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Work System Barriers and Facilitators of a Team Health Information Technology

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Abstract

Designing health IT aimed at supporting team-based care and improving patient safety is difficult. This requires a work system (i.e., SEIPS) evaluation of the technology by care team members. This study aimed to identify work system barriers and facilitators to the use of a team health IT that supports care transitions for pediatric trauma patients. We conducted an analysis on 36 interviews – representing 12 roles – collected from a scenario-based evaluation of T^3. We identified eight dimensions with both barriers and facilitators in all five work system elements: person (experience), task (task performance, workload/efficiency), technology (usability, specific features of T^3), environment (space, location), and organization (communication/coordination). Designing technology that meets every role's needs is challenging; in particular, when trade-offs need to be managed, e.g., additional workload for one role or divergent perspectives regarding

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The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

specific features. Our results confirm the usefulness of a continuous work system approach to technology design and implementation.

Keywords

Team health information technology; SEIPS; pediatric trauma care

1. Introduction

1.1 Challenges of health IT for teams

Health information technology (IT) has the potential to improve patient safety and facilitate communication between clinicians from diverse disciplines (Institute of Medicine, 2012). However, recent reviews report evidence of poor usability of health IT, e.g., challenges for users to quickly identify critical information, impacting the use of health IT and resulting in technology-induced errors (Turner, Kushniruk, & Nohr, 2017; Zayas-Cabán & White, 2020). In an analysis of usability flaws in 229 reports, Marcilly et al. (2019) noted that most usability issues dealt with the user interface. Usability issues with health IT (such as the EHR or Electronic Health Record) represent a specific safety challenge when used by clinicians who care for children. Ratwani et al. (2018) reported that usability issues, e.g., poor visual display of information, contributed to more than a third of EHR-related medication safety event reports for hospitalized children. Therefore, it is important to improve the design of health IT in order to support patient safety, in particular for hospitalized children.

Often, health IT has been designed to support specific tasks rather than team-based care processes (Walker & Carayon, 2009). Therefore, we need to pay attention to the design of health IT for teams as recommended by Carayon and Hoonakker (2019). One form of team health IT is integrated information displays that organize and present critical patient information on a large, single display (Parush, 2014; Wright et al., 2019). A few studies have shown how integrated information displays can support information sharing within teams, especially during time-sensitive care processes, e.g., resuscitation (Parush et al., 2017; Pickup et al., 2019; Wu et al., 2017). Questions remain about how multiple care team members perceive the technology and its fit with the rest of the work system. In our study, we evaluate a team health IT designed to support the work of pediatric trauma teams during care transitions between the emergency department (ED), operating room (OR), and pediatric intensive care unit (PICU).

1.2 Health care context for the study: pediatric trauma care transitions

Pediatric trauma care is a complex, team-based care process that is distributed over space and time; team members may or may not be co-located in the ED, OR, and PICU and intervene at different times to care for the child (Wooldridge et al., 2018). Children with traumatic injuries are vulnerable to safety issues, in particular during care transitions as information may not be available, communicated, or accessible (Hoonakker, Wooldridge, et al., 2019). Team health IT is one potential solution to improve information flow between multiple roles involved in pediatric trauma care transitions to provide high-quality, safe care (Hoonakker, Wooldridge, et al., 2019; Wooldridge et al., 2020). We applied a human-centered design (HCD) approach to develop a team health IT, called Teamwork Transition Technology (T^3) (Carayon et al., 2022). See figure 1 for the T^3 mock-up, which includes 11 specific features: (1) patient information, (2) status prior to arrival (PTA), (3) patient family/caregiver, (4) time elapsed, (5) current, (6) ins/outs, (7) mannequin, (8) timeline, (9) care team members, (10) transition to OR and (11) transition to PICU/floor. In a previous study, we provided evidence for the high usability of T^3 as measured by the SUS (System Usability Scale) questionnaire (Carayon et al., 2022). Usability is an important characteristic of health IT, but it is not sufficient; we also need to ensure that the technology fits with the rest of the work system. This is the essence of the sociotechnical systems approach such as the Systems Engineering Initiative for Patient Safety (SEIPS) model (Carayon et al., 2006; Carayon et al., 2014).

1.3 Multiple perspectives of perceived work system barriers and facilitators

The SEIPS model is widely used to analyze and design sociotechnical systems with the aim of improving health care quality and safety (Holden & Carayon, 2021). The SEIPS model includes the five work system elements: person, task, tools and technologies (e.g., team health IT), physical environment and organization (Carayon, 2009; Smith & Sainfort, 1989). The fit, or lack of fit, of work system elements can create barriers or facilitators to work performance. The SEIPS model emphasizes interactions between the work system elements to influence care process, patient outcomes, and employee/organization outcomes (Carayon et al., 2006; Carayon et al., 2014). Designing team health IT thus requires a focus on the technology's usability as well as an understanding of how the technology fits with the rest of the work system (Carayon et al., 2006; Carayon et al., 2014). In addition, it is important to evaluate health IT with different team members in order to identify and compare their perceptions.

Understanding and comparing multiple perspectives of different team member roles on an intervention or a technology has been done in a few studies. As part of the evaluation of an infection prevention bundle, using the SEIPS model, Musuuza et al. (2019) identified work system barriers and facilitators perceived by 3 groups: environmental services staff, physicians, and nurses caring for infected patients with *Clostridioides difficile*. One barrier perceived by both physicians and nurses was limited knowledge about *Clostridioides difficile* resulting in negative consequences, such as delays in posting isolation signs. Musuuza et al. (2019) also identified barriers unique to environmental services, e.g., expeditiously cleaning and disinfecting a patient's room, which was actually a facilitator for physicians. Catchpole et al. (2022) conducted an evaluation "in the wild" of a clinician-centered smartphone app aimed at supporting teamwork and communication among physicians, nurses, and imaging technicians caring for trauma patients. ED staff were less positive about the smartphone app usability as compared to clinicians in the OR or ICU, while neurology and orthopedic teams found it most useful. These two studies show that evaluating interventions (i.e., infection prevention bundle and health IT) with team members provides important information about barriers and facilitators experienced by different groups of users. Our research builds on these studies by using the SEIPS model (Carayon et al., 2006; Carayon et al., 2014) in order to identify work system barriers and facilitators to the use of a team health IT (i.e., the T^3 mock-up) and compare barriers and facilitators reported by different members of the team.

