen an AIP (regardless of its state of development) against the use errors known in the literature. This screen can rapidly identify risk-associated elements that must be analyzed in more detail and addressed with risk management solutions. Nevertheless, several steps remain to be finalized before CAPU is fully optimized and operational for risk management professionals working on AIPs.

Now that CAPU includes the use errors' conditions of application, the checklist's format will have to be optimized to make the design and evaluation of AIPs more efficient. A software version of CAPU is probably the way to go. Rather than being structured around the steps in use and correct use, CAPU could (for example) be presented as a software-based decision tree focused on the AIP's operating characteristics, the user interface and context of use; hence, only relevant errors that must be taken into account would be displayed. An initial decision tree is being developed.

The present version of CAPU is based solely on the results of a literature review. As recommended in the appendix of standard IEC 62366-2 (International Electrotechnical Commission 2016), other sources of knowledge on the risks of AIP use errors could be used to complete and strengthen the level of proof of the data used for CAPU. For example, incident report databases (such as the FDA's MAUDE database) could be analyzed in order to not only complete CAPU in terms of use error categories and reporting frequencies in real life but also to identify the consequences of these errors when they occur. If risk management professionals had more information about AIP use errors and the latter's consequences, they could design and implement appropriate solutions. Performing regular checks on incident report databases (whether manual or automatic) is still challenging (Marcilly et al. 2019; Schiro et al. 2017).

Lastly, CAPU's understandability, perceived usefulness and psychometric qualities must be investigated further. To this end, risk management professionals working on AIPs will have to apply CAPU to a set of AIPs. This application will provide an opportunity to collect expert opinion on CAPU and to check the level of interrater

Table 1 Extracts of the use errors known for the AIPs with the title and description, together with correct use and the step in use concerned. The errors' conditions of application are given in italics between brackets. The number of publications mentioning the type of error is given between brackets (n = …). For the sake of succinctness, the bibliographic references for the publications on the use errors are not quoted

Step in use	Correct use	Description of the use error
Choosing the device	a. Choosing the right device	Choice of the wrong device—The users take the wrong device, if there is a choice (e.g. an inactive device, or a device with another drug) (n = 2)
	b. Not reusing a device (if the device is not reusable)	Performance of several injections with the same device—The users try to reuse the same device (n = 1)
Checking the device	a. Checking device intactness	Not checking device intactness—The users do not check whether the device or the needle's external cap is damaged or whether the seal has been broken (n = 6)
	b. Checking device validity	Failure to check the device's "use by" date—The users do not check the "use by" date (n = 9)
		Failure to check the content's validity—The users do not check the state of the liquid (n = 6) (if there is a window for checking the contents)
Taking off the cap (for devices with a cap)	a. Taking off the cap	Cap not removed or removed incorrectly—The users do not know that they must remove it, or forget to remove it, or remove it in an incorrect manner (if special handling is required) (n = 30)
	b. Taking off the caps in the right order (if several caps are present)	Caps removed in the wrong order when there are several of them—The users remove the caps in the wrong order (n = 2)
	c. Not replacing the cap before the injection	Replacement of the cap—The users replace the cap before the injection (n = 1)
	d. Not touching the injection tip	Touching the tip—The users touch the injection tip (n = 5)
Preparing the injection site	a. Choosing the right injection site (if a particular injection site is recommended)	Incorrect injection site—the injection is not performed at the recommended injection site (n = 16)
	b. Changing the injection site each time (if rotation of the site is requested)	Failure to rotate between injection sites—The users use the same injection site several times in a row (n = 2)
	c. Removing clothing (for injections on bare skin)	Failure to remove clothing—The users do not remove the clothing covering the injection site (n = 2)
	d. Disinfecting the site (if disinfection is necessary)	Failure to disinfect the injection site—The injection site is not disinfected (n = 7)

(continued)

Table 1 (continued)

Step in use	Correct use	Description of the use error
Holding the device	a. Holding the device the right way up and holding the device perpendicular to the injection site	Device held upside down—The users hold the device upside down (n = 19)
		Device held at the wrong angle—The users do not place the device perpendicularly to the thigh or do not withdraw the device perpendicularly to the thigh after the injection (n = 4)
	b. Holding the device as recommended (if a particular way is recommended)	Device held incorrectly—The users do not hold the device in their hand in the recommended way (n = 2)
Triggering the injection	a. Pressing on the bouton hard enough (if triggered by a button)	Failure to press the button or failure to press hard enough—The users do not know that they must push a button to trigger the injection or do not push hard enough to trigger the injection (n = 7)
	b. Pushing the device against the skin long enough (if triggered by pressure)	Failure to push on the device long enough to trigger the injection—The users do not comply with the minimum contact time between the device and the injection site required to trigger the injection (n = 3)
	c. Pushing the device against the skin hard enough (if triggered by pressure)	Failure to push the device against the injection site or to push the device hard enough—The users do not actuate the injection because they have not pushed the device against the injection site or have not pushed hard enough (n = 16)
		Pushing the device against the injection site too hard—The users push the device too hard against the site and break the needle or the device (n = 1)
Holding the device at the injection site	a. Holding the device for long enough for the injection (if the injection is not instantaneous)	Incorrect injection duration—The users do not maintain the device in place for long enough for a full injection or maintain it for too long (n = 43)
	b. Keeping the device still during the injection (if the injection is not instantaneous)	Failure to keep the device still during the injection—The users do move the device during the injection (n = 1)
	c. Keeping the injection site still	Failure to hold the injection site still during the injection—The intended injection site moves during the injection (n = 2)
Checking the dose administered	a. Checking the dose administered (if there is a window for checking the contents)	Failure to visually check the dose administered—The users do not visually check that the right dose has been administered (n = 7)

(continued)

Table 1 (continued)

Step in use	Correct use	Description of the use error
Disposing of the needle and the device	a. Putting the cap back on the needle (if the device has a needle)	Failure to put the cap back on the needle after the injection—The users do not cover the needle after the injection or do not cover it in the recommended way (n = 9)
	b. Removing the needle from the device (if the device has a needle)	Incorrect removal of the needle from the device—The users do not remove the needle after the injection or do not unscrew the needle with its cap (n = 5)
	c. Not touching the needle (if the device has a needle)	Touching the needle after the injection—The users touch the needle after the injection (n = 1)
	d. Disposing of the needle (if the device has a needle)	Incorrect disposal of the needle—The needle's inner cap (rather than the outer cap) is used for disposal or the needle is not disposed of in a safe way (n = 5)
	e. Disposing of the device	Incorrect disposal of the device—After the injection, the device is not placed in the sharps box or in a safe place (n = 3)

agreement for each type of use error: in other words, for a given AIP, do two experts score a use error in the same way?

Even if CAPU becomes a very useful tool for risk management experts working on AIPs, it will not replace the need for input by a human factors engineer. This expertise is always essential for (i) understanding the AIP's context of use, (ii) analyzing the risks identified by CAPU in detail, (iii) implementing all the required regulatory evaluations (e.g., the development of test scenarios for summative evaluation, test performance, and analysis of the test data), and (iv) defining appropriate risk management solutions (e.g., redesigning the interface user or the instructions for use, or providing training).

5 Conclusions

On the basis of a literature review, we developed a paper checklist for identifying errors in disposable AIP use. Feedback from human factors engineers with expertise in AIPs enabled a first round of improvements. The current version of CAPU features 50 categories of use error reported in the literature and ordered according to 19 steps in AIP use. In the future, the inclusion of additional data, software development, and expert validation of CAPU should increase the tool's usefulness for risk management professionals working on AIPs.

Appendix: CAPU QR Code

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COVID-19 and Beyond: Impact on Work System Design

Analyzing the Work System Elements Impacting Burnout of Health Care Professionals in a COVID-19 Testing Laboratory

Carolina Carvalho Manhães Leite, Alexandra Chronopoulou, and Abigail R. Wooldridge

Abstract Diagnostic laboratories have faced unprecedented challenges during the COVID-19 pandemic, being under immense pressure to maintain workplace safety while remaining operational and providing the best quality of diagnostic testing. In this study, we analyzed the work system (WS) elements impacting the burnout of three health care professionals (HCPs) working in a COVID-19 testing laboratory. Data collection took place between July and August of 2021 and used surveys to capture the participants' burnout and job and organizational characteristics. We performed correlation analyses to identify the job and organizational characteristics associated with higher burnout scores and used the Systems Engineering for Patient Safety (SEIPS) framework to analyze the WS elements influencing the burnout of these HCPs. The variables highly correlated with burnout were: physical environment, social support from supervisor, social support from family/friends, control, skill underutilization, role conflict, role ambiguity, intragroup and intergroup conflict, and responsibility for people. Sixty percent of them (role conflict, role ambiguity, intragroup and intergroup conflict, social support from supervisor, and responsibility for people) were part of the organization element of the WS model, likely as a direct consequence of the abrupt and rapidly evolving status of the COVID-19 pandemic, which saw diagnostic laboratories redesigning their workflow, policies, and procedures to introduce adequate guidelines against virus diffusion. Future research will expand the sample size and timeframe of data collection to holistically explore WS design requirements (i.e., systems-based interventions) to prevent burnout of laboratory workers, a very important, and often overlooked, group of HCPs during the COVID-19 pandemic.

C. Carvalho Manhães Leite (✉) · A. R. Wooldridge
Department of Industrial and Enterprise Systems Engineering, University of Illinois Urbana-Champaign, Champaign, IL, USA
e-mail: leite2@illinois.edu

A. Chronopoulou
Department of Statistics, University of Illinois Urbana-Champaign, Champaign, IL, USA

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1 Background

Diagnostic laboratories have been essential in the fight against COVID-19 as rapid, effective, and accurate testing plays a fundamental role in identifying the disease in a timely manner and controlling further spread of the virus. Health care professionals (HCPs) working in these laboratories have been subjected to intense workload, being at a higher risk of infection due to their constant exposure to samples contaminated with the virus (Lu et al. 2021). As we navigate the third year of the pandemic, direct and continuous exposure to such stressors increases the risk of burnout. Defined as an occupational syndrome resulting from prolonged, chronic stress at work (Orrù et al. 2021), burnout results in poor health outcomes for those suffering from the condition and puts a strain on health care organizations, contributing to increased absenteeism, turnover, tardiness (Vahey et al. 2004), and low organizational commitment (Leiter and Maslach 2009). Identifying and analyzing the elements that contribute to laboratory workers' burnout has practical implications for the development of support interventions during the current COVID-19 pandemic and possible future outbreaks (Cotel et al. 2021).

1.1 A Framework for Identifying and Analyzing the Elements Contributing to Burnout

A systematic way of identifying and analyzing the elements that contribute to burnout is through the Systems Engineering Initiative for Patient Safety (SEIPS), a human factors/ergonomics (HFE) framework developed to facilitate our understanding of the system factors that contribute to healthcare quality (Carayon et al. 2006, 2014, 2020). According to the SEIPS framework, a person (or a team) performs a range of tasks using various tools and technologies, and the performance of these tasks occurs within a certain physical environment and under specific organizational conditions. This structure—the work system (WS)—affects dimensions of healthcare quality (in our case, quality of diagnostic testing) as well as outcomes associated with HCPs (e.g., stress and burnout) and organizations (e.g., organizational performance; Carayon et al. 2006). The five WS elements can be described as follows (Carayon et al. 2006, 2014, 2020):

- Person/Team: individual (or group of individuals) at the center of the system. Individuals bring with them their education, skills, and knowledge, as well as motivation and needs, physical and psychological characteristics.

- Environment: layout, noise, lighting, temperature, humidity, air quality, workstation design.
- Task: variety of tasks, job content, challenge, utilization of skills, autonomy, job control and participation, job demands.
- Organization: teamwork, coordination, collaboration and communication, organizational culture, culture, work schedules, social relationships, supervisory and management style, performance evaluation, rewards, and incentives.
- Tools/Technologies: information technologies, devices, human factors characteristics of technologies (e.g., usability).

1.2 Objective

The objective of this pilot study is to analyze the WS elements impacting the burnout of HCPs working in a COVID-19 testing laboratory.

2 Methodology

The IRB at University of Illinois Urbana-Champaign approved this study, which is part of a larger project developing improved strategies to predict burnout (Carvalho Manhães Leite et al. 2022).

2.1 Setting and Sample

We used purposeful sampling to recruit participants working in a COVID-19 testing laboratory at a University in the Midwestern United States. During the period of data collection, the laboratory processed an average of 590 COVID-19 tests per day. Three HCPs consented to participate in the study, a male and two females, with an average of 9.7 months of organizational tenure at the time of data collection. One participant had a managerial role.

2.2 Data Collection

Data were collected in July and August of 2021. For the purposes of this study, we used data from two surveys, administered 10 workdays apart for the participant with the managerial role and 20 workdays apart for the other two participants—in the larger project, participants signed up for an initial period of 10 workdays and had the chance to volunteer to continue in the study for an additional 10 workdays. The

surveys repeated the same instruments to capture the participants' burnout and job and organizational characteristics.

We assessed burnout with the Burnout Measure Questionnaire (Pines and Aronson 1988), a 21-item validated tool that has participants evaluating on a 7-point Likert scale how often they experience feelings of physical, emotional, and mental exhaustion (Malach-Pines 2005). The final burnout score, a continuous variable between 1 and 7, is the average of the 21 items, with higher scores indicating higher levels of burnout.

