HHS Public Access

Author manuscript

Appl Ergon. Author manuscript; available in PMC 2023 March 19.

Published in final edited form as:

Appl Ergon. 2023 January ; 106: 103846. doi:10.1016/j.apergo.2022.103846.

Managing Multiple Perspectives in the Collaborative Design Process of a Team Health Information Technology

Bat-Zion Hose[1], **Pascale Carayon**[2,3], **Peter L. T. Hoonakker**[3], **Joshua C. Ross**[4,5], **Benjamin L. Eithun**[4], **Deborah A. Rusy**[4,6], **Jonathan E. Kohler**[7], **Thomas B. Brazelton III**[4,5], **Shannon M. Dean**[8], **Michelle M. Kelly**[4,5]

[1]Department of Anesthesiology and Critical Care at the Perelman School of Medicine, University of Pennsylvania

[2]Department of Industrial and Systems Engineering, University of Wisconsin-Madison

[3]Wisconsin Institute for Health Systems Engineering, University of Wisconsin-Madison

[4]American Family Children's Hospital, UW Health

[5]Department of Pediatrics, University of Wisconsin School of Medicine and Public Health

[6]Department of Anesthesiology, University of Wisconsin School of Medicine and Public Health

[7]Department of Surgery, UC Davis Children's Hospital

[8]St. Jude Children's Research Hospital, Memphis, Tennessee

Abstract

We need to design technologies that support the work of health care teams; designing such solutions should integrate different clinical roles. However, we know little about the actual collaboration that occurs in the design process for a team-based care solution. This study examines how multiple perspectives were managed in the design of a team health IT solution aimed at supporting clinician information needs during pediatric trauma care transitions. We focused our analysis on four co-design sessions that involved multiple clinicians caring for pediatric trauma patients. We analyzed design session transcripts using content analysis and process coding guided by Détienne's (2006) co-design framework. We expanded upon Détienne (2006) three collaborative activities to identify specific themes and processes of collaboration between care team members engaged in the design process. The themes and processes describe how team members collaborated in a team health IT design process that resulted in a highly usable technology.

Keywords

Collaborative design; Team health information technology; Pediatric trauma care transitions

Corresponding author: Bat-Zion Hose, PhD, Postdoctoral Scholar, Department of Anesthesiology and Critical Care, University of Pennsylvania, Perelman School of Medicine, 4423 Guardian Drive, 333 Blockley Hall, Philadelphia, PA 19104, USA, Bat-Zion.Hose@Pennmedicine.upenn.edu.

1. Introduction

Health care often requires that individuals with diverse knowledge and from different disciplines work in teams (Dinh et al., 2020; Mitchell et al., 2012; Salas, Wilson, Murphy, King, & Salisbury, 2008). Members of a multidisciplinary care team work together to provide high-quality, safe care through multiple complex, distributed care processes, including care transitions (Lane-Fall et al., 2018; Wooldridge et al., 2018). Team-based care processes can be challenging as care team members with multiple roles must gather and share information about the patient (Wooldridge et al., 2020). When care team members are distributed over time (e.g., different shifts) and space (e.g., emergency department (ED), operating room (OR) and pediatric intensive care unit (PICU)), patient-related information may not be available, accessible or transferred, or it may be incomplete and inaccurate (Hoonakker et al., 2019); therefore leading to patient safety issues.

Health information technology (IT) has been proposed as one solution for supporting information sharing between care team members to facilitate high-quality, safe patient care (Carayon & Hoonakker, 2019). One form of team health IT, integrated information displays, can provide cognitive support to team members by organizing relevant patient information on a shared display (Parush, 2014; Wright et al., 2019). These displays can facilitate teamwork, including communication, coordination and information sharing, during time-sensitive processes, like resuscitation (Parush et al., 2017; Pickup et al., 2019; Wu et al., 2017). The design of team health IT solutions involves the integration of multiple perspectives as teams are diverse and include various roles; this may introduce conflicts regarding what information to include on the shared display (Parush, 2014; Parush et al., 2017; Pickup et al., 2019). In this study, we explore the collaboration of multiple roles in the design of a team health IT solution to support clinicians caring for traumatically injured children; we focus on the multiple perspectives of care team members participating in the design process.

1.1 Participation in health IT design

Participatory approaches provide a mechanism for involving various team members in health IT design (Kushniruk & Nøhr, 2016). Approaches vary with respect to who is involved, when, and in what role, e.g., designer, researcher or user (Sanders & Stappers, 2008). Collaborative design (co-design) is an emerging participatory approach that actively engages multiple roles (and perspectives) in designing team health IT: users collaborate with designers to provide critical knowledge of the work domain (Kushniruk & Nøhr, 2016; Sanders & Stappers, 2008). For example, a physician and nurse were embedded in the design team for an interprofessional clinical communication platform (Tang, Lim, Mansfield, McLachlan, & Quan, 2018). We need detailed case studies about the actual collaboration that occurs in co-design processes, in particular when multiple perspectives are involved.

1.2 Multiple perspectives in design processes

Involving multiple roles in co-design allows the inclusion of a wide range of perspectives and produces unique benefits (Hundt, Adams, & Carayon, 2017; Lyng & Pedersen, 2011;

Parush et al., 2017; Pickup et al., 2019; Wu et al., 2017). For instance, the involvement of participants with different organizational and clinical roles in electronic health record (EHR) design led to significant improvements in the technology and high user satisfaction (Hundt et al., 2017). Engaging multiple perspectives in designing a team health IT can promote successful implementation (Pickup et al., 2019), enhance usability and improve support to cognitive work and communication (Parush et al., 2017; Wu et al., 2017).

Studies have described the benefit of involving different perspectives in health IT design; but only four studies provide detailed information on the actual collaboration and interactions between care team members as the design process unfolds (Irestig & Timpka, 2008; Scandurra, Hagglund, & Koch, 2008; Vermeulen et al., 2014; Xie et al., 2015). Vermeulen et al. (2014) identified barriers and facilitators to collaboration in teams involved in the design of telecare products and services for older people with diabetes or chronic obstructive pulmonary disease. They found that reaching consensus on design requirements with a multidisciplinary team was particularly challenging. Irestig and Timpka (2008) used discourse analysis of meeting transcripts to analyze a health IT design process and identified multiple instances of conflict between team members. Only two of the four studies report data on the quality of solutions produced by the design teams, including an IT solution with high usability (Scandurra, Hagglund, et al., 2008) and a redesigned care process that met the information needs of multiple team members (Cox et al., 2017; Xie et al., 2015). We, therefore, address two major gaps in the literature: (1) lack of detailed description of the actual collaboration during a design process with multiple perspectives, and (2) further understanding of how a co-design process can produce a ‘high-quality’ solution, such as a usable team health IT. In addition, our research is embedded in a conceptual framework of collaboration, a concept that has been studied by human factors and ergonomics (HFE) researchers. The HFE research on collaborative work has focused on defining factors involved in this complex phenomenon in various domains (Bedwell et al., 2012; Li, Abel, & Negre, 2019; Patel, Pettitt, & Wilson, 2012). In contrast, we know little about collaboration that occurs in the actual design process for a team health IT solution involving different clinical roles representing multiple perspectives.

In this study, using the co-design conceptual framework of Détienne (2006), we describe how multiple perspectives are managed to produce a usable health IT that meets the information needs of multiple team members.

1.3 Detienne’s co-design framework

According to Détienne (2006), co-design includes a team of designers from a range of disciplines who interact in three inter-related collaborative activities used to manage the confrontation and combination of multiple perspectives:

1. Establishment of common ground (CG): occurs when team members refer to knowledge that they have in common, e.g., about the current state of a problem or solution.
2. Perspective clarification (PC): occurs when a team member provides reasoning for proposals and/or alternative solutions, often associated with a team member’s interests based on role.

3. Convergence/divergence (C/D): occurs when a team member expresses a proposal and presents substantiating information that is then discussed among other members who either converge or diverge towards a negotiated solution.

Détienne's (2006) framework has been used to analyze collaboration among student teams participating in architectural design (Safin, Verschuere, Burkhardt, Détienne, & Hébert, 2010) and to characterize participation in agricultural design (Barcellini, Prost, & Cerf, 2015). The framework has yet to be applied to evaluate collaboration between team members engaged in health IT design. In this study, we use Détienne's framework in a case study to examine how multiple perspectives are managed in the co-design of a team health IT to support care transitions. Our design process is a useful case study as it resulted in a highly usable IT solution that supports the information needs of a complex team that cares for injured children (Hoonakker et al., 2022).