2. Methods

This study was conducted as part of a large study on designing a team health IT to support care transitions for traumatically injured children (Carayon et al., 2022). Our HCD process included four in-person, hour-long sessions with the same pediatric trauma care team member representatives from emergency medicine, surgery, anesthesia, pediatric intensive care medicine, nursing, pediatric trauma management, hospitalist, and medical informatics. During design sessions, clinicians agreed and disagreed on information to include on T^3 for supporting their work in caring for a traumatically injured child; this feedback was incorporated into iterative revisions of the T^3 mock-up (Hose et al., 2023).

In a previous study by Hoonakker et al. (2022), we conducted a three-phase scenario-based evaluation to assess the usability and usefulness of the T^3 mock-up. In phase 1, a researcher read a realistic patient scenario about a child's ED stay. While reading the scenario, the researcher presented five mock-up screens to illustrate how T^3 would evolve with populated data throughout the child's ED stay. The scenario can be found in Appendix A of Hoonakker et al. (2022). In phase 2, participants filled out a survey, which included the SUS (Brooke, 1996). The analysis showed that T^3 was perceived as highly usable (Carayon et al., 2022). In phase 3, we conducted a debrief interview with questions organized around the work system elements (see Appendix A for the interview guide). In this study, we use the qualitative interview data collected in phase 3 of the scenario-based evaluation to describe work system barriers and facilitators to using T^3.

2.1 Setting and participants

A total of 36 clinicians and support staff participated in the scenario-based evaluation; 3 individuals in each of the following 12 groups: (1) emergency medicine (EM) attending physicians, (2) EM resident, (3) ED nurse, (4) anesthesiologist, (5) anesthesia resident, (6) anesthetist, (7) OR nurse, (8) surgery attending, (9) surgery resident (trauma chief), (10) surgical technician, (11) PICU attending physician, and (12) PICU nurse. Additional information on participant characteristics, i.e., age and gender, is provided in Hoonakker et al. (2022).

2.2 Data collection

The average duration of the debrief interviews was 25 minutes (range: 10 to 52 minutes), for a total of 15 hours and 21 minutes.

2.3 Data analysis

Interviews were audio-recorded and transcribed by a professional service. Transcripts were cleaned and de-identified. The qualitative data analysis included a primary deductive content analysis (Elo & Kyngäs, 2008) guided by the five work system elements (Carayon, 2009; Smith & Sainfort, 1989), in order to identify barriers and facilitators (Carayon, Gurses, Hundt, Ayoub, & Alvarado, 2005). We also performed an inductive content analysis to describe emerging dimensions in each of the five work system elements, and holistic coding (Saldaña, 2015), i.e. 'macro-level coding', to compare and contrast the perspectives of the different groups of team members on work system barriers and facilitators.

The iterative data analysis process included the following three phases and steps:

Phase 1: Initial deductive and inductive content analysis to identify emerging dimensions of work system barriers and facilitators to a team health IT mock-up.

- Deductive content analysis guided by work system elements: Two researchers individually coded an interview transcript and met to review coding on work system barriers and facilitators.
- Inductive content analysis to identify emerging dimensions of work system barriers and facilitators: The researchers reached consensus on coding and identified emerging dimensions of work system elements. The process was repeated for six additional interview transcripts, which allowed refinement of the dimensions for each work system element and their definitions.

Phase 2: Follow-up deductive and inductive content analysis to refine definitions of the emerging dimensions.

- Deductive content analysis guided by work system elements: One researcher separately coded work system barriers and facilitators for the remaining 29 interviews. Transcripts were coded in Dedoose©, a qualitative data analysis software. Excerpts were then exported to Excel®.
- Inductive content analysis to finalize the dimensions of work system barriers and facilitators: The two researchers summarized excerpts for each work system element and met periodically to refine dimension definitions, providing opportunities for skeptical peer review (Devers, 1999).

Phase 3: Comparing and contrasting care team member perspectives.

- Holistic coding: During their periodic meetings, the two researchers also discussed comparisons for different groups of participants.
- Respondent validation: The data analysis included (1) a peer-feedback meeting with two HF researchers and (2) member checking with seven clinicians involved in the T^3 design sessions. The HF researchers and the clinicians provided feedback on the dimensions, their definitions, as well as the comparison of the different groups (Mays & Pope, 2000).

3. Results

We identified eight dimensions with both barriers and facilitators in all five work system elements (table 1). The number of interviewees, out of 36 total, mentioning a particular dimension were not evenly distributed across the five work system elements, as shown in table 1. Four of the eight dimensions, i.e., task performance (task), specific features of T^3 (technology), location for T^3 (environment), and communication and coordination (organization), were mentioned by 30 or more of the 36 interviewees as facilitators.

3.1 Person – experience

We identified one dimension for the person element: clinical experience. Two of the 36 interviewees, an anesthesia resident and a PICU attending, respectively, described a barrier and facilitator associated with the person element. The anesthesia resident mentioned a barrier for experienced ("senior") care team members needing to change the way they work to accommodate the health IT: *"More senior residents or…faculty who have been…for the last few years… doing everything…the exact same way…that could be challenging."* The PICU attending mentioned a facilitator for clinically experienced care team members, like himself, who might benefit more from T^3 than less clinically experienced care team members, e.g., an intern.

3.2 Task

We identified two dimensions for the task element: (1) task performance and (2) workload and efficiency. Thirty-four of the 36 interviewees commented about task performance; 16 of the 36 interviewees commented about workload and efficiency.