For the participants' job and organizational characteristics, we used 17 subscales of the National Institute for Occupational Safety and Health (NIOSH) Generic Job Stress Questionnaire (National Institute for Occupational Safety and Health 2017): physical environment, role conflict, role ambiguity, intragroup conflict, intergroup conflict, job future ambiguity, perceived control, lack of alternative opportunities, social support from supervisor, social support from co-workers, social support from family and friends, quantitative workload, variance in workload, responsibility for people, skill underutilization, mental demands, and job satisfaction. The interpretation of the NIOSH subscales follows in Table 1.

Table 1 Interpretation of the NIOSH subscales used in the study

NIOSH subscale	Interpretation
Physical environment	The higher the score, the worse the physical environment
Role conflict	The higher the score, the higher the role conflict
Role ambiguity	The higher the score, the higher the role ambiguity
Intragroup conflict	The higher the score, the higher the intragroup conflict
Intergroup conflict	The higher the score, the higher the intergroup conflict
Job future ambiguity	The higher the score, the higher the job future ambiguity
Perceived control	The higher the score, the higher perceived control
Lack of alternative opportunities	The higher the score, the higher the lack of alternative opportunities
Social support from supervisor	The higher the score, the lower the social support from supervisor
Social support from co-workers	The higher the score, the lower the social support from co-workers
Social support from family/ friends	The higher the score, the lower the social support from family/ friends
Quantitative workload	The higher the score, the higher the quantitative workload
Variance in workload	The higher the score, the higher the variance in workload
Responsibility for people	The higher the score, the higher the responsibility for people
Skill underutilization	The higher the score, the higher the skill underutilization
Mental demands	The higher the score, the higher the mental demands
Job satisfaction	The higher the score, the higher the job satisfaction

All survey data were collected and managed using a Health Insurance Portability and Accountability Act (HIPAA)-compliant, electronic tool: REDCap (Harris et al. 2009, 2019).

2.3 Data Analysis

We extracted the data as CSV files and manipulated them using R Statistical Software (v4.1.2; R Core Team 2021) and Microsoft Excel. We used the average scores of the two surveys in further analyses, to minimize the likelihood of outliers. We calculated the Pearson correlation between the burnout score and the 17 NIOSH subscales representing job and organizational characteristics. The NIOSH subscales that had correlations above 75% (in absolute value) with the burnout score were used in further analyses. In a consensus-based process, two researchers evaluated the signs of the correlations to identify whether the NIOSH subscales showed the expected direction of their relationship with burnout (e.g., higher levels of burnout associated with lower perceived control). The same researchers, again in consensus, categorized the NIOSH subscales into the five elements of the WS model embedded into the SEIPS framework (Person/Team, Environment, Task, Organization, and Tools/Technologies; Carayon et al. 2006, 2014, 2020).

3 Results

3.1 Correlation Analysis

Table 2 shows the Pearson correlations between the burnout score and the 17 NIOSH subscales.

Ten NIOSH subscales had correlations above 75% (in absolute value) with the burnout score: physical environment (−84.24%), role conflict (93.44%), role ambiguity (95.88%), intragroup conflict (99.49%), intergroup conflict (91.76%), perceived control (−99.97%), social support from supervisor (96.65%), social support from family and friends (88.79%), responsibility for people (−96.65%), and skill underutilization (99.21%). Among them, eight had the sign of their correlations reflecting the expected direction of their relationship with burnout (Table 3). We did not establish any expected relationship between "responsibility for people" and burnout because we understand that this relationship is not linear (i.e., having either too much or too little responsibility for others might both contribute to higher levels of burnout, while having some responsibility for others may help reduce burnout).

Table 2 Pearson correlations between the burnout score and the 17 NIOSH subscales

NIOSH subscale	Correlation with burnout score
Physical environment	−0.8424
Role conflict	0.9344
Role ambiguity	0.9588
Intragroup conflict	0.9949
Intergroup conflict	0.9176
Job future ambiguity	0.7457
Perceived control	−0.9997
Lack of alternative opportunities	0.6454
Social support (supervisor)	0.9665
Social support (co-workers)	0.2335
Social support (family and friends)	0.8879
Quantitative workload	−0.2042
Variance in workload	0.0455
Responsibility for people	−0.9665
Skill underutilization	0.9921
Mental demands	−0.0694
Job satisfaction	−0.5388

3.2 Work System Analysis

We used the descriptions of the five elements of the WS (Carayon et al. 2006, 2014, 2020) to categorize the 10 NIOSH subscales. "Organization" was the WS element that concentrated the majority of subscales—role conflict, role ambiguity, intragroup conflict, intergroup conflict, social support from supervisor, and responsibility for people were all classified under this element of the WS. "Task" had two NIOSH subscales—perceived control and skill underutilization—whereas "person/team" and "environment" had each one NIOSH subscale: social support from family/friends and physical environment, respectively. Figure 1 consolidates the final distribution of the number of NIOSH subscales categorized into the WS elements.

4 Discussion

Our results show that role conflict, role ambiguity, intra- and intergroup conflict, lack of social support (from supervisor and family/friends), better physical environment, lack of control, lower responsibility for people, and higher skill underutilization were all associated with higher levels of burnout. Among them, only physical environment

Table 3 NIOSH subscales, expected relationships with burnout, signs of correlations with burnout, interpretations of the correlation signs, and whether the expected relationships were observed in the data

NIOSH subscale	Expected relationship with burnout	Sign of correlation with burnout	Interpretation of the correlation sign	Expected relationship observed in the data?
Physical environment	Worse physical environment, higher burnout (Wu et al. 2008)	Negative	Lower scores for physical environment associated with higher scores for burnout, i.e., the better the physical environment, the higher the burnout	No
Role conflict	Higher role conflict, higher burnout (Maslach et al. 2001)	Positive	Higher scores for role conflict associated with higher scores for burnout, i.e., the higher the role conflict, the higher the burnout	Yes
Role ambiguity	Higher role ambiguity, higher burnout (Maslach et al. 2001)	Positive	Higher scores for role ambiguity associated with higher scores for burnout, i.e., the higher the role ambiguity, the higher the burnout	Yes
Intragroup conflict	Higher intragroup conflict, higher burnout (Elshaer et al. 2018)	Positive	Higher scores for intragroup conflict associated with higher scores for burnout, i.e., the higher the intragroup conflict, the higher the burnout	Yes
Intergroup conflict	Higher intergroup conflict, higher burnout (Livers 2003)	Positive	Higher scores for intergroup conflict associated with higher scores for burnout, i.e., the higher the intergroup conflict, the higher the burnout	Yes
Perceived control	Lower control, higher burnout (Maslach 2007)	Negative	Lower scores for control associated with higher scores for burnout, i.e., the lower the control, the higher the burnout	Yes

(continued)

Table 3 (continued)

NIOSH subscale	Expected relationship with burnout	Sign of correlation with burnout	Interpretation of the correlation sign	Expected relationship observed in the data?
Social support (supervisor)	Lower social support, higher burnout (Maslach 2007)	Positive	Higher scores for social support from supervisor associated with higher scores for burnout, i.e., the lower the social support, the higher the burnout	Yes
Social support (family/friends)	Lower social support, higher burnout (National Academies of Sciences, Engineering, and Medicine 2019)	Positive	Higher scores for social support from family/friends associated with higher scores for burnout, i.e., the lower the social support, the higher the burnout	Yes
Responsibility for people	N/A	Negative	Lower scores for responsibility for people associated with higher scores for burnout, i.e., the lower the responsibility for people, the higher the burnout	N/A
Skill underutilization	Higher skill underutilization, higher burnout (National Academies of Sciences, Engineering, and Medicine 2019)	Positive	Higher scores for skill underutilization associated with higher scores for burnout, i.e., the higher the skill underutilization, the higher the burnout	Yes

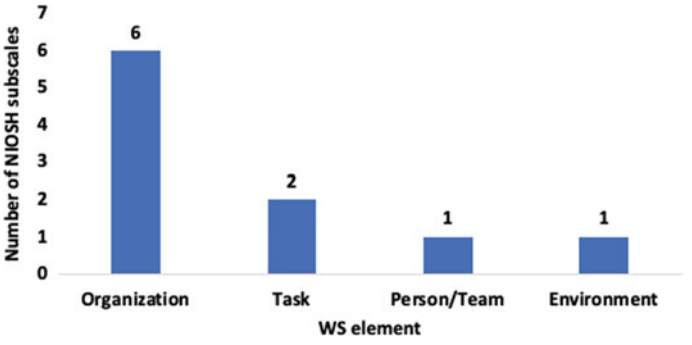

Fig. 1 Number of NIOSH subscales categorized into the WS elements

did not show the expected direction of its relationship with burnout—we discuss in detail below. The fact that job and organizational characteristics are related to burnout is hardly a surprise—research on burnout has long focused on them (Maslach et al. 2001). Maslach and Leiter (1997) formulated a burnout model centered on the degree of mismatch between individuals and their organizational environment: the greater the mismatch, the greater the likelihood of burnout and vice versa. They identified six characteristics predictive of higher levels of burnout: work overload, lack of control, insufficient rewards, breakdown in community, absence of fairness, and value conflicts (Maslach 2007). Our findings align with their model.

Sixty percent of the job and organizational characteristics highly correlated with burnout (i.e., role conflict, role ambiguity, intra- and intergroup conflict, social support from supervisor, responsibility for people) were in the "organization" element of the WS model, likely as a consequence of the abrupt and rapidly evolving status of the COVID-19 pandemic. Rationing or cessation of routine services, repurposing of clinical areas, and redeployment of staff were among the many changes imposed to diagnostic laboratories during the pandemic (Leo et al. 2021; Virk et al. 2021). For instance, the site analyzed in this study had to convert their current space to a COVID-19 testing laboratory in a matter of weeks. Even though the space was not optimal for this work, time and resource constraints precluded extensive renovation or the construction of a new, customized space. While not reported in this study, brief observations of the laboratory identified some ergonomics concerns (e.g., crowded space, challenging workstations), yet the participants rated their physical environment fairly well. This may be due, at least in part, to their relatively high level of control in making changes to the physical environment. In other words, participants in our sample were experiencing higher levels of burnout due to other factors—which may have included a poor physical environment from an ergonomic perspective—but perhaps since they were involved in controlling their physical space, they perceived it positively. Health care organizations should involve HCPs in developing and implementing workplace changes (Burgess-Limerick 2018), as "end-users that are closer to a flow during the process of design… better appreciate the final working environment" (Vink et al. 2006, p. 540).

In our sample of HCPs, almost half of the stressors involved some sort of role conflict (i.e., incompatible work demands; Beehr and Glazer 2005) and/or role ambiguity (i.e., lack of clarity about duties, objectives, and responsibilities; Beehr and Glazer 2005, p. 12). One of the major challenges faced by HCPs during the COVID-19 pandemic involved discrepancies in guidelines and protocols coupled with constant administrative and organizational changes in response to them. Such discrepancies lead to the absence of precise job descriptions, increasing the distance between the "task" and the "activity" at hand (i.e., prescribed task vs real task; Leplat 1994) and resulting in increased perceptions of role conflict and ambiguity (Alyahya et al. 2021). Work-family conflict, another type of role conflict, was also present during the pandemic, with HCPs conflicted between their duty and the fear of getting infected or spreading the infection among family members (Orrù et al. 2021). Health care organizations should support communication, coordination, and cooperation (Salas et al. 2008), encouraging a blame-free environment for laboratory

workers to report incidents, encouraging self-assessment and symptoms reporting (Baskota et al. 2021).

In dealing with organizational stressors such as role conflict, role ambiguity, and lack of social support from supervisors, the concept of organizational resilience has been proposed, so as to build reserves prior to a crisis and establish workplace cultures and systems successful in buffering work stress and increasing individual resilience (Lu et al. 2021). Sahay et al. (2022), in their study of role conflict, job crafting, stress, and resilience, established that improvisation and job crafting—"the actions employees take to shape, mold, and redefine their jobs" (Wrzesniewski and Dutton 2001, p. 180)—enhanced adaptive resilience and helped nurses cope with the challenges posed by the COVID-19 crisis. They suggest that, in noncausality crisis situations like the COVID-19 pandemic (i.e., a crisis no single organization is primarily responsible for), "organizations should work on setting realistic goals for job crafting based on available resources, communicating consistent directions around new roles, and arranging training for crisis situations" (p. 8). Just as importantly, fostering job crafting might also increase employees' perceived feelings of control and skill utilization.

Our study has its limitations—the main one relates to our small sample size; with three participants, the generalizability of the results is limited. Nonetheless, to the best of our knowledge, our study is one of the first ones to use a systematic approach like the SEIPS model to investigate the WS elements impacting burnout of laboratory workers, a very important group of HCPs during the COVID-19 pandemic. Future work will expand both the sample size and the timeframe of data collection and will holistically explore WS design requirements to address and prevent burnout.