1.4 Health care context

In the U.S., over 10 million children visit the ED each year resulting in 250,000 hospital admissions from unintended, traumatic injuries (Centers for Disease Control, 2020). Pediatric trauma care is a complex team-based process that is distributed over time (e.g., arrival to the ED, transfer to the OR) and space (e.g., ED, OR, hospital unit). On average, traumatically injured children experience 2.2 care transitions with as many as 53 roles involved (Wooldridge et al., 2018). Unfortunately, problems with information flow between team members may result in a child's known or suspected injuries being missed, which occur in up to 16% of injured children (Soundappan, Holland, & Cass, 2004). We designed a team health IT, Teamwork Transition Technology (T^3), to support the information needs of the pediatric trauma care team during ED-OR-PICU care transitions (Carayon et al., 2022). Using Détienne's (2006) framework, we examine how multiple perspectives were managed in the design process.

2. Methods

This study was conducted as part of a large study on designing health IT to support care transitions for traumatically injured children (Carayon et al., 2022). The current study focuses on the co-design process and the identification and analysis of information elements necessary for the shared display.

2.1 Setting

The participating hospital is an American College of Surgeons accredited level 1 pediatric and adult trauma center with an 87-bed children's hospital, a 21-bed PICU, and 9 pediatric ORs. From 2013 to 2017, there were 1,487 pediatric trauma patients (Wooldridge et al., 2018). In 2008, the participating hospital implemented a system-wide EHR (Epic Systems Corporation, Verona, Wisconsin, United States). The University of Wisconsin-Madison Institutional Review Board (IRB) considered this study as a quality improvement project, which was therefore exempt from IRB oversight.

2.2 Collaborative design of Teamwork Transition Technology (T^3)

The entire human-centered design (HCD) process of T^3 took place over 30 months; it is described in detail in another publication (Carayon et al., 2022). The HCD process included a phase of co-design, with four design sessions from January-October 2018. Table 1 provides an overview of the T^3 co-design process.

An HFE researcher moderated the four in-person, hour-long design sessions with the help of three other HFE researchers. The sessions included team members representing the different clinical roles critical to the care of traumatically injured children: emergency medicine, surgery, anesthesia, pediatric intensive care medicine, nursing, pediatric trauma management, hospitalist, and medical informatics. HFE expertise was available and used during the discussions in the design sessions; it was also incorporated in discussions and decisions made outside of the design sessions. The overall HCD process produced a set of HFE design principles (e.g., support to situation awareness, information integration and interpretation) that are described in the publication mentioned above (Carayon et al., 2022).

2.2.1 T^3 Mock-ups and information elements—In design session 1, the paper mock-up of T^3 consisted of six large Post-it® papers for the following categories: (1) patient demographics, (2) past, (3) current, (4) care team members, (5) patient family/caregiver and (6) care plan (Figure 1). Clinicians voted on which information elements to include; this was followed by a discussion about information elements.

In design session 2, the paper mock-up of T^3 consisted of seven large Post-it® papers for the following categories: (1) patient information, (2) prior to arrival (PTA), (3) current, (4) care team members, (5) patient family/caregiver, (6) care plan and (7) timeline (Figure 2). Information elements were written in black marker on pink Post-it® papers. During design session 2, clinicians drew mock-ups of the T^3 timeline feature and presented them to the group.

In design session 3, the mock-up of T^3 was created in LucidChart© and included 8 categories of information: (1) patient information, (2) PTA, (3) current, (4) mannequin, (5) timeline, (6) care team members, (7) patient family/caregiver and (8) care plan (Figure 3). The mock-up included information elements populated with fictitious patient information (e.g., *patient name*), and graphical representations for the mannequin and timeline. Between design sessions 2 and 3, the clinicians filled out a survey to rate the relevance of 50 information elements (Table 1). During design session 3, clinicians reviewed and discussed the results of the survey, in particular information elements that they disagreed on as being necessary.

In design session 4, the mock-up of T^3 was created in Adobe InDesign® and included 9 categories of information: (1) patient information, (2) PTA, (3) patient family/caregiver, (4) time elapsed, (5) current, (6) mannequin, (7) timeline, (8) care team members and (9) transition plan (Figure 4). The mock-up included information elements populated with fictitious patient information, and graphical representations for the mannequin, timeline and transition plan. During design session 4, HFE researchers specifically asked about information elements the clinicians did not agree on in the individual feedback sessions.

2.3 Data collection and analysis

Design sessions were audio-recorded and transcribed by a professional service. Transcripts were cleaned and deidentified. Two researchers first identified transcript excerpts related to discussion of at least one information element by the design team. The excerpts began when an information element was mentioned and ended when the discussion about the element concluded. Sometimes excerpts overlapped when related information elements were discussed; for instance, when elements were located in the same section of T^3. Another researcher reviewed the segmented transcripts and the two researchers met to make final decisions about the segmentation.

The qualitative data analysis included a primary deductive content analysis (Elo & Kyngäs, 2008) guided by Détienne (2006) co-design framework. We then performed an inductive content analysis (Elo & Kyngäs, 2008) to identify themes for establishment of common ground and perspective clarification. Finally, we performed process coding (Saldaña, 2015) to identify processes of convergence/divergence. This was an iterative data analysis process where two researchers met periodically, providing opportunities for skeptical peer review (Devers, 1999). As data analysis proceeded, one researcher revised code definitions, and added exemplary excerpts and “things to look for”. The data interpretation included peer-feedback meetings with HFE researchers and member checking with clinicians.

3. Results

All of Détienne’s (2006) collaborative activities were identified in the four design sessions. Establishing common ground (CG) was mentioned in 60 excerpts, perspective clarification (PC) in 61, and convergence/divergence (C/D) in 59 (Table 2). Across all 4 design sessions, 63 of the 79 excerpts, with *information element in italics*, were coded for more than one collaborative activity. When present at design sessions, participants with different roles, representing multiple perspectives, all engaged in information element discussions (Table 3).

3.1 Establishment of common ground (CG)

The inductive analysis produced five themes related to CG (Table 4).

1. In 3 of the 4 design sessions, clinicians mentioned information elements to include on T^3 (e.g., *patient name* and *age*).
2. In design sessions 3 and 4, clinicians further explained the meaning of information elements (e.g., for acronyms), the difference from another element (e.g., *inputs* vs *outputs*), or another name for the element (e.g., *FFP* and *plasma*) as the mock-up of T^3 evolved (Figure 1). Clinicians explained where the information element should be and how to visually represent it (e.g., ‘admit order placed’ should be ‘admit order/card dropped’ in the transition plan).
3. Across all design sessions, clinicians explained the pediatric trauma care process and referred to documentation policies (e.g., that electronic sticky notes are used to track an unidentified *child’s name* or *preferred name*).

4. Across all design sessions, clinicians explained the source of information, i.e., whether information is available, accessible or accurate and opportunities, and challenges with the integration and synthesis of EHR information within T^3 (e.g., *injuries* can be pulled from the EHR problem list).

5. Across all design sessions, clinicians discussed several information elements together (e.g., explained that understanding *heart rate* depends on the child's *age)*.

3.2 Perspective clarification (PC)

The inductive analysis produced three themes related to PC (Table 5).

1. Across all design sessions, clinicians applied their perspective to explain an information element that is (un)important for their role, e.g., a clinician explained that *gender* does not need to be on T^3 because "it [*gender*] doesn't change what I do."

2. Across all design sessions, clinicians justified information elements for specific tasks, e.g., a clinician explained the need for a *total CPR timer* to help care team members with resuscitation and timing the administration epinephrine.

3. Across all design sessions, clinicians explained information elements that are important for other roles, e.g., two clinicians, present in the ED, explained the need to include *pertinent medical history* and *injuries*, especially for the anesthesiologist in the OR.

3.3 Convergence and divergence (C/D)

Our process coding produced 3 C/D processes (Table 6).

3.3.1 Someone (clinician or HFE moderator) expresses an information element, and one or more clinicians immediately agree.—

Across all design sessions, we found instances where a clinician (or HFE moderator) expressed an information element and another clinician agreed. In design session 1, clinicians made quick decisions about *vitals* and *injuries*. In design session 2, clinicians presented their timeline mock-ups to the group and expressed agreement with other clinicians' proposals about information to include, "Like [clinical role #2], if you're able to graph it [*vitals*] separately, that would be nice."