3.2.1 Task performance—Four of the 36 interviewees: an anesthesiologist, two anesthetists and one OR nurse discussed how T^3 could hinder their ability to perform specific tasks, primarily because of the issue of information accuracy when making decisions. In particular, one anesthesiologist and two anesthetists discussed concerns about the accuracy of the child's weight information to make decisions about drug dosing. One nurse anesthetist explained that weight, in the patient information banner, is not listed as the child's estimated or true weight, which impacts medication dosing, *"[T^3] doesn't clearly delineate…an estimated weight and not a true weight…that can be important for drug dosing…maybe this patient is 30% bigger than we're thinking…and they need a bigger dose."*

A majority of the interviewees, 34 out of 36, discussed aspects of T^3 that support task performance, such as understanding the child's stable or critical condition, identifying what needs to be done, preparing the OR and making decisions about patient care preparation.

EM attendings, EM residents, ED nurses, anesthesiologists, surgeons, trauma chiefs, PICU attendings and PICU nurses mentioned that T^3 supports their ability to understand the child's current status and responses to interventions and treatments. For instance, an ED nurse explained, *"I like that you can tell the Is[ins] and Os[outs]…you can know…we're behind, and, or…no wonder the patient's blood pressure is 70."* An EM attending explained that the timeline feature, with vital trends and interventions, helps to understand if the child is getting better or worse, *"I like the vital trends because that's a snapshot of everything… I can both see how an intervention affected what we're seeing…from start to finish…are we getting better, or…worse?…might trigger me to do an additional intervention."* Similarly, a PICU nurse explained the benefits of the timeline to understand the child's response to interventions, like blood transfusions, after receiving report, *"The timeline…it's just nice…*

from arrival, her heart rate started out in the 180s, and now since I got report that she got some packed cells and FFP [(Fresh Frozen Plasma)], now she's actually come down to a more normal [heart rate] for a 5-year-old." An anesthesiologist explained the utility of time elapsed to understand the child's condition, *"You can see how long the patient has been in the trauma bay…gives you a sense of…how critical…you're not going to be…worked up…as long as she is hemodynamically stable."*

The anesthesiologists, anesthesia residents, anesthetists, OR nurses and surgical technicians talked about how T^3 supports their task of preparing the OR and making decisions. An anesthesiologist explained the importance of having the patient information feature to provide care, *"It's got things that are important to me, the weight, allergies, and pertinent history. And…have a big impact on what I'm going to do."* An OR nurse explained that the ins/outs feature helps prepare the OR with blood products, especially for children who are actively transfusing, *"The prior to admission… in preparing the OR…we…always have blood products available but knowing that the tourniquet was placed is going to help."* A surgery technician explained that the mannequin feature helps him prepare the OR, *"Now, where's the injury? What type of injury? So, we can get the right stuff ready for that procedure."*

Similarly, the PICU attendings and nurses discussed how T^3 helps to anticipate care and prepare the PICU. A PICU attending explained how T^3 helps to anticipate care and make decisions, *"Being able to quickly see who the patient is, what their injury was…what's been done so far, helps you to make those decisions …what potential issues may arise based on what's happened previously."* A PICU nurse explained how T^3 helps to prepare the child's room, *"What's happened prior to admission…we… need to know…it helps with preparing the room…getting a feel for how stable or unstable the patient is going to be on admission and potential problems."*

3.2.2 Workload and efficiency—

Five of the 36 interviewees, i.e., an EM attending, two ED nurses, anesthesiologist and OR nurse, discussed how T^3 could create additional work for a team member, specifically the ED nurses who need to enter data into T^3.

Fifteen of the 36 interviewees discussed how T^3 reduces time or effort for team members; therefore, improving efficiency. Interviewees mentioned how T^3 could help them prepare the OR, make decisions faster without having to 'dig' in the EHR and reduce the number of phone calls. An anesthetist explained how T^3 helps to be efficient in the OR, *"I'm up in the OR, and I'm getting together an arterial line kit, but I see now somebody has just placed one… that's not me spending time now making an arterial line and holding up surgery… Now I can draw up my drugs."*

3.3 Technology

We identified two dimensions for the technology element: (1) usability of T^3 and (2) specific features of T^3. Of the 36 interviewees, 28 commented on usability; 33 of the 36 interviewees commented on some specific features of T^3.

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3.3.1 Usability—

Of the 36 interviewees, 11 discussed usability challenges with T^3 missing information, being another data source to review, being challenging to read, wordy and poor format. One EM attending described concerns that T^3 is another data source to review, *"But it is another data [source] that we need to assimilate while we're taking care of the patient… I worry there may be some sensory overload."* An anesthesia resident described a challenge of information on T^3 blending together, *"It's all the same color and… font…If you just glance at it …Each section kind of looks the same from a distance."*

All three anesthetists mentioned usability as a barrier and commented that T^3 resembles and should look more like the intraoperative record. Only one nurse, in the ED, mentioned usability as a barrier, commenting on T^3's inconsistent font—compared to the trauma flowsheet. All other nurses in the ED, OR and PICU, including the one ED nurse who described usability as a barrier, also mentioned usability as a facilitator because T^3 integrates information that is quick to understand.

Of the 36 interviewees, 22 commented on usability as a facilitator. Interviewees mentioned T^3 containing pertinent information, liked the integrated visual summary, and thought the format was easy to read. One OR nurse talked about T^3 being a nice visual summary, *"This is exactly what I'm looking for when I want.. a good picture. It doesn't take a lot for me to figure out what's happening here on this screen… it's a really nice design."* A PICU attending also commented how T^3 provides useful orientation, *"The kind of quick orientation to who the patient is so you know what you're dealing with… the main strengths of this."*

3.3.2 Specific features of T^3—

Thirty-three of the 36 interviewees commented on specific features of T^3. Five out of 11 most frequently mentioned features are: patient information, ins/outs, mannequin, transition to OR, and timeline; see figure 2.