5 Conclusions

In this small pilot, we identified and analyzed the WS elements impacting the burnout of three HCPs working in a COVID-19 testing laboratory. Sixty percent of the job and organizational characteristics highly correlated with burnout were nested into "organization", likely as a consequence of the abrupt and rapidly evolving status of the COVID-19 pandemic, which saw diagnostic laboratories redesigning their workflow (Ieni and Tuccari 2021) in a situation of extreme time and resources pressure.

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Digital Health

Investigating the Design of Online Health Consultation Platforms and Patient Experience: An Exploratory Study

Lanyun Zhang, Jingyi Yang, and Haiou Zhu

Abstract Online health consultation (OHC) platforms have been extensively used since the outbreak of COVID-19, that the number of active users has been increasing dramatically in China. OHC interfaces require a more immersive environment to support the entire medical consultation journey. This study intends to explore the design features of existing OHC platforms, and how they relate to patient experience and patient OHC journey. A literature review of design features, patient experience, and patient OHC journey was conducted to generate a framework to guide the study. Then, semi-structured interviews with 10 participants were carried out. The notions of "Design Features" were interpreted differently by individuals. For example, 'graphic design' was viewed as colour, font, icon, etc. Design Features have varying degrees of influence on "Patient Experience" and "Patient OHC Journey". This study explores what comprises Design Features of OHC platforms. The associations between Design Features and Patient Experience found in this study are different from the associations that have been found in other contexts, like e-commerce. The design on telemedicine platforms especially OHC should be studied as an independent topic to inform the design of a better patient experience throughout the OHC journey.

Keywords Online health consultation · Interface design · Patient experience · OHC journey

1 Background

Online health consultation (OHC) platforms enable patients to make inquiries regarding their health conditions and seek professional advice from physicians via the Internet. Since the outbreak of COVID-19, the number of active users who sought

L. Zhang (✉) · J. Yang
Industrial Design, Nanjing University of Aeronautics and Astronautics, Nanjing, China
e-mail: lanyunzhang@nuaa.edu.cn

H. Zhu
School of Design and Creative Arts, Loughborough University, Loughborough, England

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OHC services has been increasing in China and has reached over 15 million in June 2021 alone. Compared to other types of mobile health (mHealth) services, the OHC requires a relatively more immersive environment to support the entire medical consultation journey, so its interfaces have been viewed as an important portal to create positive user experience. Existing work have studied various types of mHealth platforms such as the telemedicine portals for rehabilitation care and Web-based patient education platforms (Dekkers et al. 2021). Design features of these platforms are categorised in different themes, e.g. visual, content, and social-cue design. Literature has also summarised several design checklists to facilitate building trust of online health sites (Van Velson et al. 2015) and to improve the overall user experience of a website (Fimberg and Sousa 2020a, b). However, the design features of OHC platforms and how the features should be practised have not been examined systematically. In particular, we aim to investigate:

(1) the design features of existing OHC platforms;
(2) how the design features influences patient experience;
(3) how the design features can be utilised to facilitate each step on patients' OHC journey.

In the following sections, firstly, to guide the study design of this paper, existing research on design features, patient journey, and patient experience are reviewed. Then, our methodological approach is described with an explanation of the results in the next two sections. Finally, a discussion of our findings is given with a conclusion.

2 Related Work and Study Design

2.1 Related Work of Design Features

Design features have been examined across different fields of studies. Wang and Emurian (2005) studied the design of e-commerce platforms and established a framework that divided web design features into three dimensions: visual design, content design, and social cue design. In the field of mHealth, existing work has explored the impact of design from various angles, e.g. how information architecture, visual effects, and information density influence patient experience (Shan et al. 2019; Jeminiwa et al. 2019; Danaher et al. 2005). However, it lacks an exploration of the design features from the very beginning of an OHC journey to the very end. Since the design of a whole OHC journey includes multiple functions and diverse features, this paper intends to adopt a concept—Form and Function, to guide the establishment of the framework in this study. The concept of Form and Function was originally discussed in the field of architecture (Greenough 1969) and it generally moved into the fields of product design and software design (Proto.io 2017). It describes the relationships between how a product looks and how a product works. In this context, OHC services can be viewed as a digital product in medical practices, that we propose its

design features to be grouped into 4 main dimensions across the 'Form—Function' axis: graphic design, information architecture, information content, and functional interaction.

2.2 Related Work of Patient OHC Journey

Customer journey map is a diagram that depicts the stages that customers go through when interacting with a service provider. Customer journey map describes the whole journey in either three or five stages according to the timeline: (1) three stages—pre-service, service, and post-service (Rosenbaum et al. 2017); (2) five stages—awareness, interest, purchase, retention, and advocacy (Guest Post 2022). Customer journey map has multiple applications and appears in various forms across different fields of studies. In the research of business and user experience, the five-stage customer journey map is frequently used and tested. In this context, patient journey map is a type of customer journey map that focuses on visualizing patient journey with the service of OHC. Efforts have been made to create patient journey map by utilising data from observations, questionnaires, and semi-structured interviews (He et al. 2021; Reay et al. 2017; de Ridder et al. 2018). OHC can be viewed as a type of private credence information goods (Wan et al. 2021). Thus, the five-stage customer journey map was adopted to structure patient OHC journey in the framework of this study.

2.3 Related Work of Patient Experience

Patient experience is an important perspective to evaluate the quality of healthcare (Ahmed et al. 2014). Previous studies have explored patient experience in mHealth mainly from two dimensions: usability experience and sociability experience (Nambisan 2011). Portz et al. (2019) explored patient experience of a patient portal in terms of usability, usefulness, credibility, and satisfaction among older adults with multiple chronic conditions. Borsci et al. (2018) explored how trust is related to the concept of user experience in the design of healthcare technology. Thus, drawing on these works, we decided to investigate understandability and usefulness as the factors of usability experience, while trust and social presence as the factors of sociability experience. In addition, health literacy is a significant aspect of patient experience because it represents one's capacity to understand, use, learn, and benefit from health information to promote and maintain one's health (Aoki and Inoue 2017). Thus, we proposed to examine the following five elements that represented patient experience in this study: understandability, usefulness, trust, social presence, and learning.

2.4 Framework Proposed to Guide the Study

Based on the research questions and integrated with the findings from literature review, a framework to guide this study was proposed (see Fig. 1). The framework consisted of three layers: "Design Features", "Patient OHC Journey", and "Patient Experience". There are multiple elements within each layer. While the elements of "Design Features" were fixed, the elements of "Patient OHC Journey" and "Patient Experience" were not fixed and can be adjusted via our empirical study later.

3 Methodology

A qualitative and inductive methodology was adopted due to the exploratory nature of this research. We conducted semi-structured interviews with 10 participants (5 male, 5 female). The participants were recruited on the university campus, aged between 22 and 25, with interests in mobile health and new technologies. Previous OHC experiences were not required in this study. After reading the information sheet of this study and signing the consent form, each participant was instructed to complete the study in four parts (see Table 1). The first part described the scenario of this study, followed by an explanation of the OHC platform. Presentation slides (see Fig. 2a) and a mock-up App on Adobe XD (see Fig. 2b) were developed to illustrate how to use the OHC platform. Here, the mock-up was developed based on a popular Chinese OHC platform, Yilu (医鹿). The participants were allowed to ask questions at this stage. The second part started with an introduction of the general concept of design features, followed by asking the participants to specify the design elements they noticed. The third and fourth part began with an introduction of patient OHC journey and patient experience, followed by asking the participants to specify their opinions regarding

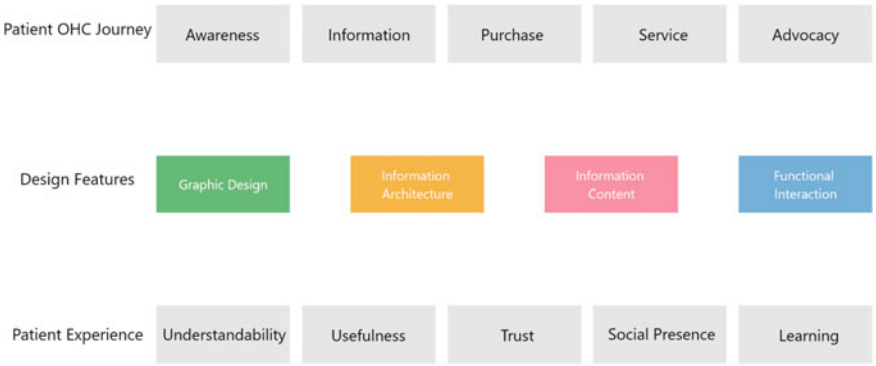

Fig. 1 Framework proposed to guide this study

Table 1 Study procedure

Part 1: Scenario	*One day, you find yourself have a rash on your neck. Since the rash is not extremely itchy or burning, and you are busy recently, so you decide to not visit the GP or see an off-line physician. As a result, you decide to choose an alternative: online health consultation platform 'Yilu', for professional help. Yilu is one of the mostly used OHC platform in China* Presentation slides and a mock-up App were developed to illustrate the existing version of Yilu App and how to use it. At this stage, please listen carefully and ask if you have any questions
Part 2: Questions about Design Features	The general concept of design features is introduced, including graphic design, information architecture, information content, and functional interaction. **Question**: please feel free to play with the mock-up App and write down any specific design feature you notice while browsing the App
Part 3: Questions about the relations between Design Features and Patient OHC Journey	Five stages of OHC journey are introduced, including awareness, information acquisition, payment, service, and advocacy. **Question**: what design feature(s) you just wrote down in Part 2 have significant impact on each stage of OHC journey? How? And why?
Part 4: Questions about the relations between Design Features and Patient Experience	Five dimensions of patient experience are briefly introduced, including understandability, usefulness, trust, social presence, and learning. **Question**: what design feature(s) you just wrote down in Part 2 can significantly influence patient experience? How? And why?

whether there was a design feature that influenced OHC journey and patient experience. Figure 3 shows the collected on-paper data from one participant. The stickers with four colours represented the four categories of "Design Features": green—graphic design, orange—information architecture, pink—information content, and blue—functional interaction.

4 Results

4.1 Design Features

Design features were classified into four themes based on the thematic analysis of the audio recordings—graphic design, information architecture, information content, and interactive features (see details in Table 2).

Graphic Design. Colour, font and icon were the most frequently mentioned elements by participants, in which 7 participants emphasized the importance of colour. As for the reason why colour was viewed important, firstly, patients' perception of professionalism was influenced by the choice of colour, that whether it matched up with the healthcare context. One participant specified that *"I would link to blue or green when physicians were mentioned. If the platform chooses other*

Fig. 2 Presentation slides (**a**) and a mock-up App based on Adobe XD (**b**) developed for this study

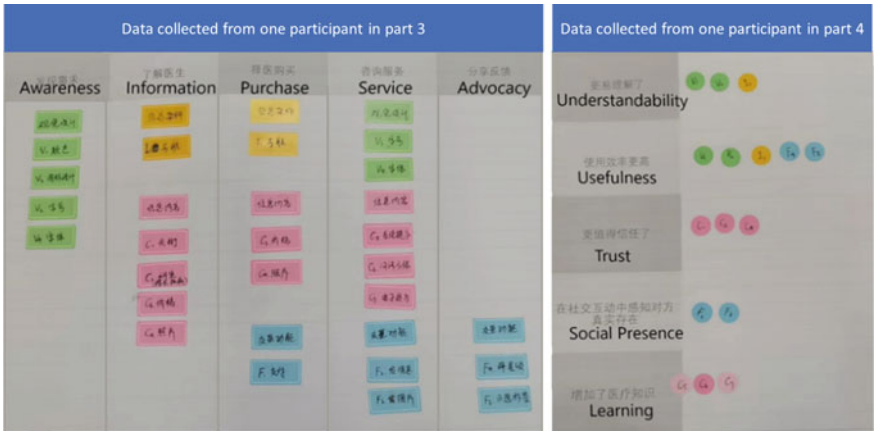

Fig. 3 The collected on-paper data from one participant

colours, it will make me feel a little bit strange". Secondly, colour could implicitly influence emotions and behaviours, as one participant stated that *"Colour combinations clearly affect patients' mood. The platform should look clear and neat, just as a hospital should do. For example, the choice of colour should be harmonious rather than complementary"*.

With regards to font, it was agreed that the choice of font influences the navigation, i.e. how quickly one can find the needed information. The remaining elements mentioned by the participants were banner, superscript, style, and white space.

Table 2 The elements mentioned under 4 different design feature themes

Design features	Number	Element		Number of cases coded
Graphic design	G1	Colour		7
	G2	Font		6
	G3	Icon		6
	G4	Banner		4
	G5	Superscript		2
	G6	Style		1
	G7	White space		1
Information architecture	I1	Navigation		8
	I2	Layout		5
	I3	Search		3
Information content	C1	Hospital information		4
	C2	Physician information	Fee	7
	C3		Rating	4
	C4		Review	3
	C5		Rank	3
	C6		Photo	3
	C7		Profile	2
	C8		Typing status	2
	C9		Favourable rate	1
	C10		Expertise	1
	C11	Other information	Consultation summary	2
	C12		Risk disclaimer	2
	C13		Function title	2
	C14		Patient's medical record	1
	C15		Support	1
Functional interaction	F1	Navigation	Search	3
	F2		Department navigation	3
	F3		Tab navigation	1
	F4		Area selection	1
	F5	Information collection	Evaluation	5
	F6		Medical record collection	2
	F7	Payment		3

(continued)

Table 2 (continued)

Design features	Number	Element		Number of cases coded
	F8	Service	Consulting	3
	F9		Choose consulting method	1

Highlighted: elements that are found unique in OHC services

Banner is a graphical unit for web-advertising, usually in the form of long strips. Superscript refers to the small label on top of an icon to provide additional information. Style represents the appearance of the interface, usually related to visual impression. White space is the blank area around the content and functional elements, which is usually left blank intentionally.