3.3.2 Back-and-forth dialogue with some clinicians in agreement and some hesitant clinicians resulting in agreement on an information element.—

In design sessions 1, 3 and 4, clinicians engaged in back-and-forth dialogue about information elements and reached consensus to agree on either including or excluding an information element.

In design session 1, clinicians initially disagreed about including *pain*, "Like if it [*pain*] is bad, you will see it in medication." One clinician redirected the discussion back to *pain*, "I'm sorry, just to back up. The *pain*…I kind of want to bring it back…I don't

want it to get totally missed because patients who have traumatic *injuries*, they need *pain* management." Another clinician proposed that *pain* be represented as *last analgesic* and everyone compromised, "We could say *last analgesic*… I agree. *Pain* is something, but I think the *pain* scores are exceedingly useless." In this example, the back-and-forth dialogue led to agreement to include *last analgesic*.

3.3.3 Back- and-forth dialogue with some clinicians in agreement and some hesitant clinicians resulting in disagreement (or lack of agreement) on an information element.—

In design sessions 1, 3 and 4, clinicians engaged in back-and-forth dialogue about information elements that they were unable to agree on either including or excluding.

In design session 3, clinicians began discussing the issue of known versus unknown information, like *patient name*, as a result of caring for traumatically injured unidentified children. One clinician proposed to include both the child's *unidentified name*, e.g., XXAruba, and reconcile the *preferred name* from a referring chart; the second clinician immediately agreed. A third clinician proposed to ask parents to confirm the child's name and the second clinician explained that currently happens. The third clinician did not state a decision about *patient name*. A fourth clinician was hesitant about including the child's *preferred name* and argued for keeping the *unidentified name* because that is what the child is referred to as s/he is being cared for. In this example, after a lengthy back-and-forth dialogue, no decision or agreement was reached about *patient name*.

In design session 4, HFE researchers focused the discussion on information elements that were not agreed upon during the individual meetings with physician team members (Table 1). Clinicians would initially agree to include an information element, e.g., *gender*, and then disagree about how to visually represent it, e.g., male/female symbol versus text.

3.4 Linkages and temporal patterns of collaborative activities

In order to deepen our analysis of the collaborative activities, we further examined linkages between the activities and the temporal patterns of collaborative activities across the design sessions. Therefore, we focused the next step of the data analysis on five information elements that were discussed multiple times across the four design sessions. This allowed us to describe in detail the flow of discussion and the associated collaborative activities for each information element. We identified five information elements discussed more than once, both within and across design sessions:

- Vitals
- Current injuries
- Patient name
- Pertinent medical history
- Anticipated unit

See figure 5 for a key of the collaborative activity themes and processes short-hand notation. Figure 6 includes a flowchart with the collaborative activity coding for the five information elements discussed more than once.

3.4.1 Multiple discussions on vitals—Clinicians discussed *vitals* in nine excerpts over three design sessions (1, 2 and 4). In three out of nine excerpts, clinicians engaged in all three collaborative activities: CG, PC and C/D (Figure 6).

In design session 1, clinicians quickly agreed (C/D #1) to include *vitals*. In subsequent discussions, clinicians explained how *vital* trends are useful for everyone (PC #3) and reached agreement (C/D #2) on specific *vital* trends to include on the timeline: *blood pressure* and *heart rate*. In design session 2, during the timeline mock-up activity, clinicians discussed where *vitals* are displayed in the EHR, e.g., MyChart Bedside (CG #4). In design session 4, clinicians went back-and-forth discussing color coding (CG #2) *vital* trends to identify abnormal ranges linked to the child's *age* but did not reach agreement (C/D #3). After design session 4, HFE researchers decided to delay the decision about whether to color code vitals until the implementation of T^3; researchers discussed the need to understand which vitals are continuously pulled from either a device (e.g., heart rate) or entered in an EHR flowsheet (e.g., temperature).

3.4.2 Multiple discussions on current injuries—Clinicians discussed *current injuries* in nine excerpts across all four design sessions. In seven out of nine excerpts, clinicians engaged in all three collaborative activities: CG, PC and C/D (Figure 6).

In design session 2, clinicians quickly agreed (C/D #1) on including notations, e.g., green box, to represent *current injuries* on the mannequin. In design session 4, clinicians went back-and-forth discussing visual representations, e.g., illuminate body parts, for *current injuries* on the mannequin (CG #2), but did not reach agreement (C/D #3). After completing the design sessions, HFE researchers met with the pediatric trauma program manager and decided to include visual support, i.e., colored rectangles on the mannequin, to represent the location of injuries.

3.4.3 Multiple discussions on patient name and pertinent medical history—Clinicians discussed *patient name* and *pertinent medical history* five times in design sessions 1 and 3. In four out of five excerpts and two out of five excerpts, respectively for *patient* name and *pertinent medical history*, clinicians engaged in all three collaborative activities: CG, PC and C/D (Figure 6).

In design session 1, clinicians discussed *patient name* with other information in the patient demographic box (CG #5). For *pertinent medical history*, clinicians mentioned it (CG #1). Later, two clinicians stated its importance (PC #1), especially when administering an anesthetic (PC #2).

In design session 3, clinicians discussed *patient name* and *pertinent medical history* when reviewing the results of the information element survey. Clinicians disagreed (C/D #3) about how to visually represent an unidentified *patient name*. After design session 3, HFE

researchers decided to include *patient name* in the information banner with the child's unidentified name (xxAntarctica, Unident 24) and preferred name in quotes ("Jennifer"). For *pertinent medical history*, clinicians disagreed (C/D # 3) about how much information to display, e.g., hemophiliac disease, and whether the information is accurate (CG #4). After the individual feedback sessions, HFE researchers decided to delay the decision about what qualifies as pertinent medical history until the implementation of T^3.

3.4.4 Multiple discussions on anticipated unit—Clinicians discussed *anticipated unit* four times in design sessions 3 and 4. In three out of four excerpts, clinicians engaged in all three collaborative activities: CG, PC and C/D (Figure 6).

Before session 3, T^3 was being designed with emphasis on the ED-to-OR transition. During session 3, clinicians began advocating for including another transition and anticipating a PICU admission. Clinicians explained information to include and how it should be represented (CG #2) in the transition plan, e.g., traffic lights; clinicians reached agreement (C/D #2) about including *anticipated unit*.

In design session 4, clinicians went back-and-forth discussing information in the transition plan, including the units a child could go to after the OR (CG #3). The clinicians had multiple discussions about the different *anticipated units* after the OR (CG #3) and did not reach agreement (C/D #3) on a name for the information element. After design session 4, HFE researchers met with the pediatric trauma program manager and decided to split transition plan to (1) transition to OR, which included *anticipated unit*, and (2) transition to PICU/floor.

4. Discussion

This study examined how care team members, representing multiple perspectives, collaborated in the design of a team health IT (T^3) that supports cognitive work during pediatric trauma care transitions. While other studies have defined factors influencing collaborative work (Bedwell et al., 2012; Li et al., 2019; Patel et al., 2012), this is the first application of Détienne (2006) framework to study collaboration in the design of team health IT. Our systematic analysis identified that clinicians engaged in all three collaborative activities described by Détienne (2006), as they discussed information elements for T^3.

4.1 Expanding Détienne's (2006) framework

Through this study, we expanded Détienne's (2006) co-design framework by identifying themes and processes for the three collaborative activities: establishment of common ground (CG), perspective clarification (PC) and convergence/divergence (C/D). These themes and processes provide a detailed description of the collaboration amongst care team members involved in the T^3 design process.

For the establishment of common ground (CG), we identified five themes: mentioning (CG #1) or explaining (CG #2) an information element, explaining the pediatric trauma care process (CG #3) or information source (e.g., whether information is available or accessible) (CG #4) and explaining related information elements (CG #5). Previous studies describe

how multiple perspectives were embedded as part of the design team (Tang et al., 2018) or involved in activities, e.g., workshops (Pickup et al., 2019) or simulations (Parush et al., 2017; Wu et al., 2017); however, these studies do not provide detailed information about how clinicians were actually engaged in the co-design process, such as bringing up different information elements in light of a team-based care process (CG #3). The five CG themes show how clinicians engaged in the process by mentioning and explaining an information element, sometimes in light of the entire care process. Clinicians also bring up the issue of where the information, e.g., *birthday* and *estimated blood loss*, may come from and whether it is accurate and trustworthy (CG #4).