3.3.2.1 Specific features of T^3: patient information: Seven of the 36 interviewees, an EM attending, ED nurse, anesthesiologist, anesthetist, surgeon, PICU attending, and PICU nurse, described barriers related to patient information. Interviewees mentioned challenges with identifying whether weight and age are estimated, insufficient information on home medications, and lack of highlight for the allergies.

Five of the 36 interviewees, EM resident, ED nurse, anesthesiologist, anesthesia resident, and OR nurse, described facilitators related to patient information. Interviewees mentioned pertinent, visible information, e.g., weight and allergies.

3.3.2.2 Specific features of T^3: ins/outs graph: Twelve of the 36 interviewees described issues related to the ins/outs graph. Interviewees mentioned the color of the ins/outs graph was confusing and information was insufficient, unclear (e.g., about administered products) and inconsistent with EHR data. Interviewees reporting barriers related to the ins/outs graph were primarily physicians and advanced practice providers (anesthetist).

Six of the 36 interviewees, an EM attending, EM resident, anesthesiologist, anesthesia resident, anesthetist and PICU attending, described facilitators related to the ins/outs graph.

They mentioned the ins/outs graph was useful with critical and important information. OR nurses, surgeons, and trauma chiefs did not mention ins/outs as a facilitator.

3.3.2.3 Specific features of T^3: mannequin: Six of the 36 interviewees, two EM attendings, EM resident, OR nurse, and two trauma chiefs, described barriers related to the mannequin. Interviewees mentioned challenges with mannequin information on access points and the injury location being unclear with too much data presented – especially when the child has multiple injuries. Interviewees reporting barriers related to the mannequin were primarily EM attendings, EM residents, and trauma chiefs.

Eight of the 36 interviewees, an anesthesiologist, two anesthesia residents, OR nurse, trauma chief, surgical technician, PICU attending, and PICU nurse, described facilitators related to the mannequin. Interviewees mentioned the useful information on injuries and access points and visual representation of icons on the mannequin being easy to read. Interviewees reporting facilitators related to the mannequin were primarily anesthesiologists, anesthesia residents, PICU attendings, and PICU nurses.

3.3.2.4 Specific features of T^3: transition to OR: Seven of the 36 interviewees, EM resident, anesthetist, OR nurse, surgeon, trauma chief, and two PICU attendings, described barriers related to transition to OR. Interviewees mentioned information in transition to OR was confusing, like 'PICU notified', and being unclear about whether the child has already moved to the OR. Interviewees reporting barriers related to transition to OR were primarily OR nurses, surgeon, and trauma chief.

Five of the 36 interviewees, anesthetist, surgical technician, two PICU attendings, and PICU nurse, described facilitators related to transition to OR. Interviewees mentioned facilitators about the useful information and visual cues – with traffic lights representing completion of tasks. Interviewees reporting facilitators related to transition to OR were primarily PICU attendings and PICU nurses.

3.3.2.5 Specific features of T^3: timeline: Nine of the 36 interviewees, EM attending, two EM residents, ED nurse, anesthesiologist, anesthetist, OR nurse, surgeon, and PICU nurse, described barriers related to the timeline. Interviewees mentioned the confusing layout for vitals and missing information for imaging, administration of medications and blood products.

Twelve of the 36 interviewees described facilitators related to the timeline. They mentioned the utility of vital trends with timing of interventions and administration of medications and blood products. All three trauma chiefs mentioned facilitators related to the timeline feature of T^3.

3.4 Environment – space and specific location for T^3

We identified two dimensions for the environment element: (1) space for T^3 and (2) location for T^3. Seven of the 36 interviewees commented about space for T^3; 33 of the 36 interviewees commented about location for T^3.

3.4.1 Space for T^3—Five of the 36 interviewees, two EM attendings, anesthesiologist, anesthesia resident, and trauma chief, discussed challenges in finding space for T^3 in the small, crowded ED trauma bay with posters, lights, bags, and fluids hanging. One EM attending described the trauma bay rooms as big, but small when all the consultants gather.

3.4.2 Specific location for T^3—Four of the 36 interviewees, two ED nurses, OR nurse, and PICU attending, discussed barriers about location for T^3: those were locations to avoid placing T^3, such as next to the computers used by residents, where information could get more easily missed, or facing the hallway, which would provide unintentional access to the wrong people and violate HIPAA.

Of the 36 interviewees, 32 interviewees discussed specific useful locations for T^3, primarily in the ED trauma bay and some other options in the OR and PICU. Clinicians, excluding surgical technicians and PICU nurses, proposed three locations in the ED trauma bay: (1) at the head of the bed, (2) by the computers used by residents and (3) outside the trauma bays by the badge reader. Anesthesiologist, anesthesia residents, anesthetists, and OR nurses proposed two locations in the OR: (1) next to the nursing and anesthesia monitors and (2) by the OR board. Anesthesia residents, PICU attendings, and PICU nurses proposed two locations in the PICU: (1) in the patient's room and (2) next to the nurse station monitors.

3.5 Organization – communication and coordination

We identified one dimension for the organization element: communication and coordination.

One out of 36 interviewees, an EM attending, mentioned that T^3 could hinder communication and coordination. The EM attending was unclear about which role was responsible for notifying the PICU about the child's admission and requesting a PICU bed.