Information Architecture. Navigation was mostly mentioned that 8 participants expressed their understandings of navigation through using the following words: "navigation", "sidebar", "hospital department", and "navigation menu". These words were grouped under the theme navigation because the participants intended to express that OHC functions and icons should be classified into sub-groups to help patients find their way around. One participant stated that "the (OHC) platform has a lot of functions, so its navigation is important as to help users know which function to click, where, and how". 5 participants highlighted the importance of layout. Layout describes the rationale and form of how OHC information is presented. The words mentioned included order, sequence, card, and physician information layout. One participant believed that the layout of a page should be simple to reduce noise. At last, search was mentioned by 3 participants. For example, one participant expressed that the OHC interface should enable users to search keywords manually, that "it is helpful to find the functions I need directly".

Information content. The elements of information content discussed have crossed multiple and mixed dimensions. In consequences, we divided all elements into three groups: hospital information, physician information and other information. Relatively speaking, there was little discussion about hospital information, with only 4 participants mentioning it. When it comes to physician information, the mostly mentioned phrases included consultation fee (7), physician's score (4), physician's review (3), rank of a physician (4), physician's profile photo (3), and physicians' current typing status (2). 2 participants stressed the importance of physician's current typing status, as one participant said that "If I see 'typing…', I will know that whoever I am speaking to is still online. It will make me more confident and comfortable about this consultation". A few participants mentioned the elements that were classified under the theme other information, such as consultation summary (2), risk disclaimer (2), function title (2), patient's medical records (1), and support (1). Regarding consultation summary, one participant said that "it's important to have a summary of a health consultation that can help me have a snapshot of my current condition and future treatment plans". Support was also critical in OHC services, as

one participant mentioned that "Due to the lack of medical knowledge, I have trouble finding the right out-patient specialist for my symptoms. Maybe a guide should be provided to advise me to a specialist".

Functional interaction. The designs of functional interaction were classified into navigation, information collection, payment, and service. Search and department navigation were the mostly mentioned topics, as one participant said that "Choosing the right out-patient specialist is very important. Only if I get to the right people, can I have my symptoms checked". Five participants emphasised that the interaction in the evaluation page at the end of the OHC experience was critical. Two participants pointed out the design of collecting personal medical information, that one said "I noticed that there was an automatic programme asking me questions at the beginning with a template. It's good that I don't need to enter all the information manually".

4.2 Relationship Between "Design Features" and "Patient OHC Journey"

Figure 4 illustrates the relationship between "Design Features" and "Patient OHC Journey". The OHC journey was derived from the standard customer journey map, including five stages: awareness, information acquisition, purchase, service, and advocacy. Firstly, most participants expressed that graphic design had strong influence on the stage of awareness and information acquisition. Only one participant believed that graphic design was more important in the advocacy stage, that he specified "well designed graphics will encourage users to leave feedbacks and share experiences, which is a good thing for the continued growth of the platform". Secondly, a large number of participants agreed that information architecture was critical in the stage of awareness and information acquisition. Only one participant expressed that information architecture had great impact on purchase and service, that "there are multiple tasks in purchase and service stage. For example, patients need to fill in personal information, symptoms, and make payment in the purchase stage. A priority is required and should be properly represented through information architecture". Thirdly most respondents mentioned that information content was closely related to the stage of information acquisition, followed by the stage of service. Lastly, functional interaction was equally mentioned among the five stage of patient OHC journey.

4.3 Relationship Between "Design Features" and "Patient Experience"

Figure 4 also illustrates the relationship between "Design Features" and "Patient Experience". The patient experience includes five dimensions: understandability,

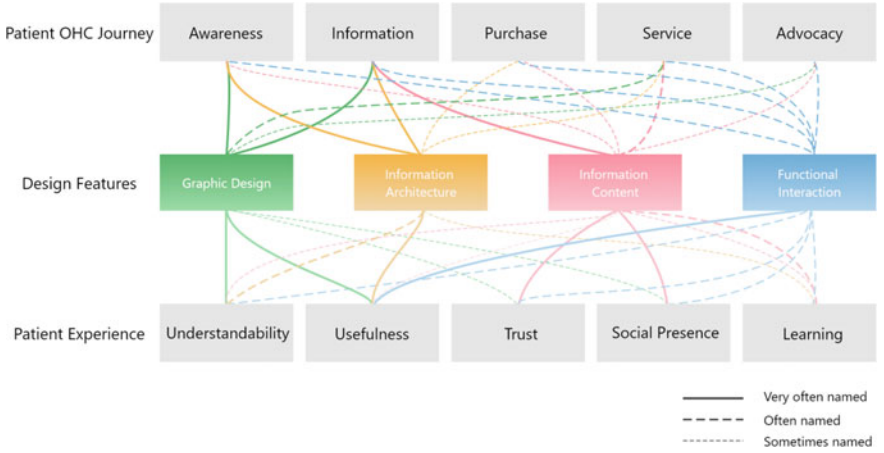

Fig. 4 The relationships of "Design features—Patient OHC Journey" and "Design Features—Patient Experience"

usefulness, trust, social presence, and learning. Firstly, visual design was frequently mentioned with relation to understandability and usefulness of patient OHC experience, more specifically, colour, icon, and font. Secondly, Information architecture (navigation and layout) was viewed to be influential to usefulness. Thirdly, information content was viewed to mostly impact on patient trust and social presence. Lastly, the elements of functional interaction were found to be more influential to the experience of usefulness, compared to other user experience elements.

5 Discussion

In this study, we found a number of design features in the current OHC platforms, that they have been categorised in four themes: graphic design, information architecture, information content, and functional interaction. Some of the design features we found have been discussed by existing papers, but some are different and unique in this context of OHC. For example, the elements in graphic design and information architecture, such as colours, fonts, icons, and navigation have already been thoroughly discussed by previous studies in the online environment (Seckler et al. 2015; Huang et al. 2018; Shen et al. 2021; Kim and Lee 2002). The uniquely found elements were all from the themes: information content and functional interaction, including physician rank, physician photo, physician typing status during online consultation, consultation summary, patient medical information collection, department navigation, consulting, and choose consultation method. These design features enrich our understandings of the interface design of OHC.

In addition, we also found that graphic design and information architecture were viewed more important at the early stage of patient OHC journey, while information content and functional interaction tend to play an important role at the late stages. Our findings are consistent with the findings of previous studies (Fimberg and Sousa 2020a, b; Lindgaard et al. 2006) that patients mainly scroll through the OHC interface to browse information or locate specific functions at the early stages. At this moment, the visual aspects of interface design such as graphic design are responsible for creating a positive first impression. Then, patients will pay more attention to the actual information content and quality of consulting as they decide to continue using the OHC services.

To address the last research question, we investigated the relationship between "Design Features" and "Patient Experience". It is consistent with previous studies that well designed graphics and information architecture can enhance users' perceived usability (Tuch et al. 2012). Our findings also show that elements of graphic design and information architecture were also frequently mentioned when understandability and usefulness were asked. However, these elements were rarely mentioned when trust was asked, which is quite different from existing findings in the context of e-commerce. Previous studies have found that well designed graphics is more likely to gain customer's trust (Li and Yeh 2010) and evoke positive emotions (Plass et al. 2020). Future work could explore further regarding this difference.

6 Conclusions

This study contributes to the knowledge of design features in the context of OHC interfaces and extends the understandings of how design features influence patient experience and patient OHC journey. Further, our findings provide a number of implications for the design of OHC platforms. In terms of graphic design, practitioners should choose the appropriate colour, colour combination, font, and icon; in terms of information architecture, clear layout design is needed to make sure that users get the required information and function quickly; in terms of information content, relevant information should be reasonably arranged so patients can understand more easily; in terms of functional interaction, the attention lies in the service delivering, which is the substantial goal of OHC platforms.

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Building Understanding of Experience Design in Digital Health: Preliminary Results Based on Semi-Structured Interviews

Tingting Wang, Shuxian Qian, Haiou Zhu, Richard Goossens, Guido Giunti, and Marijke Melles

Abstract Design is expanding its influence on shaping future healthcare. Ideally, designers apply human-centered design and human factors that introduce theory, principles, and methods to design to optimize people's healthcare experiences in both digital and non-digital environments. To discuss and implement experience design in healthcare, consensus about experience design in healthcare is needed. Objectives: Therefore, the purpose of this study is to investigate designers' views on experience design in health, and to uncover their understanding about three experience design concepts, i.e., user experience (UX), patient experience (PEx), and digital patient experience (dPEx). We conducted online semi-structured interviews study with convenience samples who met the eligibility. We used ATLAS.ti for an in-depth data coding following thematic analysis. 24 international designers of digital health solutions, either in industry or in academia took part in the interviews. We found the similarities and differences mentioned between healthcare design and non-healthcare design relate to (1) design principles, (2) user attributes, and (3) design contexts. Furthermore, the differences between UX, PEx, and dPEx can be mapped on five dimensions: people, contexts, purposes, means, and usage scenarios. These insights can help designers and human factors specialists build a common design language for experience design in healthcare. Our study can also assist designers and human factors specialists with experience design in digital health by pointing out the areas where design thinking generally is appropriate and the places where particular expertise in healthcare design is needed.

T. Wang (✉) · S. Qian · R. Goossens · M. Melles
Delft University of Technology, Delft, The Netherlands
e-mail: t.wang-8@tudelft.nl

H. Zhu
Loughborough University, Loughborough, UK

G. Giunti
University of Oulu, Oulu, Finland

Trinity College Dublin, Dublin, Ireland

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1 Background

Design is expanding its influence on shaping future healthcare (Groeneveld et al. 2018; Tsekleves and Cooper 2017). For instance, designers are promoting the use of digital technologies and medical equipment in care domains by working at the interface between people and technology (Groeneveld et al. 2018). As the focus of healthcare shifts from disease toward patient experience (Ekman et al. 2011), experience design has become a crucial part of healthcare design for creating an efficient healthcare system and improving care quality (Lee 2019). Designing experience in healthcare brings together a variety of disciplines and stakeholders, which requires aligning the goals of organizations, technology, and people in the real world. Ideally, designers apply human-centered design (Bazzano et al. 2017) and human factors (Cafazzo and St-Cyr 2012) that introduce theory, principles, and methods to design to optimize people's healthcare experience, in both digital and non-digital health sectors.

Experience is generally defined as what a person thinks, feels, and says about the experience of a service, process or product the person has encountered (Bate and Robert 2006). Design is emerging as an influential field in understanding experiences of these situations and how they can be improved (Jones 2013). Experience design starts by clarifying the needs and emotions involved in an activity. It then shapes the functionality that can deliver the experience and finds an appropriate way of making the functionality into action (Cafazzo and St-Cyr 2012). In the field of healthcare, individuals may play the roles of consumers or patients, and their interpretations of the term "experience" can vary (Castle-Clarke and Imison 2016). Similar to this, designers could have different perspectives on "design experience for patients". Design can impact or promote "experience", but without agreement on a common design language (Jones 2013), the designed outcomes may not be successfully ingrained in reality. Furthermore, as digital technology becomes ubiquitous in healthcare, which adds another dimension to the complex healthcare design (Jones 2013). Given how easily it can be misunderstood in the context of healthcare, it is crucial to clarify what experience means at the very beginning.

In healthcare design practice, patient experience is one of the widely used experience concepts. It is defined by The Beryl Institute as the sum of all interactions, shaped by an organization's culture, that influence patient perceptions, across the continuum of care (Institute et al. 2021). Besides, user experience is often used when talking about the design of digital health. In the current study, we define it as a person's perceptions and responses that result from the use and/or anticipated use of a product, system or service (Bolton 2018; Jokela, et al. 2003). In keeping with our earlier research (Wang et al. 2022), which investigated the concept of digital patient experience (dPEx) and defined it as the sum of all interactions affected by

a patient's behavioral determinants, framed by digital technologies, and shaped by organizational culture, that influence patient perceptions across the continuum of care channeling digital health. Therefore, in this study, we aim to (1) investigate designers' views on experience design in health, and (2) uncover their understanding about three core concepts, i.e., user experience (UX), patient experience (PEx), and digital patient experience (dPEx).

2 Methodology

We conducted a semi-structured interview study with purposive sampling (Etikan et al. 2016) until the saturation threshold was achieved (Fusch and Ness 2015). The study was approved by the Human Research Ethics Committee of Delft University of Technology in September 2021.

2.1 Participants Recruitment

Using snowballing recruiting method (Streeton et al. 2004), designers were recruited between November and December 2021. The inclusion criteria of interviewees were proposed by TW and adjusted by GG, MM, and RG as follows:

- Currently working in industry or academia
- Involving in at least one digital health design-related project
- English or Chinese speakers.