We identified three themes for perspective clarification (PC). Scandurra et al. (2008) mentioned the benefit of conducting interprofessional group discussions to understand different roles' workflows (e.g., PCPs and NAs). Clinicians' workflows could be linked to information needs for specific tasks and categorized as one or more of our PC themes. The first two themes are related as clinicians clarify their own perspective (PC #1) to argue for their information needs, often linked to a specific task (PC #2). The third PC theme highlights the importance of engaging different care team members in co-design sessions; clinicians bring up someone else's perspective to explain an information element that is important for other roles. PC occurred as clinicians, strongly influenced by their role, discussed their information needs and clarified reasoning for or against an information element.

We identified three C/D processes that occurred as clinicians discussed and agreed or sometimes disagreed on information elements to include on T^3. Three studies describe design decision making for multidisciplinary teams as challenging (Xie et al., 2015), time consuming (Vermeulen et al., 2014) and resulting in conflict (Irestig & Timpka, 2008). Our three C/D processes are useful for describing how a multidisciplinary design team, with clinicians who may have different information needs, reaches agreement or disagreement for an information element.

4.2 Collaboration evolves as clinicians discuss complex information elements multiple times

According to Détienne (2006), the collaborative activities of PC and C/D are interrelated as designers reach a negotiated solution. Our analysis of information elements discussed more than once showed that often (19 out of 32 excerpts) clinicians engage in all three collaborative activities, or a mix of CG, PC and C/D, when discussing information elements. Moreover, as the design process evolves, decision making can become complicated.

Xie et al. (2015) identify preparation for meetings (e.g., creating meeting agendas) as a crucial phase of the co-design process. In the co-design process for T^3, HFE researchers had an important role in preparing design sessions (Table 1), which facilitated active involvement and influenced collaboration in the design of T^3. For instance, HFE researchers prepared an activity for design session 2 where clinicians spent time individually working on timeline mock-ups and then presented them to the team. As a result of having dedicated time to mock-up timelines, clinicians quickly agreed (C/D #1) on information, e.g., *vitals*. Before design session 3, HFE researchers conducted a survey on information elements that

clinicians participated in; the discussion during design session 3 focused on the results of the information elements survey, specifically the information elements that clinicians disagreed on including on T^3. As a result, clinicians went back-and-forth and disagreed (C/D #3) on how to represent an unknown *patient name* and how much *pertinent medical history* to include on T^3.

Information element discussions deepened as the T^3 mock-up evolved from paper in session 1 to a graphic in Adobe InDesign in session 4 (Figure 1): clinicians increasingly engaged in back-and-forth dialogue (C/D #2 and #3). For example, in design session 1, clinicians discussed whether to include or exclude (CG #1) *vitals* on T^3. Then, in design session 4, clinicians presented ideas for representing *vitals* (CG #2) as color-coded trends to identify abnormal ranges linked to the child's *age* (CG #5). In later design sessions 3 and 4, clinicians tended to focus on how T^3 could be integrated with the EHR, i.e., the information source for information elements (CG #3), and how to represent information on T^3 (CG #2). As a result, clinicians engaged in back-and-forth discussions either converging to reach agreement (C/D #2) or disagreement (C/D #3). We observed more disagreement or lack of agreement (C/D #3) in later design sessions 3 and 4 (Figure 6) about complex information elements, e.g., *vitals*, as the T^3 mock-up became more realistic.

Similar to Xie et al. (2015), our design team experienced challenges with making decisions that satisfy all clinicians. After design sessions 3 and 4, clinicians had not yet agreed on some information elements (C/D #3), even after multiple discussions. For example, clinicians did not converge on how to represent an unknown *patient name* or the *ins and outs* on the mannequin. When there was disagreement on an information element (C/D #3), HFE researchers considered the different options presented by clinicians and applied HFE design principles to make the final decision. In this final decision making process, the HFE researchers also consulted clinicians outside of the design sessions. In the end, our evaluation showed that T^3 had high usability scores and met the information needs of multiple roles (Hoonakker et al., 2022). Therefore, the co-design process may not require clinicians to agree on all the information elements to be included or excluded on the shared display. HFE expertise is also needed to make decisions based on HFE design principles, sometimes outside of the co-design session, in particular when clinicians are unable to reach agreement on information elements.

4.3 Limitations

One limitation of this research is that it is a single case. The collaborative activity themes that we identified may not be generalizable. For example, the CG theme of explaining the pediatric trauma care process and documentation policies is specific to the design of T^3, although we speculate that these themes may be generalized to "examining the team-based care process". Additional cases would allow for a comparison of co-design processes that resulted in solutions that successfully (or unsuccessfully) met the information needs of multiple perspectives.

Another limitation is that the systematic analysis excluded discussions outside of the co-design sessions, which occurred between HFE researchers and occasionally some clinicians, especially when clinicians were unable to converge (C/D #3) on an information element.

These discussions were not systematically recorded and, therefore, could not be analyzed. An important area for future investigation is to identify practices and strategies about organizing a team health IT design process that result in successful, i.e., highly usable solution, or an unsuccessful outcome; this could be done by systematically recording and analyzing discussions before and in-between design sessions across multiple case studies.

5. Conclusion

Co-design of team health IT provides a mechanism for including multidisciplinary care team members in designing solutions that support complex, team-based care processes, like pediatric trauma care transitions. We systematically analyzed a co-design process for our team health IT solution, called T^3. This co-design process resulted in a solution that met the information needs of clinicians with different roles and perspectives to facilitate the care of pediatric trauma patients.

Acknowledgements

This research was supported by the Agency for Healthcare Research and Quality through the Understanding Clinical Information Needs and Health Care Decision Making Processes in the Context of Health Information Technology program (Grant # R01-HS23837) and by the Clinical and Translational Science Award program, through the National Institutes of Health National Center for Advancing Translational Sciences (Grant UL1TR002373). The content is solely the responsibility of the authors and does not necessarily represent the official views of the funding agencies. We would like to thank all the clinicians who participated in the T^3 collaborative design sessions.

References

Barcellini F, Prost L, & Cerf M (2015). Designers' and users' roles in participatory design: What is actually co-designed by participants? Applied Ergonomics, 50, 31–40. [PubMed: 25959315]

Bedwell WL, Wildman JL, DiazGranados D, Salazar M, Kramer WS, & Salas E (2012). Collaboration at work: An integrative multilevel conceptualization. Human Resource Management Review, 22(2), 128–145.

Carayon P, & Hoonakker P (2019). Human factors and usability for health information technology: old and new challenges. Yearbook of medical informatics, 25(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]

Centers for Disease Control. (2020). Leading causes of Death by Age Group, United States. https://wisqars.cdc.gov/data/lcd/home. Accessed 2 Mar 2022

Cox ED, Jacobsohn GC, Rajamanickam VP, Carayon P, Kelly MM, Wetterneck TB, … Brown RL (2017). A Family-Centered Rounds Checklist, Family Engagement, and Patient Safety: A Randomized Trial. Pediatrics, 139(5). doi:10.1542/peds.2016-1688

Détienne F (2006). Collaborative design: Managing task interdependencies and multiple perspectives. Interacting with computers, 15(1), 1–20.

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]

Dinh JV, Traylor AM, Kilcullen MP, Perez JA, Schweissing EJ, Venkatesh A, & Salas E (2020). Cross-Disciplinary Care: A Systematic Review on Teamwork Processes in Health Care. Small Group Research, 51(1), 125–166.

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

Hoonakker PLT, Hose B-Z, Carayon P, Eithun B, Rusy DA, Ross JC, … Kelly MM (2022). Scenario-based Evaluation of Team Health IT 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]

Hundt AS, Adams JA, & Carayon P (2017). A Collaborative Usability Evaluation (CUE) Model for Health IT Design and Implementation. International Journal of Human-Computer Interaction, 33(4), 287–297.