Of the 36 interviewees, 32 discussed how T^3 supports communication and coordination by ensuring information, e.g., weight and allergies, does not get missed, providing an overview of information, and allowing team members to identify and anticipate what is needed for the OR and PICU transitions. One ED nurse described the benefits of T^3 supporting information exchange between care team members, *"Nothing will get missed. There will be no patient harm…Everyone will be on the same page… The patient will have better outcomes."* An OR nurse explained how T^3 supports communication and coordination for team members in the OR and PICU, *"I think it [T^3] informs OR sooner. It [T^3] notifies the PICU…they need to be preparing for…It [T^3] helps with nurse staffing levels because you know what you're anticipating…The sooner the OR knows about stuff from the ED, we can prepare faster so we're ready to go sooner.* A PICU attending explained how T^3 is helpful when arriving to the trauma bay and communicating with other team members, *"This is really, me walking in from the ICU and saying… "Do you think you have the bleeding under control?"… The arriving members of the team are the ones who are going to need most of this."*

4. Discussion

Designing health IT to support the work of a care team, representing different roles, is not easy. This study provides an in-depth analysis of a team health IT that was found to be highly usable in a simulation setting (Carayon, 2022); we found both barriers and facilitators in all five work system elements. This information can provide input for the next phase of technology design.

4.1 Importance of systems approach to evaluate team health IT

Our results demonstrate the usefulness of a systems approach, such as the SEIPS model (Carayon et al., 2006; Carayon et al., 2014), to assess a technology: interviewees talked about barriers and facilitators in all five work system elements. Our results emphasize the need to look at other elements, besides just the technology. Six of the eight dimensions had more interviewees reporting facilitators than barriers — except for experience (person element) and sufficient space for T^3 (environment element), see table 1. This analysis provides evidence that implementing a team health IT can affect all of the other work system elements in both positive and negative ways. This suggests the value of an analysis of work system barriers and facilitators when evaluating a technology aimed at supporting information needs of a diverse care team, which can help to continuously improve the design of the technology (Carayon, 2022).

4.2 Designing team health IT to support task work and teamwork

One challenge for health IT design is to support team-based care processes as well as specific tasks (Walker & Carayon, 2009). Examining different care team members' perspectives of work system barriers and facilitators is crucial for ensuring a team health IT supports both individual tasks and team processes, e.g., communication and coordination. A majority of the 36 interviewees, 34 and 32, respectively, mention facilitators for (1) task performance (task element) and (2) communication and coordination (organization element). Also, the "care team members" feature was mentioned most frequently as a facilitator in the analysis of specific features: 18 interviewees commented that the list of clinicians involved in the child's care is helpful. As evidence by T^3's SUS score (Carayon et al., 2022), our HCD process resulted in a team health IT that was indeed perceived as usable; moreover, results from this qualitative study support that our team health IT mock-up supports both individual taskwork and teamwork. However, there are still design issues that need to be addressed in order to support both taskwork and teamwork; in particular, assuring accuracy of information displayed on T^3 is an important patient safety issue (Hoonakker, Carayon, et al., 2019).

4.3 Managing tradeoffs in design of team health IT

Prior research on team health IT describes the design process used to create solutions that support team-based care processes, e.g., resuscitation, but does not actually evaluate how multiple care team members perceive the technology and its fit with the rest of the work system (Parush et al., 2017; Pickup et al., 2019; Wu et al., 2017). In a manner similar to these studies, we applied a HCD approach to develop the T^3 mock-up, involving different groups of care team members to provide input in the design and evaluation (Carayon et al., 2022). We went beyond the description of the design process and conducted an in-depth scenario-based evaluation of T^3 that involved 12 different roles and looked at the fit (or lack of fit) of the technology in the rest of the work system. In this evaluation, we found several dimensions of work system barriers (see table 1). This feedback from team members can be used to continue improving the design of the technology, but conflicting opinions between different roles can be challenging to address.

Our analysis identified tradeoffs for decisions about design and implementation of the technology in order to satisfy the needs of all team members. In particular, three dimensions of work system barriers and facilitators point to tradeoffs: (1) workload and efficiency, (2) specific features of T^3 and (3) location for T^3.

Out of 12 groups, ED nurses were the only team members that mentioned T^3 creating additional work with inputting information. In the trauma bay, ED nurses perform multiple tasks to provide patient care and complete documentation. In a prior analysis, we found that about 90% of all information on T^3 can be pulled from data fields currently documented in the EHR (Carayon et al., 2022; Hoonakker et al., 2022). The remaining 10% of information would be additional work for the ED nurse (i.e., data entry to feed data for T^3), while also caring for a critically injured child. Future design effort should identify solutions for mitigating this additional workload for ED nurses. For instance, technical solutions could be developed that directly connect medical devices and the EHR, so that the ED nurse does not need to re-enter data to feed into T^3.

Many of the interviewees perceived that T^3 supports the pediatric trauma care team and reported more facilitators than barriers for seven of the 11 specific features (figure 2). However, the ins/outs graph needs improvement and was frequently mentioned as a barrier, by 12 out of 36 interviewees, as compared to being mentioned as a facilitator by only six out of 36 interviewees. Feedback on the ins/outs graph provided by interviewees, such as colors and description of the blood products, could be incorporated in revising T^3 design. This next phase of design should not only involve input from team members, but also usability heuristics in order to ensure that the ins/outs graph is clear and consistent with current representation of EHR data.

Interviewees did not converge on a single location for T^3. For instance, they mentioned three different locations to place T^3 in the ED trauma bay: at the head of the bed, above the computers used by residents, and outside by the badge reader. Choosing one of the three locations requires discussion from an interdisciplinary team of clinicians and HF experts in order to converge on a solution. This could be done via focused usability testing and simulation to compare the three proposed ED locations.

We evaluated a team health IT mock-up that was perceived as highly usable according to the SUS questionnaire (Carayon, 2022); but we still identified multiple barriers, which can help to produce design recommendations and address implementation challenges, e.g., concerns about information accuracy. We recommend embedding care team members and HF experts in the continuous design of team health IT to address potentially divergent opinions and ensure that implemented solutions are highly usable.

4.4 Limitations

One limitation of this study is that the evaluation of T^3 relied on a paper mock-up; at the time of the scenario-based evaluation, T^3 was not implemented. In the scenario-based evaluation, we assumed that T^3 would be integrated with the EHR relying on data pulled from documentation done by the ED nurse. Thus, interviewees had to imagine what using T^3 would be like in their real work context. Future research is needed to conduct evaluations "in the wild", like Catchpole et al. (2022).