Participants were asked to think back on an impressive digital health-related design project they had been involved in and share the project information (if applicable) in advance with the interviewer (TW), for example, project name, description, or relevant link.

2.2 Interview Procedure

An outline with semi-structured questions was developed to obtain the overall experiences and views of designers in relation to how the digital patient experience was addressed in their design process. Each interview lasted between 1–2 h and was conducted in English or Chinese using online meeting software. The interview consisted of 4 phases:

- Phase 1: warm up conversations
- Phase 2: introduction of interviewees about their background and work experience
- Phase 3: diving into the main theme of dPEx
- Phase 4: closing questions.

Following the interview, a follow-up questionnaire with two close-ended questions was administered to understand designers' priorities in regards to previously identified influencing factors and evaluation metrics (Wang et al. 2022).

2.3 Data Extraction and Thematic Analysis

Audio-recordings were transcribed and deidentified to prepare for analysis. Anonymized transcriptions were imported into ATLAS.ti (Scientific Software Development GmbH; Version 22.1.0; 3475) for data analysis. Data were extracted from the following aspects: (1) participants' characteristics, including gender, major, year of graduation, job title, work domains, work years, numbers of digital health projects involved, company type, company size, and work location; (2) characteristics of digital health design-related projects, such as design contexts, target users; (3) views of healthcare design and understandings of experience concepts in healthcare; (4) the typical workflow of digital health design; (5) influencing factors of dPEx; (6) evaluation metrics of digital PEx; (7) good dPEx's elements; (8) healthcare design challenges; and (9) healthcare design knowledge building. Considering the research objectives of the current study and the limited writing space, in this paper, we only present the findings of the first three aspects mentioned above as the preliminary results of the current study. The remaining results will be presented in another parallel publication.

We used Braun and Clarke's six-phase thematic analysis method (Braun and Clarke 2006) to analyse the extracted data. After becoming familiar with the data, an initial coding scheme was generated by TW. Three coders were involved in the entire iterative coding process (TW, QS, and HZ). Three transcriptions were used by TW, QS, and HZ as initial samples to test the coding scheme, followed by a group discussion to deal with any discrepancies about the codes. When coders reached an agreement, the remaining 21 transcriptions were randomly divided, and each coder coded 7 transcriptions independently. The whole coding process followed a few coding techniques: (1) Generate codes as close to the original texts as possible; (2) Use clear structures (e.g., verb phrases, noun phrases) to formulate the codes; (3) Simplify and clarify the codes; (4) Minimize the number of codes; (5) Use English codes to code Chinese texts; and (6) Highlight uncertain codes for later group discussions.

3 Results

3.1 Participant Characteristics

A total of 24 digital health designers were interviewed, which covered a diverse set of backgrounds and healthcare design practices. Of them, 18 (75%) were female designers. Most participants (n = 20/83%) hold master's degrees, while

two individuals (n = 2/8.5%) hold bachelor's and two individuals (n = 2/8.5%) hold doctoral degrees. They graduated from 2005 to 2020. Their years of working experience ranged from 1 to more than 16 years, with 5.5 years being the average. They are employed as (industrial, UX, service, interaction, or strategic) designers; design researchers; design leads; engineers; advisors; managers; or founders. As of company size, 8 (33.3%) of them work for small businesses (less than 50 employees), 4 (16.7%) work for medium businesses (50–200 employees), 10 (41.7%) of them work for large corporations (over 200 employees), and 2 (8.3%) work in academia. These companies, which are in the Netherlands, China, the United States, the United Kingdoms, Canada, Sweden, Norway, or Spain, are involved in design agencies, hospitals and healthcare, electronic manufacturing, medical equipment, internet-related sectors, consultant agencies, or universities.

3.2 Project Characteristics

During the interview, each participant was asked to share one of their most impressive digital health-related projects. Most of these projects (n = 20/83.3%) were professional projects; the remaining projects (n = 4/16.7%) belonged to master students. We categorized these projects into the following three types:

- Interaction design: the design of interfaces, websites, and mobile applications (n = 17/71%).

"To develop a mobile app that can be used to conveniently explain the use of the device for people who are having migraine. And that can be also used to survey these people, people about their experience throughout the treatment." [P2].

- Strategic design: the design of new care models, patient journeys, innovative roadmaps, care centres or departments (n = 9/37.5%).

"To help them to translate all these ideas or these visions, or all these ways in which they thought about the future of health, get to bring that together and connect this knowledge to facilities management to the people were eventually gonna design the look." [P20].

- Product design: the design of industrial medical products or wearable devices (n = 3/12.5%).

"We developed a screening and monitoring device, which is used to diagnose patients with respiratory disease and asthma problems". [P14].

Among the reported projects, there were three distinct stakeholder groups mentioned to be involved in the design process (see Fig. 1). Notably, not all stakeholders were involved in each project.

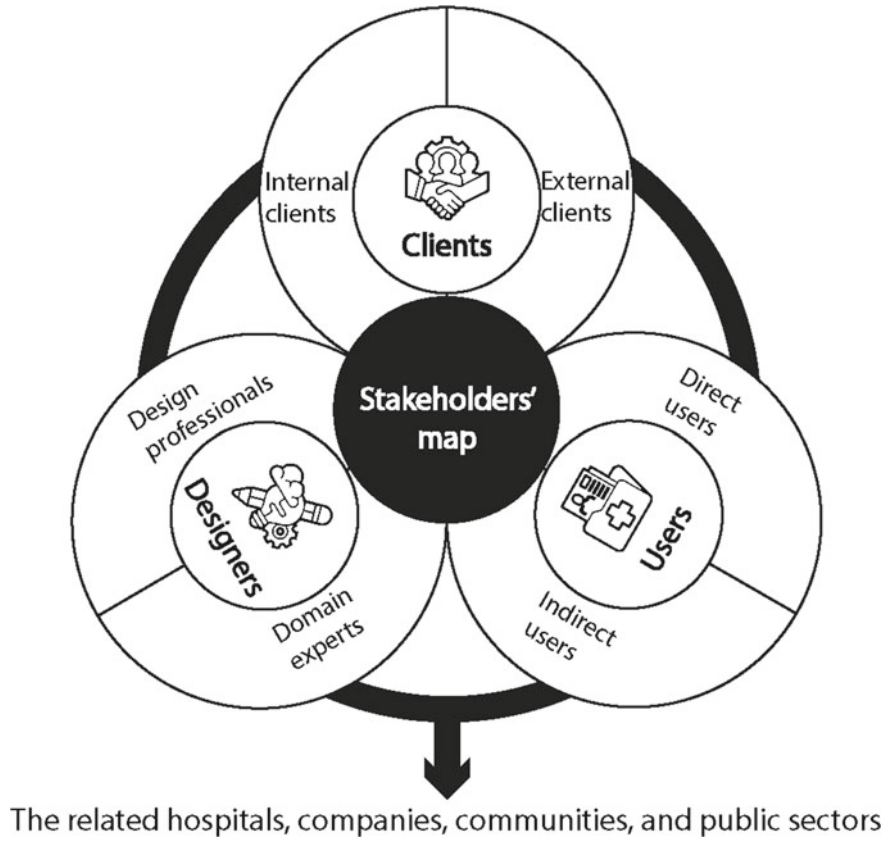

Fig. 1 Stakeholders' map of healthcare design

- Clients

Internal and external business customers who initiate a design proposal. Half of the reported projects (n = 12/50%) were initiated by external clients, such as hospitals or third parties, and the rest (n = 12/50%) were self-developed.

"When I joined, the one of my first projects… is a remote based monitoring solution for episodic care…" [P9].

- Designers

Design professionals (e.g., managers, designers, engineers, and programmers) and domain experts (e.g., medical experts, policy experts, business experts, and patient representatives) who work on the design project. Most professional projects are processed by big design teams that have both design professionals and domain experts. However, rather than having a real team, participants in the student projects

claimed that there were people (such as supervisors, physicians, or patients) who were assisting them.

"We've got so many more designers and developers and managers and executives, so that there's always a bigger team." [P22].

- Users

Direct and indirect users who contribute to testing design outcomes and are the sources of healthcare needs. Most participants work directly with patients or conduct observations. While when it comes to the vulnerability and privacy concerns of the target patient groups, designers frequently receive information on patients (i.e., direct users) from doctors or nurses (i.e., indirect users).

"I had a lot of help from the care staff to understand what was happening from dementia point of view. But on the other hand, the family members were knowing their parents from the past like…" [P22].

Besides, many participants mentioned the hospitals, companies, communities, as well as public sectors to have an impact on the entire design process as well. Considering the health issues, the majority of initiatives (n = 15/62%) were centred on chronic illnesses, including diabetes, migraine, sleep problems, insomnia, high blood pressure, kidney cancer, breast cancer, stroke, cognitive impairments, psychological therapy, and multiple sclerosis, and followed by acute illnesses (n = 4/17%, orthopaedic surgery, COVID-19, asthma, post-surgery), and other (n = 5/21%, pregnancy, general health difficulties).

3.3 Design in Health

Regarding differences and similarities between designing for patients and designing for healthy people there was a clear division in opinions among the participants: some (n = 13/54%) argued there is a big difference, while others (n = 11/46%) believed that design for patients and design for healthy people is the same. We found the similarities and differences mentioned between healthcare design and non-healthcare design relate to (1) design principles, (2) user attributes, and (3) design contexts (see Table 1).

- Design principles

More than half of the participants think there is no difference between designing for patients and for healthy people because they share the same design process and methods. However, other participants argued that the biggest focus of healthcare design is curing patients, while the objective of non-healthcare design is making

Table 1 Differences and similarities between healthcare design and non-healthcare design

Categories	Themes	Same (√) or different (x)	Quotes
Design principles	Design process	√	P1: I wouldn't say that the process would be different, because there are a lot of situations or topics that can be sensitive, not only if you're ill. So no, I would say there's no difference
	Design methods	√	P18: Design principles, methods and empathy are the same in each domain
	Design value	x	P13: Experience and comfort come as fasting when you're designed for healthy people, because the people are already healthy. So, it's basically making their lives a little bit easier. And for patients, the biggest focus is saving them. So, it's basically making it comfortable on saving the patients. Two objectives
	Design requirements	x	P2: But, in general, for designing for the medical field…you have to make sure your quality management throughout the development process is well built up and well documented. Because in the medical fields, you always have to prove the things work… and you have to test and show that you made the best decisions. So that's very different
User attributes	Health status	√	P12: Design solution based on different scenarios, not between healthy or unhealthy status
		x	P3: I try to think about patients in the context of their lives that they are not their diseases, they are not their conditions…But I also don't want to lose sight of the fact that they do have extreme circumstances that need to be accounted for
	Health needs	√	P7: Patient and general user are somehow the same because sometimes they don't know their real need
		x	P10: patients and healthy people have different expectations, patients want to be normal, but healthy people want to be better than normal life
	Engagement	x	P20: Maybe there is one big difference that I've seen. It's the amount of engagement people have with their own care data, right? Someone is sick. They will be more motivated to do measurements

(continued)

Table 1 (continued)

Categories	Themes	Same (√) or different (x)	Quotes
	Multi-users	x	P6: User experience includes different users such as patients, maintenance staff and other users in the whole service blueprint
Design contexts	Restriction of regulations	x	P18: The real differences arise from social regulations and prevailing thoughts in the field of healthcare
	Complexity of scenarios	x	P5: All these things that you don't really have to think of when you're designing consumer products, because you assume anyone has a phone. When you think of products within healthcare, it becomes a lot trickier because then you have to think of the context of use like if they're in the patient house, if they're in the hospital…And so that's a huge issue
	Maturity of industry	x	P8: And the reason that I went into healthcare also because I see that there is so much that still needs to be done if you compared to commercial market
	Sensitivity of data	x	P7: But the most significant difference is the patient privacy is more protected. Or general, you ask users I want to design a coffee machine for you, what kind of coffee do you like and spend one or two hours talking about their expectation for having coffee. But if you ask cancer patient that what's your expectations on the patient bed in the hospital, they may not be open to share everything… Also, the ethical issue should be taken more into consideration…

users' normal lives a little bit better. The healthcare field requires much more evidence-based design than in other domains.

- User attributes

Some participants believe that patients' health status is different from that of healthy individuals, which has unexpected consequences that even patients themselves may not be aware of. However, others argue that a healthy individual can sometimes be a patient with ups and downs in daily life while a patient also has daily life needs just like a healthy person. As a result, there aren't many differences in designing for healthy and sick people. Additionally, some participants believe that expectations between ill and healthy persons are different. Patients desire a healthy and normal life, whereas healthy individuals want to be better than normal. Others counter that because sometimes no one is aware of their true needs, ill and healthy people are

somehow similar. The majority of participants concur that sick individuals will be more inclined to adopt and actively participate in design solutions. Additionally, they concur that there are additional users and stakeholders need to consider during the design flow of healthcare design projects.

- Design contexts

Another category is about design context. Most participants think that the design context is more complex in the healthcare domain than in the non-healthcare domain. In the healthcare industry, the regulations are more restrictive, the usage scenarios are more complicated, the business models are underdeveloped, and data collection and storage are more sensitive.