Irestig M, & Timpka T (2008). Politics and technology in health information systems development: A discourse analysis of conflicts addressed in a systems design group. Journal of Biomedical Informatics, 41(1), 82–94. [PubMed: 17765018]

Kushniruk A, & Nøhr C (2016). Participatory design, user involvement and health IT evaluation. Studies in Health Technology and Informatics, 222, 139–151. [PubMed: 27198099]

Lane-Fall MB, Pascual JL, Massa S, Collard ML, Peifer HG, Di Taranti LJ, … Barg FK (2018). Developing a standard handoff process for Operating Room-to-ICU Transitions: Multidisciplinary clinician perspectives from the Handoffs and Transitions in Critical Care (HATRICC) Study. Joint Commission Journal on Quality and Patient Safety, 44(9), 514–525. [PubMed: 30166035]

Li S, Abel M-H, & Negre E (2019, 6-8 May 2019). Towards A Collaboration Context Ontology. Paper presented at the 2019 IEEE 23rd International Conference on Computer Supported Cooperative Work in Design (CSCWD).

Lyng KM, & Pedersen BS (2011). Participatory design for computerization of clinical practice guidelines. Journal of Biomedical Informatics, 44(5), 909–918. [PubMed: 21645636]

Mitchell P, Wynia M, Golden R, McNellis B, Okun S, Webb EW, … Von Kohorn I (2012). Core principles & values of effective team-based health care. Washington, DC: Institute of Medicine.

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]

Patel H, Pettitt M, & Wilson JR (2012). Factors of collaborative working: A framework for a collaboration model. Applied Ergonomics, 43(1), 1–26. [PubMed: 21616476]

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.

Safin S, Verschuere A, Burkhardt J-M, Détienne F, & Hébert A-M (2010). Quality of collaboration in a distant collaborative architectural educational setting. Paper presented at the Design of Cooperative Systems, Provence, France.

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.

Sanders EB, & Stappers PJ (2008). Co-creation and the New Landscapes of Design. CoDesign, 4, 5–18.

Scandurra I, Hagglund M, & Koch S (2008). From user needs to system specifications: multi-disciplinary thematic seminars as a collaborative design method for development of health information systems. Journal of Biomedical Informatics, 41(4), 557–569. [PubMed: 18394969]

Scandurra I, Hägglund M, & Koch S (2008). From user needs to system specifications: Multi-disciplinary thematic seminars as a collaborative design method for development of health information systems. Journal of Biomedical Informatics, 41(4), 557–569. [PubMed: 18394969]

Soundappan SVS, Holland AJA, & Cass D. t. (2004). Role of an extended tertiary survey in detecting missed injuries in children. Journal of Trauma and Acute Care Surgery, 57(1), 114–118.

Tang T, Lim ME, Mansfield E, McLachlan A, & Quan SD (2018). Clinician user involvement in the real world: Designing an electronic tool to improve interprofessional communication and collaboration in a hospital setting. Int J Med Inform, 110, 90–97. [PubMed: 29331258]

Vermeulen J, Verwey R, Hochstenbach LM, van der Weegen S, Man YP, & de Witte LP (2014). Experiences of multidisciplinary development team members during user-centered design of telecare products and services: a qualitative study. Journal of medical Internet research, 16(5), e124. [PubMed: 24840245]

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]

Xie A, Carayon P, Cartmill R, Li Y, Cox ED, Plotkin JA, & Kelly MM (2015). Multi-stakeholder collaboration in the redesign of family-centered rounds process. Applied Ergonomics, 46, 115–123. [PubMed: 25124394]

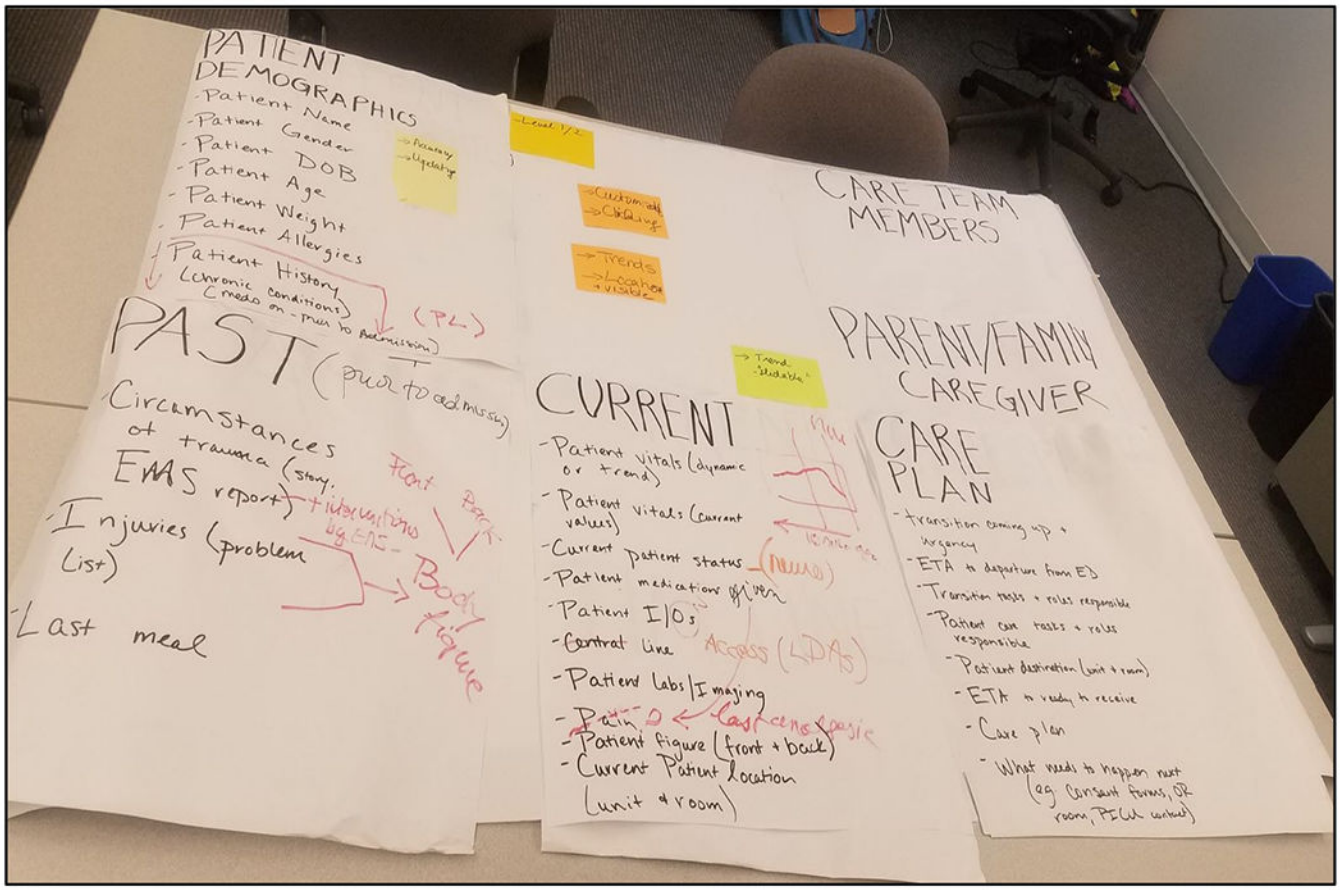


Figure 1.
T[3] mock-up at Design Session 1.