Another limitation of our study is that we examined individual perspectives of T^3 in a single scenario for a care process that is distributed over people, time, and space. Future scenario-based evaluation studies of team health IT could examine the reactions of clinicians in a simulated team scenario; however, this may be complex to organize with 12 different roles. Future research should also include various scenarios that represent the variety of pediatric trauma patients.

5. Conclusion

Our study provides valuable information about the evaluation of a team health IT designed to support information sharing for a large, distributed pediatric trauma care team. We report barriers and facilitators for all five work system elements and identified eight dimensions of barriers and facilitators; therefore, highlighting the importance of a systems approach such as the SEIPS model. In a previous study, we reported on the HCD approach used to design T^3, and the high usability of T^3; yet, in the scenario-based evaluation and the debrief interviews conducted at the end of the evaluation and used in this study, interviewees identified multiple barriers related to all five work system elements. Designing usable and useful team health IT is challenging and needs to be part of a continuous work system design approach involving care team members and HF experts.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

Brooke J (1996). SUS: A "quick and dirty" usability scale. In Jordan PW, Werdmeester BA, & McClelland AL (Eds.), Usability evaluation in industry (pp. 189–194). London: Taylor & Francis.

Carayon P (2009). The balance theory and the work system model… Twenty years later. International Journal of Human–Computer Interaction, 25(5), 313–327.

Carayon P (2022). Implementation or continuous design? The contribution of human factors and engineering to healthcare quality and patient safety. In Rapport F, Clay-Williams R, & Braithwaite J (Eds.), Implementation Science (1st ed., pp. 89–92). London: Routledge.

Carayon P, Gurses A, Hundt AS, Ayoub P, & Alvarado CJ (2005). Performance obstacles and facilitators of healthcare providers. Change and Quality in Human Service Work, 4, 257–276.

Carayon P, & Hoonakker P (2019). Human factors and usability for health information technology: old and new challenges. Yearbook of medical informatics, 28(01), 071–077.

Carayon P, Hose B-Z, Wooldridge A, Brazelton TB, Dean SM, Eithun BL, … Hoonakker PLT (2022). Human-Centered Design of Team Health IT for Pediatric Trauma Care Transitions. International journal of medical informatics, 162, 104727. [PubMed: 35305517]

Carayon P, Schoofs Hundt A, Karsh BT, Gurses AP, Alvarado CJ, Smith M, & Flatley Brennan P (2006). Work system design for patient safety: the SEIPS model. Quality & safety in health care, 15 Suppl 1(Suppl 1), i50–i58. [PubMed: 17142610]

Carayon P, Wetterneck TB, Rivera-Rodriguez AJ, Hundt AS, Hoonakker P, Holden R, & Gurses AP (2014). Human factors systems approach to healthcare quality and patient safety. Applied Ergonomics, 45(1), 14–25. [PubMed: 23845724]

Catchpole K, Privette A, Roberts L, Alfred M, Carter B, Woltz E, … Crookes B (2022). A Smartphone Application for Teamwork and Communication in Trauma: Pilot Evaluation “in the Wild”. Human Factors, 64(1), 143–158. [PubMed: 34126795]

Devers KJ (1999). How will we know “good” qualitative research when we see it? Beginning the dialogue in health services research. Health Services Research, 34(5), 1153–1188. [PubMed: 10591278]

Elo S, & Kyngäs H (2008). The qualitative content analysis process. Journal of advanced nursing, 62(1), 107–115. [PubMed: 18352969]

Holden RJ, & Carayon P (2021). SEIPS 101 and seven simple SEIPS tools. BMJ Qual Saf, 30(11), 901.

Hoonakker PLT, Carayon P, Hose B-Z, Ramsey JC, Eithun BL, Kim MK, … Reisman MM (2019). Proactive Risk Assessment of Team Health IT for Pediatric Trauma Care Transitions (T 3). Paper presented at the International Conference on Healthcare Ergonomics and Patient Safety.

Hoonakker PLT, Hose B-Z, Carayon P, Eithun BL, Rusy DA, Ross JC, … Kelly MM (2022). Scenario-Based Evaluation of Team Health Information Technology to Support Pediatric Trauma Care Transitions. Applied clinical informatics, 13(1), 218–229. [PubMed: 35139563]

Hoonakker PLT, Wooldridge AR, Hose B-Z, Carayon P, Eithun B, Brazelton TB, … Gurses AP (2019). Information flow during pediatric trauma care transitions: things falling through the cracks. Internal and Emergency Medicine, 14(5), 797–805. [PubMed: 31140061]

Hose B-Z, Carayon P, Hoonakker PLT, Ross JC, Eithun BL, Rusy DA, … Kelly MM (2023). Managing multiple perspectives in the collaborative design process of a team health information technology. Applied Ergonomics, 106, 103846. [PubMed: 35985249]

Institute of Medicine. (2012). Health IT and Patient Safety: Building Safer Systems for Better Care. Retrieved from Washington (DC):

International Organization for Standardization. (2018). ISO 9241-11 Ergonomics of Human-System Interaction-Part 11: Usability: Definitions and Concepts. Retrieved from Geneva, Switzerland: https://www.iso.org/obp/ui/#iso:std:iso:9241:-11:ed-2:v1:en

Marcilly R, Schiro J, Beuscart-Zéphir M, Catherine, & Magrabi F (2019). Building Usability Knowledge for Health Information Technology: A Usability-Oriented Analysis of Incident Reports. Applied clinical informatics, 10(3), 395–408. [PubMed: 31189203]

Mays N, & Pope C (2000). Qualitative research in health care. Assessing quality in qualitative research. Bmj, 320(7226), 50–52. [PubMed: 10617534]

Musuuza JS, Hundt AS, Carayon P, Christensen K, Ngam C, Haun N, & Safdar N (2019). Implementation of a Clostridioides difficile prevention bundle: Understanding common, unique, and conflicting work system barriers and facilitators for subprocess design. Infect Control Hosp Epidemiol, 40(8), 880–888. [PubMed: 31190669]

Parush A (2014). Displays for health care teams: A conceptual framework and design methodology. In Bisantz AM, Burns CM, & Fairbanks RJ (Eds.), Cognitive systems engineering in health care (pp. 75–95): CRC Press.