3.4 Experience Design in Digital Health

Participants provided a range of responses when asked how they perceived user experience (UX), patient experience (PEx), and digital patient experience (dPEx). Notably, even though we did not always use the term "digital health", given the participants' professional backgrounds and the study's main objective, the conversation was consistently about designing for digital health.

The differences between UX, PEx, and dPEx were mapped on five dimensions: people, contexts, purposes, means, and usage scenarios (see Table 2). They concerned with the interactions among humans and other elements of the digital health system.

- Between "specific" and "general" people: in contrast to PEx, which exclusively focuses on patients, UX is more general because it takes into account everyone involved in the entire service plan. Both of them refer to human-centered design, the former focuses on patient-centered design, the later relate to user-centered design.
- Between "continuous" and "momentary" contexts: (digital) PEx is considerably more continuous and permeates patients' everyday life than UX, which is more concerned with momentary touchpoints. This dimension indicates human–computer interactions have longer impact on (digital) PEx than general UX.
- Between "emotional" and "functional" purposes: (digital) PEx is far more emotionally loaded and is more influenced by patient specific situation than UX. The former focuses more on patients' well-being, it is substantially more complex, intangible, and challenging to measure than the latter, which focuses more on overall system performance and can be evaluated using a usability test.
- Between "digital" and "hybrid" means: dPEx is the digital way of the PEx. It highlights human-technology relationships than general PEx in healthcare context. Notably, the design of digital health and non-digital health is not a binary opposition. To some extent, participants reported that dPEx should be incorporated into the offline experience as well.

Table 2 Understandings of three experience concepts (UX, PEx, and dPEx) in healthcare design

Dimensions	Tensions	Experience concepts	Quotes
People	Specific	PEx (n = 3)	P5: When you think of the PEx… it might be too specific to not allow you to think of the other players, which are like caregivers, the community nurses
	General	UX (n = 4), PEx (n = 1)	P8: UX is broader. So, normally, we don't only look at the PEx but we also look at the caregiver's experience
Contexts	Momentary	UX (n = 4), dPEx (n = 1)	P1: I think with UX it's maybe not that emotionally loaded or like that's important. So, if I don't know where I can press a button, I won't worry about it anymore tomorrow
	Continuous	PEx (n = 8), dPEx (n = 4)	P1: I think the PEx is not only the contact with the hospital but also how we get support from experts. And I would say that the dPEx will be the same, but then only in the digital way. I think that's more continuous because it's always there
Purposes	Functional	UX (n = 4)	P3: What I see more often is situations where UX designers are being brought in, and they're being prescribed a problem. And they're going in and they're understanding it from the lens of that problem
	Emotional	PEx (n = 3), dPEx (n = 3)	P1: A PEx, in that case, is more the effects of the information you get from the digital eHealth so if you feel supported
Means	Digital	dPEx (n = 9)	P17: I see the dPEx as like a tool within that (PEx). I see the dPEx more in like, how is the application used as a tool to accommodate or solve for certain needs that the patient has in their journey

(continued)

Table 2 (continued)

Dimensions	Tensions	Experience concepts	Quotes
	Hybrid	PEx (n = 2)	P15: PEx is the integration of online and offline experiences. dPEx should be more convenient and should be incorporated into the offline experience
Usage scenarios	Concrete	dPEx (n = 2)	P19: …just that the dPEx, …I think that its purpose or its use scenario is more targeted and clearer
	Vague	UX (n = 1)	P17: It (UX) kind of forgets about the context in which the application is being used, because there are certain standards that make certain applications user-friendly or usable, and others not

- Between "concrete" and "vague" usage scenarios: the usage scenario of dPEx is clearer than UX, as the latter disregards the context in which the application is being used.

4 Discussion

Our findings show that Designers' background and their involved projects were diverse. In a professional project, designers typically only handle a portion of the entire design process. A concrete design output is required based on commercial and implementational considerations. However, in a student project, the design output is more flexible and creative. This finding is align with a previous study, which indicates that academic innovation projects focus on feasibility, whereas industry-driven projects focus on viability (Boissy 2020). Most projects involved varied stakeholders in the design process, including internal and external clients, domain experts, design professionals, indirect and direct users. We discovered that some projects are made for multiple end users, such as patients and healthcare professionals, while others are made for only one kind of end user, such as a particular patient group. Projects with multiple end users typically require extra efforts to balance the needs of different users. In terms of user research, designers in some projects investigated both direct and indirect users to gain a deeper understanding of the design context. However, due to a lack of research resources in some projects, designers only looked into either direct or indirect users. Sometimes, designers tended to understand patients by asking health professionals. According to prior research (Jones 2013; Carr et al. 2011), a product or service could, however, be mistakenly developed for an ideal user group, ignoring other players it may affect. This highlights the importance of involving all

stakeholders thoroughly in the design process. Besides, care providers mediating the contact between care recipients and designers can be a challenge (Groeneveld et al. 2018), since healthcare professionals may be unfamiliar with the role of design in health (Wildevuur 2017), and the expectations of care professionals with regard to design may be different from patients.

The design methods and processes used in healthcare design are the same as those used in design for non-healthcare domains, such as the double diamond design process, but the design values and requirements are different. Our study indicates that it is possible to examine the role that design plays in healthcare via the prism of design in other fields, which aligns with the previous study (Tsekleves and Cooper 2017). As Bate and Robert stated that "good design" of healthcare services—and the resulting "good experience"—is essentially no different from good design in any sector, including performance (functionality), engineering (safety), and the aesthetics of experience (usability) (Bate and Robert 2006). However, Jones argued that conventional user-centred design practices are insufficient to solve problems considering the complexity in healthcare (Jones 2013) which our findings seem to support. Considering the vulnerable target users and complex design contexts, healthcare designers are facing more challenges. Regarding the functionality, safety, and usability of digital health systems, more rigorous evidence-based and human factors design considerations are needed. What's more, experience is designated as "how well people understand it, how they feel about it while they are using it, how well it serves its purpose, and how well it fits into the context in which they are using it" (Bate and Robert 2007). Different focuses and approaches serve slightly different experiences. Our study surfaced five dimensions, which are people, contexts, purposes, means, and usage scenarios, to understand experience design in digital health. The five dimensions show that experience design in digital health can be shaped by "specific" or "general" user groups, influenced by "continuous" or "momentary" interaction contexts, served for "emotional" or "functional" design purposes, addressed through "digital" or "hybrid" delivery means, and targeted at "concrete" or "vague" usage scenarios. Therefore, during the design collaborations for a better healthcare experience, clear communication among the five dimensions is necessary. For example, a human-centered (patient- or user-centered) design approach should be considered in the beginning of design regarding the target user groups. A consideration of people's daily lives and emotional support is required for the design of a better (digital) PEx. In contrast to (digital) PEx, UX design concerns more problem-solving techniques and usability tests. The selection of digital or non-digital design solutions should be based on the needs at hand, since designing for digital health and non-digital health is not a binary opposition. In other words, the design considerations of dPEx should be incorporated into non-digital PEx as well. As Marc Hassenzahl (Cafazzo and St-Cyr 2012) said, while experience is intangible, volatile, an interactive product is tangible, a mass-produced piece of technology. The way we design experience in healthcare determinates how people will experience it.

Limitations: First, as a qualitative study, it is hard to collect data with a large sample size. However, we recruited a diverse group of participants, which helped

us collect rich in-depth data. Second, the participants' and projects' characteristics varied widely among the interviews, limiting meaningful comparisons between different designers and projects.

5 Conclusions

We found the similarities and differences mentioned between healthcare design and non-healthcare design relate to (1) design principles, (2) user attributes, and (3) design contexts. Furthermore, the differences between UX, PEx, and dPEx can be mapped on five dimensions: people, contexts, purposes, means, and usage scenarios. Our insights can help designers and human factors specialists to build a common design language for experience design in healthcare. Our study can also assist designers and human factors specialists with experience design in digital health by pointing out the areas where design thinking generally is appropriate and the places where particular expertise in healthcare design is needed. Considering the findings and limitations of this study, further research on how to involve as many stakeholders as possible within limited design resources in health-related design projects is needed. More studies about promoting design communication among designers of experience design in health are necessary to support better design collaborations. In addition, we propose that future research develop more design frameworks or practical tools based on our findings to assist designers in conducting evidence-based medicine and experience-based design in digital health.

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Professional Differences in Use and Perceptions of an Augmented Reality Code Cart Application

Abigail Wooldridge, John Morgan, Widya Ramadhani, Keith Hanson, Elsa Vazquez-Melendez, Harleena Kendhari, Nadia Shaikh, Teresa Riech, Matthew Mischler, Sara Krzyzaniak, Ginger Barton, Kyle Formella, Zachary Abbott, John Farmer, Rebecca Ebert-Allen, and Trina Croland

Abstract Medication and equipment must be located and retrieved quickly during resuscitation to ensure good patient outcomes; code carts are often used to store commonly used items and may be standardized to support faster retrieval. An augmented reality (AR) application to teach clinicians about the contents and organization of a standardized pediatric code cart was developed for mobile devices to improve the speed and accuracy of retrieval of items from the code cart. In this study, we explore the use, usability, and satisfaction of users of that application. We

A. Wooldridge (✉)
Department of Industrial and Enterprise Systems Engineering, University of Illinois Urbana-Champaign, Champaign, IL, USA
e-mail: arwool@illinois.edu

J. Morgan
Grainger, Lake Forest, IL, USA

W. Ramadhani
Illinois School of Architecture, University of Illinois, Urbana, IL, USA

K. Hanson · E. Vazquez-Melendez · H. Kendhari · N. Shaikh · T. Riech · M. Mischler · T. Croland
Department of Pediatrics, University of Illinois College of Medicine at Peoria, Peoria, IL, USA

T. Riech · M. Mischler
Department of Emergency Medicine, University of Illinois College of Medicine at Peoria, Peoria, IL, USA

S. Krzyzaniak
Department of Emergency Medicine, Stanford Medicine, Stanford, CA, USA

G. Barton
OSF HealthCare Children's Hospital of Illinois, Peoria, IL, USA

K. Formella · J. Farmer · R. Ebert-Allen · T. Croland
Jump Simulation, Peoria, IL, USA

OSF HealthCare, Peoria, IL, USA

Z. Abbott
InContext Solutions, Chicago, IL, USA

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conducted surveys (n = 56) with physicians, physicians in training, nurses and nurse educators who used the application. The surveys collected self-reported use, usability with the System Usability Scale (SUS) and satisfaction. We compared results from different clinical roles. The application had acceptable usability (average SUS score = 75.9) and average satisfaction of 74.9 on a scale from 0 to 100 reported after an average of nearly 3 h of application use, with no significant differences between clinical roles. While the application was acceptable, improving the interface design, features and function of the application could enhance the experience of users. Future work could include participants from other health care systems to gain a more generalizable understanding of user experience and compare the experience of users of the AR application with their experiences with other training methods.

Keywords Pediatric resuscitation · Augmented reality · System design and analysis

1 Background

Fast intervention, i.e., resuscitation, is needed when a child stops breathing or their heart stops beating. Resuscitation frequently requires medications and equipment, which are normally stored on a pediatric code cart, i.e., crash cart or trolley. Even when those carts are well designed and organized, clinicians must have some knowledge about the organization in order to retrieve items fast enough to save lives of children. While in situ simulations have been useful for clinicians to gain this knowledge, operational and pragmatic challenges limit their feasibility. Further, training provided via mixed, virtual and augmented reality tends to have similar outcomes and equally enhance performance as more traditional training approaches (Kaplan et al. 2021). Therefore, we have developed an augmented reality application as an alternative way to learn about code carts (Wooldridge et al. 2021).

As previously described by Wooldridge and colleagues (2021, 2022) and Hanson and colleagues (2021), the augmented reality application allows the user to place a virtual replica of the standardized code cart in the participating health care system in their space through the augmented reality application. The application is available for use on iOS and Android mobile devices and includes elements of gamification (e.g., leader boards) and three user modes. The first mode is unstructured exploration, where users can touch items on the virtual cart to read information about them. The second mode is a time search, where users are asked to find ten items and their accuracy and time to find the items are recorded—users can compare their performance with others through the leader boards. The third mode included medical scenarios that simulate finding and retrieving items in a clinically relevant order. Wooldridge and colleagues (2021, 2022) describe results from work system analysis of the application using focus groups, identifying tension between positive and negative aspects of the application design; for example, the physical movement required for augmented reality was engaging, but also created some apprehension about using where people

could watch. Hanson and colleagues (2021) compare accuracy and time to locate items on real code carts before and after application use, finding increased accuracy in item retrieval and reduced time to locate items. Morgan and colleagues report a pilot study with ten participants that evaluated usability of the application and compared eye tracking data of participants in the timed searches on real code carts, reporting fewer and longer fixations in the eye tracking data after application use, indicating increased expertise, and an average 82.5 System Usability Scale (SUS; Brooke 1996) score, indicating acceptable usability.

In this study, we conduct a larger evaluation of the use, usability and satisfaction of users with the application. Because nurses and physicians have different roles during resuscitations, and therefore different interactions with code carts in real life, we compared usability and satisfaction reported by each group of users to determine if there were differences in perceptions by profession.