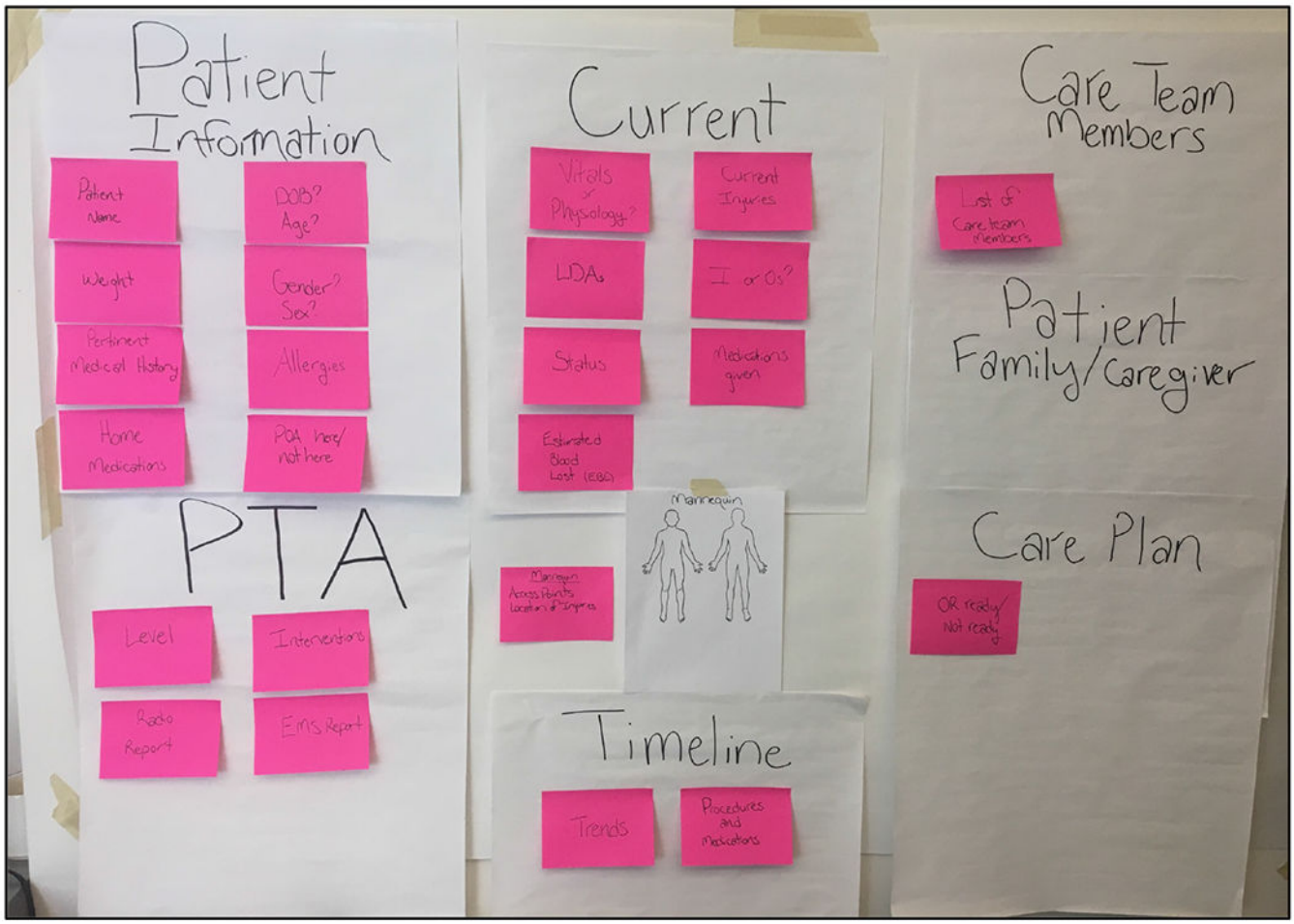


Figure 2.
T[3] mock-up at Design Session 2.

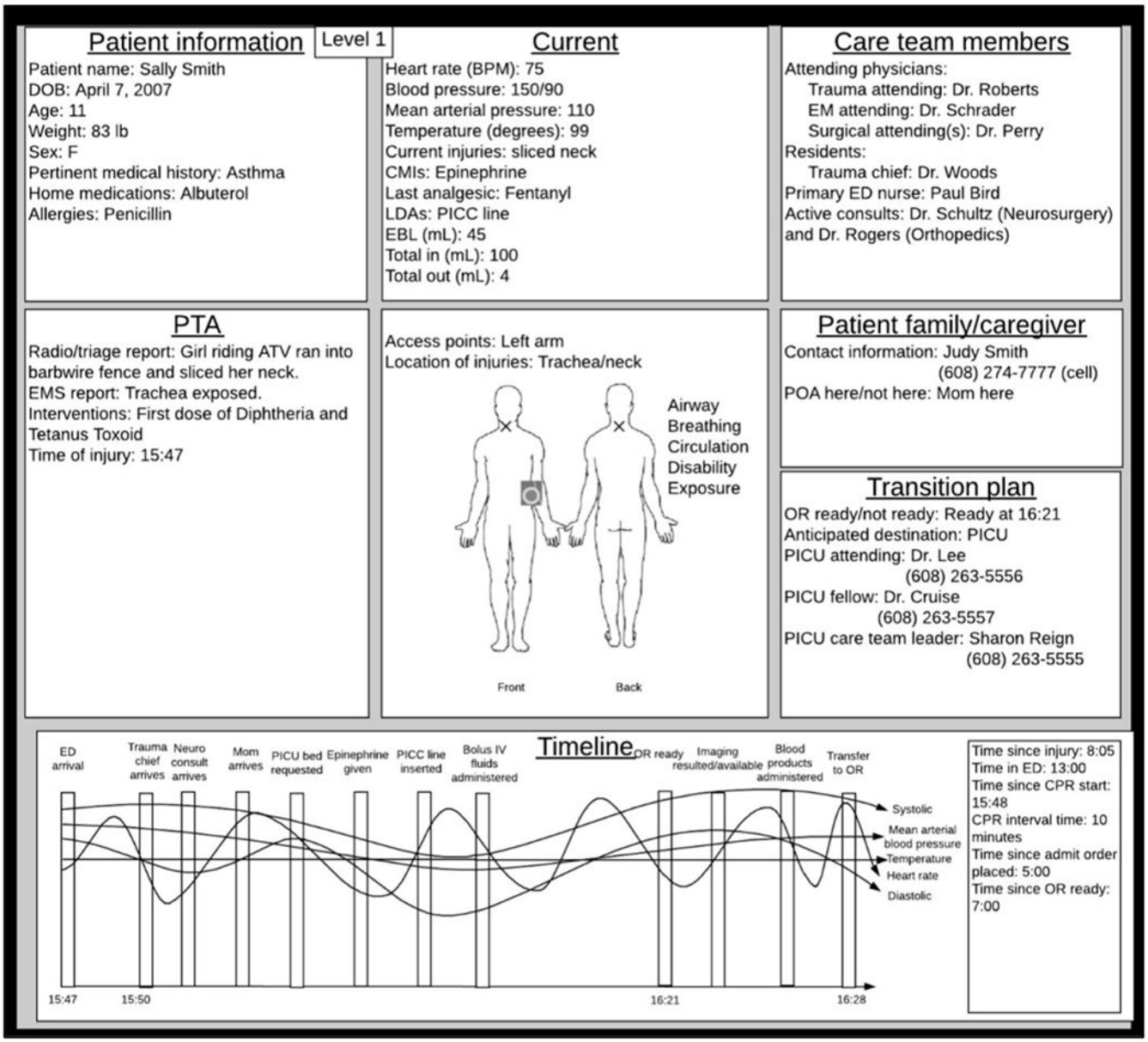


Figure 3.
T^3 mock-up at Design Session 3.