Parush A, Mastoras G, Bhandari A, Momtahan K, Day K, Weitzman B, … Calder L (2017). Can teamwork and situational awareness (SA) in ED resuscitations be improved with a technological cognitive aid? Design and a pilot study of a team situation display. Journal of Biomedical Informatics, 76, 154–161. [PubMed: 29051106]

Pickup L, Lang A, Shipley L, Henry C, Carpenter J, McCartney D, … Sharkey D (2019). Development of a Clinical Interface for a Novel Newborn Resuscitation Device: Human Factors Approach to Understanding Cognitive User Requirements. JMIR Hum Factors, 6(2), 1–13.

Ratwani RM, Savage E, Will A, Fong A, Karavite D, Muthu N, … Rising J (2018). Identifying Electronic Health Record Usability And Safety Challenges In Pediatric Settings. Health Affairs, 37(11), 1752–1759. [PubMed: 30395517]

Salas E, Wilson KA, Murphy CE, King H, & Salisbury M (2008). Communicating, coordinating, and cooperating when lives depend on it: tips for teamwork. The Joint Commission Journal on Quality and Patient Safety, 34(6), 333–341. [PubMed: 18595379]

Saldaña J (2015). The coding manual for qualitative researchers. Thousand Oaks, CA: Sage.

Smith MJ, & Sainfort PC (1989). A balance theory of job design for stress reduction. International Journal of Industrial Ergonomics, 4(1), 67–79.

Turner P, Kushniruk A, & Nohr C (2017). Are We There Yet? Human Factors Knowledge and Health Information Technology - the Challenges of Implementation and Impact. Yearbook of medical informatics, 26(1), 84–91. doi:10.15265/IY-2017-014 [PubMed: 29063542]

Walker JM, & Carayon P (2009). From Tasks To Processes: The Case For Changing Health Information Technology To Improve Health Care. Health Affairs, 28(2), 467–477. [PubMed: 19276006]

Wooldridge AR, Carayon P, Hoonakker P, Hose B-Z, Eithun B, Brazelton T, … Gurses AP (2020). Work system barriers and facilitators in inpatient care transitions of pediatric trauma patients. Applied Ergonomics, 85, 1–12.

Wooldridge AR, Carayon P, Hoonakker P, Hose B-Z, Ross J, Kohler JE, … Gurses AP (2018). Complexity of the pediatric trauma care process: implications for multilevel awareness. Cognition, Technology & Work, 21(3), 397–416.

Wright MC, Borbolla D, Waller RG, Del Fiol G, Reese T, Nesbitt P, & Segall N (2019). Critical care information display approaches and design frameworks: A systematic review and meta-analysis. Journal of Biomedical Informatics: X, 3, 1–11.

Wu P, Nam M-Y, Choi J, Kirlik A, Sha L, & Berlin RB (2017). Supporting Emergency Medical Care Teams with an Integrated Status Display Providing Real-Time Access to Medical Best Practices, Workflow Tracking, and Patient Data. Journal of medical systems, 41(12), 186. [PubMed: 29039621]

Zayas-Cabán T, & White PJ (2020). The national health information technology human factors and ergonomics agenda. Applied Ergonomics, 86, 1–9.