2 Methodology

2.1 Sample

We conducted the evaluation of use, usability and satisfaction at a 629-bed level-1 trauma center that includes a children's hospital. Participants were recruited through email, advertisement and attendance at continuing education events. This resulted in a total of 56 participants, including 8 attending physicians, 24 resident physicians, 15 nurses, and 9 nurse educators.

2.2 Data Collection Methods

Usage data was recorded as part of the application. Self-reported use, usability and satisfaction data were collected through a survey consisting of 56 Likert scale questions with a rating scale of 1 to 5 or 1 to 7; the survey also included questions about the usage of the application. The survey was based on the SUS (Brooke 1996) and the Systems Engineering Initiative for Patient Safety survey to evaluate health information technology (Hoonakker et al. 2011). The survey was administered using Qualtrics© after the participants were exposed to the application. The survey is available at https://hfss.ise.illinois.edu/files/2019/12/Usability-Survey-with-Refs.pdf.

2.3 Data Analysis Methods

The SUS score (Brooke 1996) and overall satisfaction score (Hoonakker et al. 2013) were calculated. The SUS score ranges from 0 to 100 and can be interpreted as the application being acceptable (70–100), marginally acceptable (50–70), or not acceptable (0–50) from Bangor et al. (2008). The overall satisfaction score is a rating for how satisfied the users were with the application and ranges from 0 to 100. Ranges to interpret the overall satisfaction score have not yet been established, but Hoonakker et al. (2013) identify scores from 48–58 as "moderately satisfied."

To visualize the survey data, violin pots with embedded box plots were created. This visualization can be used as a tool to assist in locating differences between groups and understanding the distribution of responses. Two Kruskal–Wallis tests were conducted to determine if the SUS and overall satisfaction scores varied by user group, as the data did not meet the normality assumption of one-way ANOVA tests. All statistical analyses were conducted and plots were created using RStudio (RStudio Team 2021).

3 Results

A technical coding error in the coding of application precluded accurate usage statistics from the application—usage data were only recorded when the application was closed by the user, which was rarely done, so the data were incomplete. Instead, self-reported usage collected in the survey are shown in Table 1. Nurse educators used the application the most, followed by nurses and then residents. Attending physicians used the application the least.

Table 1 shows the SUS scores and overall satisfaction scores. The average SUS score indicated acceptable usability (Bangor et al. 2008). Figures 1 and 2 show violin plots of the distribution of SUS scores and overall satisfaction scores, respectively, by clinical role. The attending physicians reported the highest average SUS score, followed by the nurse educators and nurses. The residents reported the lowest average

Table 1 Self-Reported Application Use, Usability and Satisfaction

Professional group	Self-reported use (hours) [mean (standard deviation)]	System usability score [mean (standard deviation)]	Overall satisfaction score [mean (standard deviation)]
Attending physician	0.7 (0.3)	80.3 (15.8)	79.4 (12.7)
Nurse	1.7 (1.6)	75.8 (20.6)	74.9 (13.9)
Nurse educator	11.1 (28.9)	76.7 (11.5)	74.1 (9.5)
Resident (physician in training)	1.1 (0.7)	74.3 (12.6)	72.1 (10.2)
All participants	2.8 (11.6)	75.9 (15.1)	74.2 (11.5)

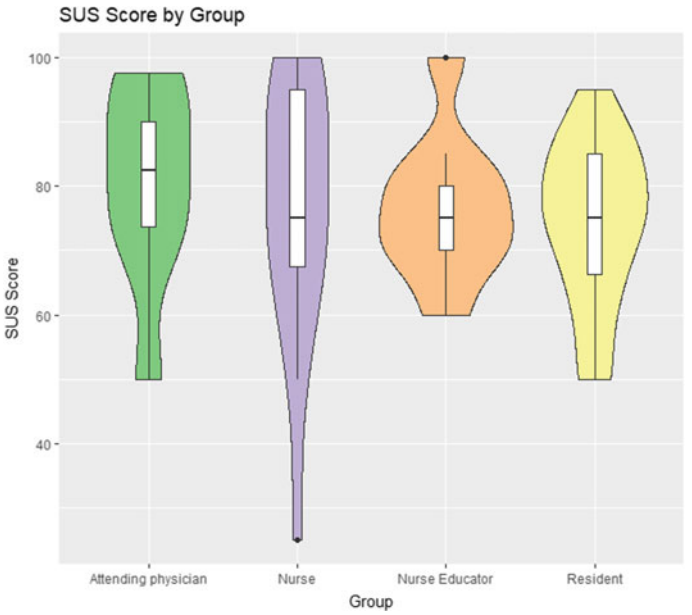

Fig. 1 Distribution of SUS Scores by Professional Group

SUS score. The Kruskal–Wallis test comparing the SUS reported by each user group found no significant different distribution of scores (χ^2 (3) = 1.3673, p = 0.7132). The attending physicians reported the highest average satisfaction score, followed by the nurses and nurse educators. The residents reported the lowest average satisfaction score. The Kruskal–Wallis test comparing the overall satisfaction scores reported by each user group found no significant different distribution of scores between user groups (χ^2 (3) = 1.4518, p = 0.6934).

4 Discussion

We found that the AR application had acceptable usability levels and relatively high overall satisfaction scores based on nearly 3 h of application use on average. The overall satisfaction scores reported in our study were approximately 20 points higher than "moderate" overall satisfaction scores reported by Hoonakker and colleagues (2013). Usability and overall satisfaction scores did not vary by user group, although the average scores reported by residents were the lowest for both usability and satisfaction. This may be due to desire of residents for additional clinical education content, e.g., what medications to use during specific scenarios, rather than simply location of cart contents.

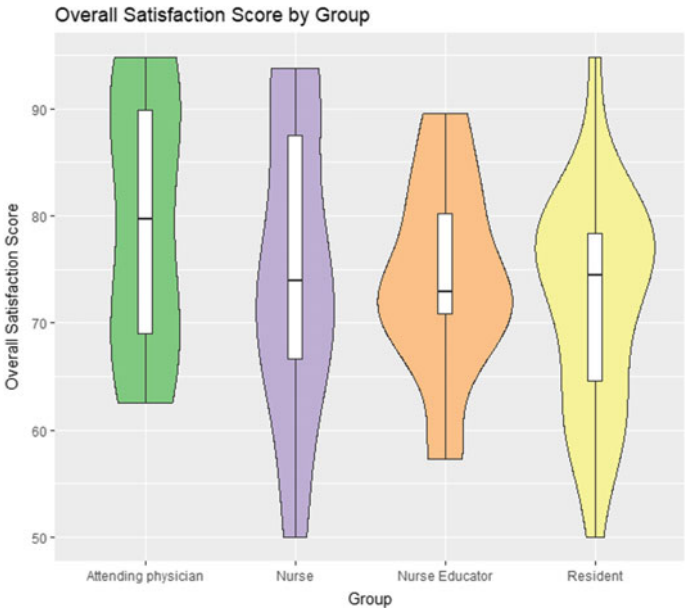

Fig. 2 Distribution of Overall Satisfaction Scores by Professional Group

While the usability was acceptable, it was not high. Opportunities to improve the application have been previously described and include providing equipment and time at work to use the application to mitigate concerns about doing work at home, on personal devices, offering similar material in modes without augmented reality, eliminating technical challenges with the application (e.g., glitches when placing the virtual cart, higher resolution of drawer images), improving the interface and additions like more clinical scenarios, an index of items, etc. (Wooldridge et al. 2021, 2022). In addition, consideration of alternative conceptualizations of usability, e.g., those proposed by Scapin and Bastien (1997), and how this technology can integrate with the workflow of users (Salwei et al. 2021) will be useful to ensure the technology is used.

Given the technical issue that precluded capturing actual time the application was used, we relied on self-reported use to understand how much participants used the application. While we believe that nearly 3 h of use on average is reasonable to form a basis to evaluate usability of and satisfaction with the application, it is possible this self-reported number is artificially inflated. Future work should capture application use in the application if possible—data about usage, in combination with information about postures adapted by users of augmented reality tools (Aromaa et al. 2018), could uncover potential physical ergonomics issues. Additionally, the generalizability of our results is limited because all participants are from a single medical center. Lastly, the larger research project this study is part of did not compare the effectiveness nor experience of participants receiving education about the code

cart through the AR application with other modalities, which could enhance our understanding of using mixed, virtual and augmented reality in training.

5 Conclusions

The AR application had acceptable usability levels and relatively high overall satisfaction scores based on nearly 3 h of application use on average, and satisfaction and usability did not vary by user group. Improvements to the application, including an improved interface, additional features like non-augmented reality modules, and organizational changes to provide time and equipment to use the application at work may improve user satisfaction and usability.

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Healthcare Services and Management

Behavioral and Systems Change in Nursing Homes with an Integrated Training Intervention

Giulia Lefosse, Laura Rasero, Tommaso Bellandi, Yari Longobucco, and Claudia Gatteschi

Abstract Training of healthcare professionals in nursing homes (NH) is fundamental to improve quality and safety. This project (funding by 2 resolutions) is carried out at a sample of 7 NHs of Tuscany Region (Italy), for evaluate a participatory approach to reduce preventable incidents and implement good practices, through behavioral and systems change. The inclusion criteria were defined to represent the different areas of the Region. The method for training sessions is based on what emerged in the literature, according to the principles of andragogy and management of human factors. It is based on interactive class, that follow action research method, with bottom-up approach to multidisciplinary groups. Each session lead by a nurse and a psychologist takes 8 h. Participants' experience of a good or a bad day of practice is elicited to let the tacit knowledge on strengths and weaknesses emerge, to help the group envision a joint commitment to improve on the more relevant themes for patient safety. Evaluation included participant reactions, learning and change in practice. Staff who attended responded very well. In the majority they appreciated training but above all the intention to change and improve their job. Follow-up (up to 2 months) was carried out in all NHs through field observations and a second meeting. In some cases, we were able to observe changes in care and organizational practices,

G. Lefosse (✉)
Clinical Science University of Florence, AOU IRCCS Meyer Children Hospital, Florence, Italy
e-mail: giulia.lefosse@meyer.it

L. Rasero
Department of healthcare professions/research development of clinical study, AOU Careggi, Florence, Italy

T. Bellandi
Eur-Erg. Patient safety unit - Tuscany NorthWest Trust, Azienda USL Toscana Nord Ovest Cittadella della salute, Lucca, Italy

Y. Longobucco
Health sciences department, University of Florence, Florence, Italy

C. Gatteschi
ARS, Regional health agency of Tuscany, Florence, Italy

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in other no changes emerged. In all NHs we have found the need for supported in working practices, the request to continue to be followed over time.

Keywords System change · Nursing homes · Patients' safety · Long term care · Training intervention

1 Background

The affecting factors that influence safety incidents within Nursing Homes (NHs) are different. They are not only related to the patient characteristics (such as age, sex, comorbidities, depression, cognitive deficit, functional status, compliance) but also extrinsic and team-related (experience, staff training, patient monitoring and evaluation, documentation, communication between different levels of functioning, workload) (Masotti et al. 2010). Among these factors, training can be considered a cornerstone, because as there is direct link between training and safety culture, between competence and measurable adverse events (Wagner et al. 2012; Andersson et al. 2018). Despite this awareness, adequate training is lacking (Husebo et al. 2015) because of poor material and structural resources, inadequate staffing contracts, high workloads, high turnover rates (Castle and Engberg 2005; De Leo and Trabucchi 2021; McGarry et al. 2020). According to World Health Organization (WHO 2015) strategies are needed to ensure adequacy of staff with an suitable mix of skills and awareness for vulnerable population. The Italian law 24/2017 applies to all healthcare organizations, which need are obliged to systematically identify, analyze and prevent risks (Lefosse et al. 2018). The same principles are required by new accreditation system of Tuscany Region for long term care structures (LTC) (Bellandi et al. 2017), highlighting the need to provide up to date skills for healthcare professional. Epidemiological curve change's is destined to redefine healthcare system, moving care from the hospital to local health services. In line with this inevitable change, NHs staff will be called upon to fill roles that will require greater professional judgment, organization, and adequate resources. Skills should be improved by educating healthcare professionals, creating conditions for continuous learning (Andrew et al. 2008).

In view of the above, the questions are: which training, and management methods are most effective for improving quality and safety in LTC? How can we decline them in a training intervention?