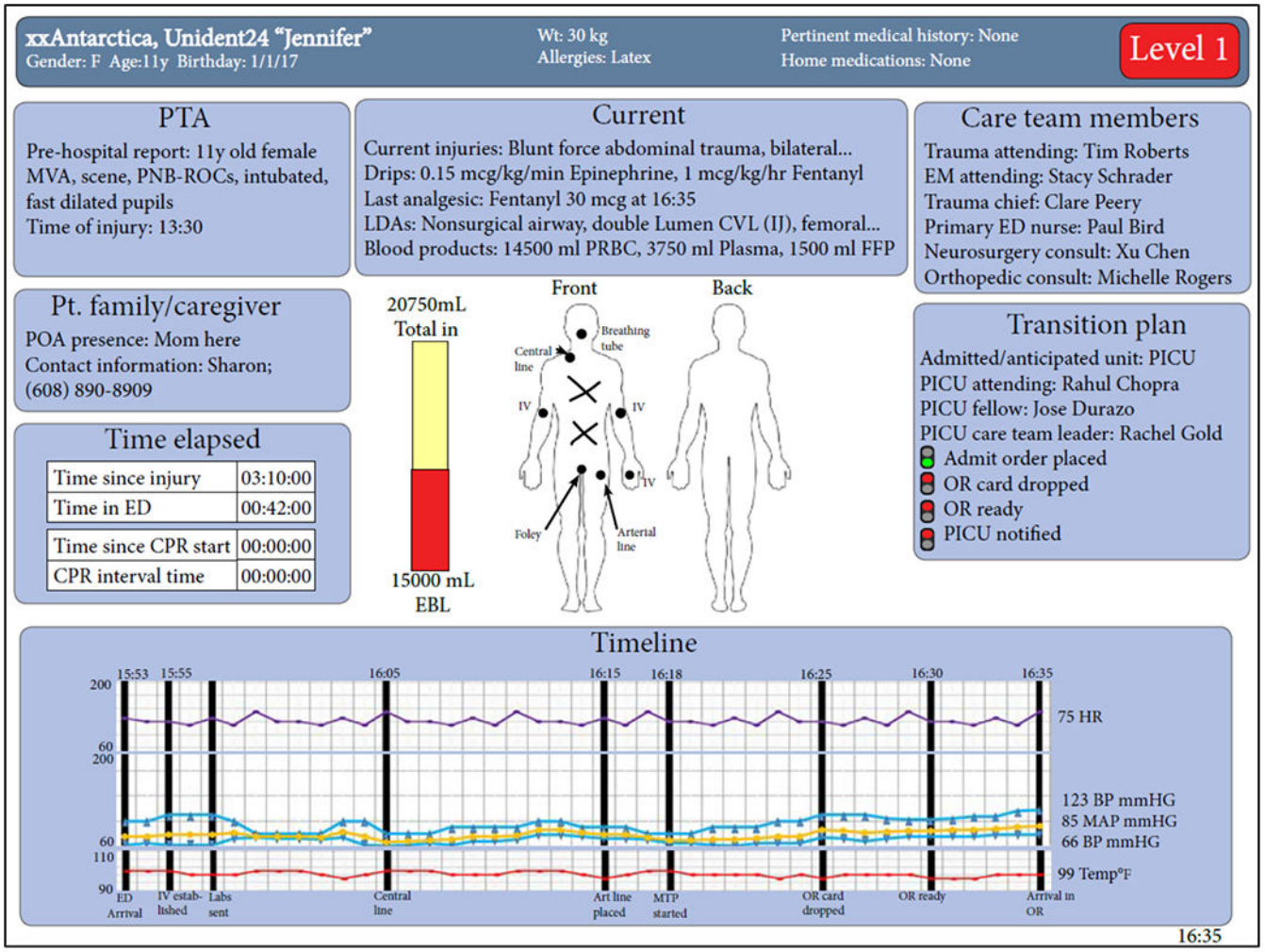


Figure 4.
T[3] mock-up at Design Session 4.

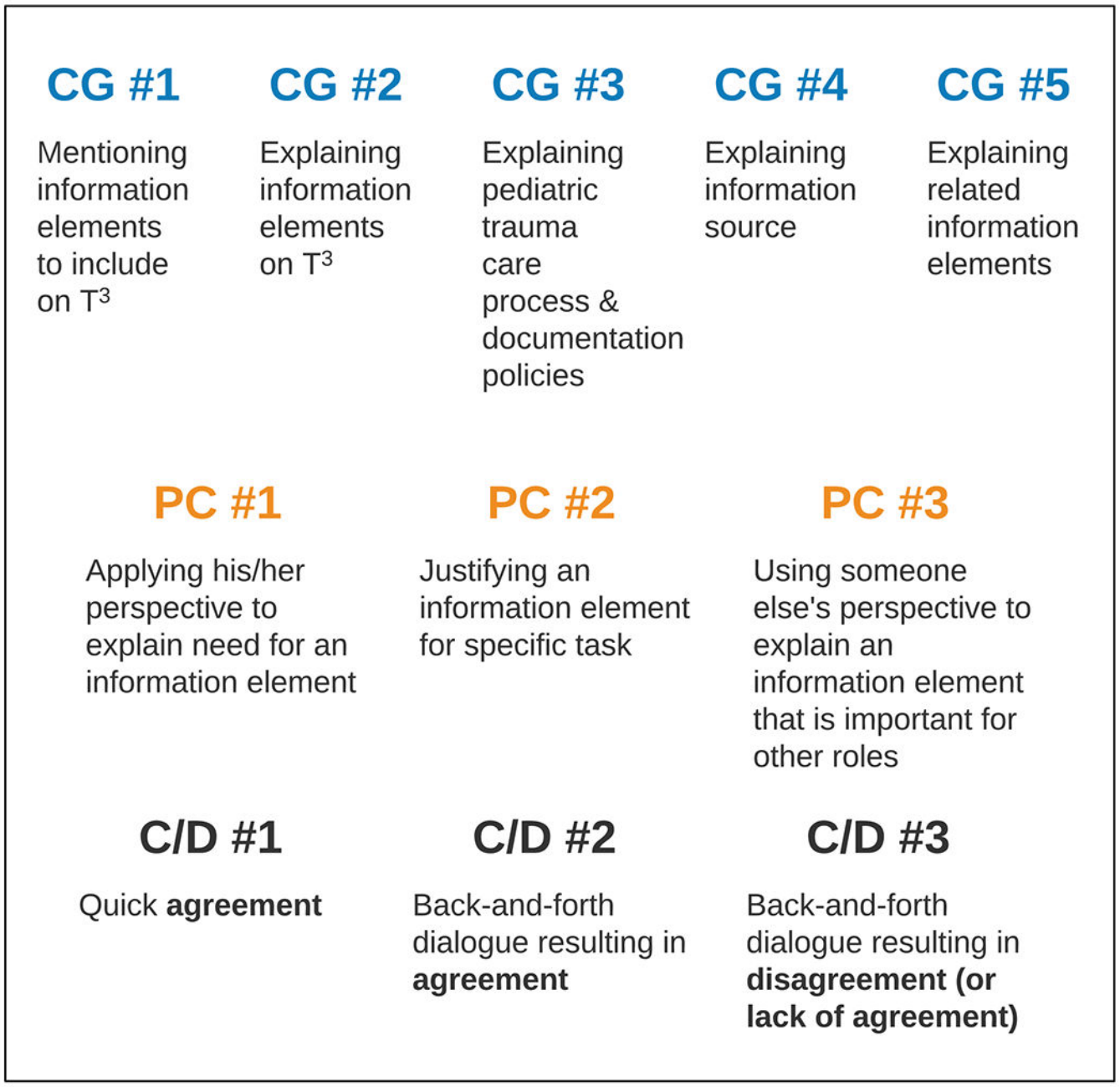


Figure 5.
Key of collaborative activity short-hand notation.

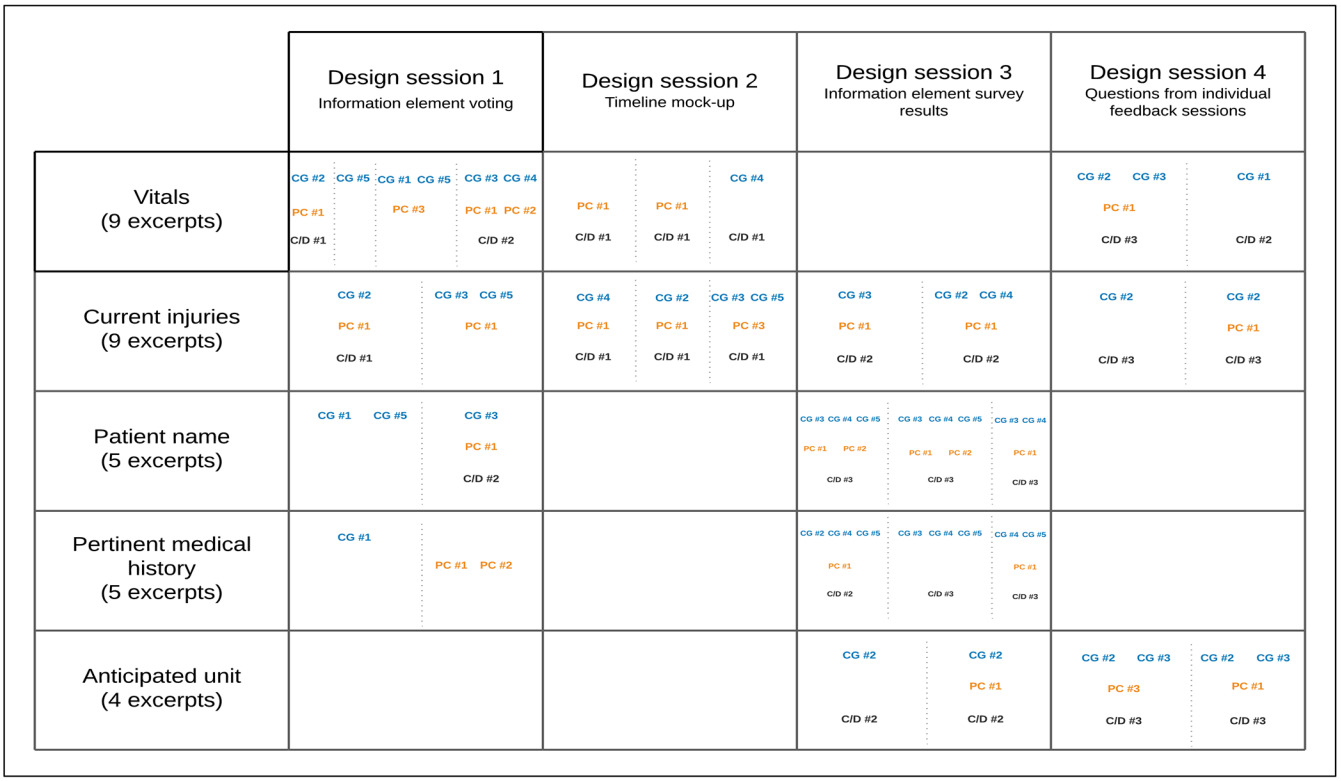


Figure 6.