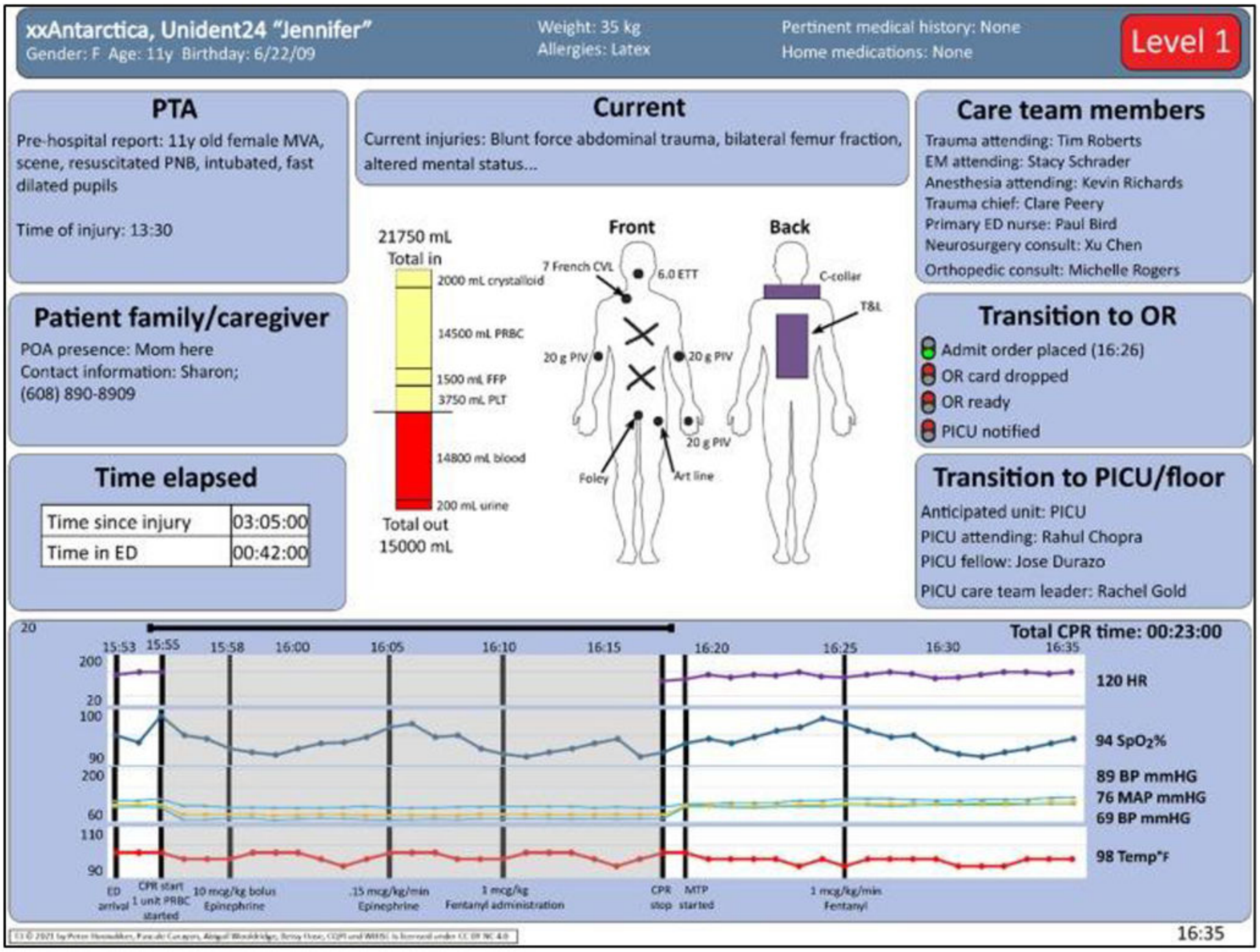

Figure 1.

Mock-up of T^3 (Teamwork Transition Technology).

T^3 ©2021 by Peter Hoonakker, Pascale Carayon, Abigail Wooldridge, Bat-Zion Hose, CQPI and WIHSE is licensed under CC BY NC 4.0.

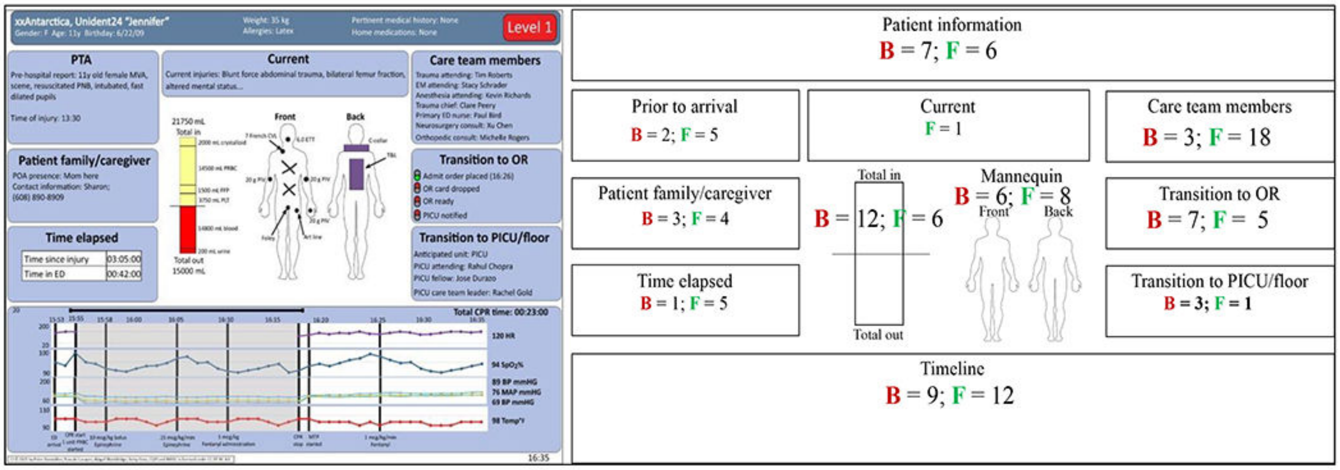

Figure 2.

T^3 mock-up on the left. Structure of T^3 with barriers and facilitators for 11 specific features on the right.

Note: B = number of interviewees that mentioned barriers for respective feature; F = number of interviewees that mentioned facilitators for respective feature. Larger font size of barrier and facilitator indicates more interviewees mentioned that specific feature.

Table 1.

Dimensions of work system barriers and facilitators of T^3 mock-up (total N = 36 interviewees).

Work system element	Dimension	Barrier definition	Facilitator definition	B (# interviewees)	F (# interviewees)
Person	Experience	*Less* clinically experienced care team members are *less* likely to understand T^3	*More* clinically experienced care team members are *more* likely to understand T^3	1	1
Task	Task performance	T^3 *hinders* team member's ability to achieve a task	T^3 *supports* team member's ability to achieve a task	4	34
Task	Workload & efficiency	T^3 *creates additional work* for team member	T^3 *reduces time or effort* for team member	5	15
Technology	Usability	The design of T^3 *affects* effectiveness, efficiency and satisfaction of users*	The design of T^3 *supports* effectiveness, efficiency and satisfaction of users*	11	22
Technology	Specific features of T^3	The design of any of the 11 specific features of T^3 is a *negative* aspect	The design of any of the 11 specific features of T^3 is a *positive* aspect	25	30
Environment	Space for T^3	There is *insufficient or inadequate room* in the physical environment to place T^3	There is *sufficient or adequate room* in the physical environment to place T^3	5	1
Environment	Location for T^3	Specific place or position in the physical environment of T^3 *hinders* its use	Specific place or position in the physical environment of T^3 *facilitates* its use	4	32
Organization	Communication & coordination	T^3 *hinders* exchange of information and coordination between care team members~	T^3 *supports* exchange of information and coordination between care team members~	1	32
			TOTAL number of interviewees	36	36

Note:

*Indicates (International Organization for Standardization, 2018)

~Indicates (Salas, Wilson, Murphy, King, & Salisbury, 2008)