From a literature review it emerges that elements based on andragogic principles are necessary to achieve effective learning (Knowles 1973; Castagna 1996) as: team and interdisciplinary work (Bandura 2000; Gaudenz et al. 2019; Knowles et al. 2005), active and participatory involvement of staff (Mortari 2003a, b; Shon 1987; Alastra 2008); organizational and emotional listening and experience of healthcare professional (Goleman 2001; Forza et al. 2017; Van Manen 1993; Mortari 2003a, b; Bensalah 2018a, b; ISFOL 2009), motivation of staff (Toode et al. 2015; Murphy 2006; Lyman et al. 2021). Multidisciplinary team is important because a

training activity, in order to be effective, must be based on principles such as sharing and collaboration (Kreiter et al. 1999a, b). Knowledge can be easily transferred to work practices when training process involves all professional figures. In addition to technical-specific skills, it is also necessary to develop non-technical skills that allow common action (Italian Ministry of Health 2013). We could speak of "organizational learning", that is learning and reasoning in a system and not just an individual logic (Alessandrini 2005). This is possible through a practice of interaction, exchange, and sharing of information in the context, so that experiences, discoveries, and evaluations of everyone become a common heritage of organization. This also becomes an important active involvement for the staff during training, in which different actors can express their actions in words or replicate them through exercises (Mortari 2003a, b; Schon 1987; Van Manen 1993). In this way it is possible to deepen not only on the technical side, but also on existential and professional vision, which tend to self-confirm, the theories and beliefs that tacitly guide our thinking and acting (Mortari 2002). To access to "tacit zone of mind", where errors and insecure actions often arise, the comparison must be adequately stimulated and facilitated. Through questions is possible to lead participants to how they came to explain the reasons for their behavior. Another theme that emerges in the literature is the way in which emotions and feelings are treated in our organizations, the value attributed to them. There is always an emotional tone brought by professional action (Heidegger 1976), which is why it is important that trainers and then management line, listen and give relevance to emotions and feeling of the staff. Emotions are drive actions and decisions of human being, so much to prevail over logical thinking and be able to condition rational reasoning. Often this is what leads to making mistakes (Forza and Menegon 2017; Goleman 2001). Therefore, it is important during training not to repress emotions, but to listening, observe, knowing and transform. The goal is to learn to manage them constructively, or better, creatively, to make them a reporting tool that can help prevent or reduce the risk of falling into error (Maso and Cicolin 2016). To do this, it is essential to use a bottom-up method, starting from deep causes underlying problem and from experience of professional healthcare and organization. This is also important to bring training contents back to daily job and that functionality and usefulness for one's work and competence is immediately brought back.

This action research project is structured inspired by these concepts. The aim of the project is to explore and evaluate an innovative participatory approach to reduce preventable accidents and implement good practices, through behavioral and system change.

2 Methodology

The intervention is part of a bigger project of Tuscany Region, called "La Buona Cura Persona Project", funding by 2 resolutions (Tuscany Region 2015, 2017), for improvement quality and safety of the NHs. This study follows the action research method, and it is conducted in agreement with managers, ensuring privacy of patients

and workers (Elliott et al. 1993; Barbier 2007; Zannelli 1998). It is qualitative research with systemic approach, based on analysis of interactions in real practice between human factors, technologies and organizational structures and processes (Holden et al. 2014), interactive workshops with operators and patients to analyse and redesign care with a participatory approach.

7 NHs were selected according to specific inclusion criteria defined by study group, to select a representative sample of the average of the NHs in the Region and are: public propriety, location in rural or urban area, different location of Region health areas, performance levels (some high performances, some low performance) (Nuti and Rosa 2012), number of beds (from 20 to 100) and presence of dementia core (Lefosse et al. 2022). Training program develops after the field observations. Field observations were conducted in non-participatory mode, collecting the observed data following the natural unfolding of activities in NH. The raw notes were written using tools (smartphone or pen and paper) and then rearranged into extended notes with internal coherence. They conducted by trainers and researchers themselves (a nurse specialized in risk management and LTC and a research psychologist specialized in geriatric age psychology) (Lefosse et al. 2018). The training activity consists of 16 h for total training, 8 for each work group. The methodology (described shortly in Table 1) follows bottom-up technique on small multidisciplinary groups, including all professional figures of first line, staff and managers.

Training meetings are interactive and structured in two thematic days: "The No Day" and "The Yes Day". This choice is inspired by work of Jeffrey Braithwaite, "From Safety One to Safety Two" (Braithwait et al. 2015). Analyzing safety from two different points of view, the first on failures and the second on successes and resources, with the aim that "as few things as possible go wrong" to ensuring that "as many things as possible go right". The aim of meetings is to bring out weaknesses and strengths through a thematic analysis without predefining about "hot" themes of care NHs. During classroom discussion the goal is to develop listening of personal experiences, both from an emotional and professional point of view, deconstructing rigid constructs that could generate from hierarchical and frontal training (Alastra 2008). This methodological choice is based on assumption that sharing of situations, especially with a high emotional impact, links and brings the team, with a climate of sharing and a sense of belonging. We know that NHs are "slow" contests, with a low number of adverse events. For this reason, we have chosen to analyze rather days and patient's conditions in a slow, chronic sense and from workers' point of view, instead of concentrating on clinical cases or specific events.

At the end of event sharing, the emerging themes are summarized in real-time by the trainers through a concept map on a flipchart. This method supports emotional learning with cognitive constructs and helps to relate various elements that have emerged in a network; that recalls the concept of a system, in which there is a concatenation between various elements (Bensalah 2018a, b). When relevant thematic areas have been identified, teachers proceed based on literature, guidelines, and best practices, and constantly trace the contents back to examples of daily practice. These examples may start from themes suggested by the participants or emerge during field observations or from clinical cases outside the reference settings. Analysis of

Table 1 Descriptors of training intervention methodology

Activity	Specific training aim	Contents	Methodology
Interactive meetings. "The day NO" and "The day YES"	Analyze and understand weaknesses and strengths in working practices in NH	Adverse events, case studies, strategies	Thematic analysis from the perspective of the participants
Interactive meetings Real-time themed analysis with concept map	Know the principles of risk management and the systemic approach. Know good practices to prevent errors	Safety in NH, regulatory evolution, systems theory, incidents' approach, good practices	Front lesson Interactive front lesson
Working in a small group	Develop skills to reduce preventable adverse events. Skills for analysis and management of Clinical Risk with an inductive process conducted in team	Analysis of clinical cases and adverse events occurred in NH. Planning for improvement actions. Error detection systems	Focus group on themes
Scenarios	Develop self -awareness and teamwork in daily actions and active participation in the success of the system	Resolution of scenarios for application of systemic thinking. Techniques and methods of self-analysis and awareness	Focus group Brainstorming
Management data sheets	Approaching health documentation, knowing how to read and interpret it, how to improve it and implement it according to changes	Define or review a check-list or an operational protocol Planning	Focus group Brainstorming Review of literature and protocols

themes that emerged (for example falls, infections, medication errors, escapes, nutritional and dehydration risk, emergency management, etc.), is carried out both from the theoretical point of view and to provide suggestions for good care practices.

The final part of the days is characterized by focus groups (maximum 5 participants). During the meeting, each group is assigned to a theme and is asked to analyze it through a track provided by trainers, and after sharing it with the whole group through a spokesperson. This method aims to strengthen teamwork, by sharing critical points, strengths, and possible improvement actions that could be undertaken. This could provide to participants with identification of common goals and clarify a collective vision defined by the group itself, according to their own points of view, priorities and methods (Cappucci 2000). At the end of the training days, the teachers structure some scenarios/clinical cases and technical management sheets to be developed for the next meeting.

This method aims to conduct the team to reflect together critically and systematically on scenarios. Starting by a story (that reports adverse or critical events of daily work practice) they are asked to abstract for define an analysis a plan-risk prevention. The management sheet provides a solid and formal structure instead,

with aim to standardize the action, normally carried out routinely, in a logical and systematic scheme. For development of management sheet, it may be necessary to consult literature and protocols, by providing inspiration for learning and by give an active part to team during definition and management process. The goal is to embrace accountability and empowerment process, as individuals and professionals (Mortari 2003a, b; Oshvandi et al. 2008).

Follow-up meeting after 1–3 months is based on a second phase of field observations and 4 h meeting with participants. Field observations aim to measure impact of method on good practices, daily and organizational management elements.. Process indicators are observed to detect the presence of changes. During the same day, meetings are held with team in which they can present resolution of scenarios and drafting management technical sheets, reflecting in brainstorming on possible improvement actions. The trainers induce to this sharing with the aim of strengthening processes of self-determination, empowerment and intrinsic motivation, by all production lines (operators, staff, management) (Alhassan et al. 2013; Shah et al. 2016; Galletta et al. 2016) and to measure intention to change and hypothesize an improvement plan for the future.

3 Results

The project in the complex was received fairly well by staff, despite some phrases of embarrassment and discomfort and the feeling of being "under scrutiny". The majority of staff took training with a good degree, but above all the intention for change and improvement was evident. Follow-up was carried out in all 7 NHs where we could see some changes care processes. The transformations involved, for example, management of urinary catheters (UC), management of behavioral disorders, patient's personal hygiene, management of risk of escapes, management of patients with enteral nutrition and communication with patient. Italics notes are extracted from follow-up observations, kept as such to make representation of results more neutral and explicit.

In a NH was observed an improvement for a patient who had a UC before training: "the nurse tells me that his CV has been removed and that he is urinating spontaneously without problems". In another structure we can observe an improved change in patient hygiene phase: "The operator says that after the training they bring more attention in starting the hygiene from clean body area and not from pelvic area as before". In fact, it starts from mouth and then goes down to neck and so on, in the meantime it speaks with guest. They close the door to ensure privacy and microclimate. In another observed case I was asked support for a clinical situation involving a patient with Percutaneous Endoscopic Gastrostomy (PEG): "He often vomits, how we can do?". In another NH, after training, non-pharmacological and postural therapies were determinants for managing a guest's behavioral disorders: "We meet the resident who was very agitated, kicked and wiggled in a wheelchair. Now they have changed the wheelchair by replacing it with a more comfortable one. He is much

calmer; he is at a different table from the last time and he is doing activities (he writes a series of numbers on a cloth placemat with a black marker). Even physically he seems calmer, every now and then he arches his back again and pulls back, but he doesn't scream anymore. We ask him how he is and he says he is fine". In another NH, an healthcare assistant explains an action she has taken to prevent risk of escape: "The assistant tells me that she wants to clarify that she did not go to get the hair spray but sent the guest to keep her busy for prevent escape, since she is a lady at risk and she learned it after training".

These are just some of data observed and positive examples found, which are accompanied by data and elements of stasis and lack of change, both in care practices and at an organizational level. However, what emerged most was the desire to do better, the motivational drive and intention to change that came from the meetings. In some NHs, in particular, was carried out to plan improvement actions and commitments for future. The work was carried out and analyzed through scenarios and technical sheets, elaborated and shared during follow-up meetings and determine some improvement actions to be implemented in the next future. The most relevant actions were selected because they were perceived as urgent and relevant by NHs, according to the researchers, for future improvement cycles. The actions concern: introduction of check list to improve hospitalization of patients in NH, introduction of protocol for management of risk of escapes, revision of protocol on administration of meal, improvement and implementation of protocol for management of enteral nutrition and devices, standardization of handover methodology and planning to improve training path of new workers. From all professional lines emerged need to improve wellness of team with dedicated courses, request for technical and relational training (work ethic, end of life, etc.), need for supervision by top management or external professionals, listening spaces, suitable work tools, professional recognition, as well as paths to implement team work.

4 Discussion

The emerged results confirm what is known from previous literature and the researchers. There is a strong need to deepen and expand, both at a technological and educational level, goods produced within NHs and responses in terms of health (Kreiter et al. 1999a, b). In fact, the observed NHs explicitly asked to be supported and trained over time, especially for the development of improvement actions. This is certainly a limitation of study, because more time is needed to measure application of improvement actions and their impact on the health of patients. The second limitation of the study is time-consume because this research method requires participation of experienced and specialized trainers and researchers in this trade. Another limit is the high involvement of researcher-trainer and its possible impact on the effectiveness of intervention and outcomes.

The strengths of the study are setting, which attribute value to research, because is under investigated but, at the same time, an indispensable element on which to

invest to ensure an optimistic future in terms of health and improvement of social and health services. Another strong point is innovative methodology centered on human factors and qualitative approach, which allows to investigate this reality in complete and holistic way. Furthermore, we must consider that this project includes 7 public NHs but belonging to different areas of Tuscany Region. This makes them not homogeneous but, despite this, there was continuity in the method and common elements are more relevant than differences.

Training the staff with methods that use nudging, which account emotions, experience and, therefore, take care of human himself, can be a motivational boost, an attraction, as well as developing the power of workers (Kjellström and Avby 2019; Freire et al. 1975). Andragogy states that an adult will learn only be if he deems what he is learning useful for his life and work, because this connection with practice stimulates self-confidence, desire to be better and looking for higher needs (Maslow 1954). A company that offers transversal and holistic professional tools is the business model to which a care setting should aspire. In this dialectic and circularity, work in a welfare environment like that of NH could acquire a connotation of values and develop a sense of pride in belonging, not only as healthcare professional but like human too.

5 Conclusions

In light of what has emerged, it is essential to implement interactive training sessions in NHs and ensure strategic support over time. A strategy to achieve this could be the creation of a network that integrates territorial structures with health and hospital structures, the establishment of local risk manager and quality and safety facilitators within NHs. The structuring of models of continuity of care could implement the monitoring and growth of socio-health systems, as well as preventing accidents. In this way, we could approach a system that is increasingly patient centered. There is a need to deepen the effectiveness of this model, to expand the sample and measure impact, also through qualitative and quantitative outcome indicators (e.g. number of infections before and after the intervention, number of falls, number of correct hand hygiene, etc…). For this purpose, a non-randomized pre-post study is underway on 2 NHs in Tuscany Region and results will be reported shortly.

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