Flowchart of collaborative activities for five information elements discussed multiple times across design sessions. Note: Dashed lines separate multiple excerpts in each of the four design sessions. For example, in design session 1, there were four excerpts where *vital* was discussed.

Table 1.

Overview of the T^3 collaborative design process

Timeline	Tasks	EM	Surgery	Anesthesia	Ped intensivist	Med informatics	Ped hospitalist	Ped trauma nursing	HFE researchers
Before	-4 HFE researchers each created T^3 mock-ups -Sent 2 studies about team health IT design to clinicians -Created initial version of T^3 with 6 macrostructure categories								4
Session 1 (January'2018)	-Presented care transition process map -Presented results from work system barriers and facilitators analysis -Reviewed 2 team health IT design studies -Discussed T^3 macrostructure categories -Conducted voting where clinicians raised green and red index cards to make decisions on information elements with follow-up discussion	✓	✓	✓				✓	6
Between 1 and 2	-Identified decisions made about design goals, HFE design principles and information elements -Created next version of T^3 mock-up -Planned for timeline mock-up task at next design session								5
Session 2 (March'2018)	-Presented summary of design session 1, including T^3 design goals and HFE design principles -Each clinician created a mock-up of T^3 timeline feature using large Post-it® paper and markers -Each clinician present his/her T^3 timeline ideas	✓	✓	✓	✓	✓	✓	✓	4
Between 2 and 3	-Identified decisions made about information elements -Met with pediatric trauma nurse program manager to discuss questions related to information elements -Created next version of T^3 mock-up in LucidChart -Created and administer Qualtrics survey about 50 information elements; the goal of the survey is to decide what information is necessary to support team cognition -Analyzed results from information elements survey							✓	6
Session 3 (May'2018)	-Presented summary of design sessions 1 and 2 [including T^3 mock-up] -Discussed results of Qualtrics survey on information elements	✓	✓	✓	✓		✓	✓	5
Between 3 and 4	-Created next version of T^3 mock-up in Adobe InDesign -Individual feedback sessions with 4 physician team members to gather information on T^3 mock-up	✓	✓	✓	✓				
Session 4 (October'2018)	-Reviewed and discussed specific questions about information elements based on results from individual feedback sessions	✓	✓	✓	✓		✓	✓	4
Afterward	-Met with pediatric trauma nurse program manager to discuss questions related to information elements -Conducted scenario-based evaluation of T^3 mock-up							✓	4

Appl Ergon. Author manuscript; available in PMC 2023 March 19.

Abbreviations: EM, emergency medicine; Ped, pediatric.

Note: A checkmark (✓) indicates the role(s) that were involved in the respective tasks.

Table 2.

Distribution of excerpts across the 4 co-design sessions and for each collaborative activity

Design session	Total number of excerpts	Collaborative activities			Number of excerpts coded for more than 1 collaborative activity
		Excerpts coded for CG	Excerpts coded for PC	Excerpts coded for C/D	
1	18	13	15	9	12
2	14	5	11	10	10
3	21	18	18	19	19
4	26	24	17	21	22
TOTAL	79	60	61	59	63

Abbreviations: CG, establishment of common ground; PC, perspective clarification; C/D, convergence/divergence.

Table 3.

Participation of clinical roles in information element discussions across the 4 co-design sessions

Design session	Total number of excerpts	Clinical roles						
		Clinical role #1	Clinical role #2	Clinical role #3	Clinical role #4	Clinical role #5	Clinical role #6	Clinical role #7
1	18	8	14	12	15	N/A	N/A	N/A
2	14	4	8	2	3	6	1	2
3	21	16	17	11	13	14	3	N/A
4	26	17	16	14	24	9	2	N/A
TOTAL	79	45	55	39	55	29	6	2

Note: N/A indicates that a participant was not present at the respective design session.

Table 4.

Themes for the collaborative activity of establishment of common ground

No.	Theme	Description	Design session	Examples
1	Mentioning information elements to include on T^3	Clinicians mention information to include on T^3.	1, 2, 4	•Demographics should include *pertinent medical history, patient name* and *age.* [DS1] •Events for the timeline should include *CPR start* and *stop.* [DS4]
2	Explaining information elements on T^3	Clinicians explain information, specifically, its meaning (especially for acronyms), difference from another information element (e.g., *inputs* vs *outputs*), another name for the information element, or where the information element should be on T^3 and how to visually represent it.	3, 4	•The timeline event, *MTP,* is *massive transfusion protocol.* [DS4] •*Blood products* in the current section, "That should say platelets not plasma. FFP and plasma are the same thing." [DS4]
3	Explaining the pediatric trauma care process and documentation policies	Clinicians explain the pediatric trauma care process and refer to documentation policies.	1, 2, 3, 4	•*Care team members* information is collected by a badge reader outside the trauma bay and documented in the EHR. [DS2] •Until the child has been confirmed, sticky notes, in the EHR, are used to put in an *unidentified child's name* or *preferred name.* [DS3]
4	Explaining information source	Clinicians explain the source of information, including: •Availability •Accessibility •Accuracy •Opportunities and challenges with T^3 integrating and synthesizing EHR information.	1, 2, 3, 4	•*Weight and age* are not necessarily accurate when the child first arrives. [DS1] •Challenge to integrate *medications* from the EHR as children may not be on some of the *medications* listed. [DS3]
5	Explaining related information elements	Clinicians explain two or more information elements together.	1, 2, 3, 4	•Understanding *heart rate* depends on the *child's age.* [DS1] •Needing the *child's name* to access *medical history.* [DS3]

Abbreviations: CPR, cardiopulmonary resuscitation; DS, design session; FFP, fresh frozen plasma; EHR, electronic health record.

Table 5.

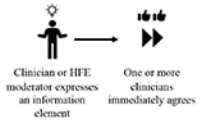
Themes for the collaborative activity of perspective clarification

No.	Theme	Description	Design session	Examples
1	Applying one's perspective to explain the need for an information element	A clinician explains information that is important/unimportant for their role.	1, 2, 3, 4	• "If you could look up at a screen and see like where are the *access points… IVs… identified injuries…*Because I find myself, all the time, standing in the back of the room… someone has to tell me or I have to go look." [DS1] • "We definitely need to know how much *crystalloid*." [DS4]
2	Justifying an information element for a specific task	A clinician justifies an element for a specific task, e.g., weight-basing drugs and CPR.	1, 2, 3, 4	• "I would say that…*weight*…I'm worried about…a trauma kid that's coming stat [immediately], all this stuff is important to me probably way more so than *age*. Because I'm weight basing my drugs." [DS1]
3	Using someone else's perspective to explain an information element that is important for other roles	A clinician brings up someone else's perspective to explain information that is important for other roles.	1, 2, 3, 4	• "It's meaningful to folks upstairs [in the OR] to know we've been in and out [of *CPR*]." [DS4]

Abbreviations: DS, design session; CPR, cardiopulmonary resuscitation.

Table 6.

Processes for the collaborative activity of convergence/divergence

No.	Process description	Design session	Outcome	Flowchart
P1	Someone (clinician or HFE moderator) expresses an information element, and one or more clinicians immediately agree.	1, 2, 3, 4	Agreement	
P2	Back-and-forth dialogue with some clinicians in agreement and some hesitant clinicians. The clinicians compromise and negotiate to reach consensus, resulting in agreement on an information element.	1, 3, 4	Agreement	
P3	Back-and-forth dialogue with some clinicians in agreement and some hesitant clinicians. The clinicians are unable to negotiate to reach consensus, resulting in disagreement on an information element.	1, 3, 4	Disagreement