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Designing and Optimizing Digital Applications for Medical Emergencies

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Abstract

In this ongoing study, we aim to redesign an existing dynamic digital checklist application (app) for trauma resuscitations in a regional trauma center. The design followed an iterative, user-centered approach. Trauma team physician leaders and research coordinators at the center participated in a survey and usability study to provide feedback for improving the user interface. Proper optimization of the user experience is necessary for future adoption of the digital checklist. This study lays the groundwork for in situ use and evaluation of the checklist by trauma team members.

Keywords

Digital checklist; user experience (UX) design; user interface (UI) design; trauma resuscitation

Introduction

Trauma resuscitation and similar medical emergencies are fast-paced, dynamic events, where critically injured patients are treated for life-saving injuries. Because resuscitations involve complex, high-stress, time-sensitive and multidisciplinary work, medical errors are common, potentially leading to adverse outcomes. To date, many hospitals have implemented checklists and other decision support systems to reduce human error [3]. Checklists for trauma resuscitations have been designed to reduce the trauma team's cognitive workload and improve protocol compliance [4]. Even so, the current resuscitation

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checklist is a static paper document manually completed by the team leader. Notes are sometimes taken in the margins, and not all data are recorded [6]. A dynamic digital checklist that is responsive to different patient scenarios and user needs would optimize care coordination, enable improved data tracking, and allow situation-specific customization to reduce errors and delays [5]. In this paper, we focus on the process of re-designing the current digital checklist app to improve user experience and explore a set of dynamic features. Visual design principles and UX/UI concepts have been applied along with the input from our medical-expert researchers who have evaluated the app in a real hospital setting. From these insights, we designed an improved interface that provides the team leaders with a dynamic tool that supports decision making and improves team performance by reducing delays and errors.

Background: Trauma Resuscitation Checklist

Our research site introduced a paper-based checklist for trauma resuscitations in 2012 [4]. The checklist was designed for trauma team leaders to improve protocol compliance. The requirements for the digital checklist were derived from an analysis of paper checklists used during 163 trauma resuscitations [6]. The app was developed using Android Studio IDE for the Android operating system and it runs on a hand-held tablet. This initial design has been used in over 200 actual resuscitations in 2017. The hospital version runs on the Samsung Galaxy Tablet A with an embedded stylus. The portrait-oriented app includes five web-style tabs, each corresponding to a section of the original paper checklist (Figure 1). These sections include (1) the pre-arrival plan, (2) the initial patient evaluation (primary survey), (3) vital signs, (4) the detailed patient evaluation (secondary survey), and (5) the departure plan (prepare for travel). The top has an area for handwritten notes and list items have space for individual note taking. Rarely used items (e.g., “If intubating”) are nested within the list and can be expanded for use when applicable.

Evaluation of the Current Digital Checklist Design

We started with a design critique of the current app’s UX/UI. The current app uses a process-based organization and long list format that requires scrolling. It displays a blue, violet, pink, green, and grey color scheme. Color-coding is an important aspect of visual design that can be used to organize the displayed information [1]. Color-coding also improves recall, which is preferable during high-stress situations [2]. We overlaid the current design with a touchscreen heat map to uncover difficult-to-reach areas (Figure 2). This test showed that most of the app’s functions are positioned at the top of the screen, making it challenging to use the tablet with one hand. The current design does not consider the user’s dominant hand or their choice to use the stylus. The text is small and few icons exist. Most titles and actions are labeled solely by text. Recognition can be improved by introducing simple icons while saving screen real estate [1]. Unique icons will require learning, as they are not universally recognizable. Steps in redesigning the app’s UX/UI included sketching, wire framing, improving flow and navigation, selecting a color scheme, creating custom iconography, and other visual adjustments.

Digital Checklist Redesign Process

The redesign process consisted of creating two prototypes, the Version-1 (v1) prototype, evaluated using an online survey, and the Version-2 (v2) prototype, evaluated through usability testing. The redesign was given to medical-expert researchers to test. One of the researchers used v2 of the app five times during actual trauma resuscitations while shadowing a physician, which allows us to test the app during the actual but separate patient care.

Research Site and Participants

Our research site is a regional level-1 trauma center at a pediatric teaching hospital. The trauma team at this center consists of 7–15 individuals who assemble upon patient arrival, including a team leader who directs other members. The team follows the Advanced Trauma Life Support (ATLS) protocol. Our participants included two trauma team leaders, one in their fourth year of surgical residency and one who is a surgical fellow. We also involved two clinical research coordinators who work closely with the team leaders.

Version-1 Prototype Design

The v1 prototype displays a dark color scheme (Figure 3). We applied the concepts of color theory [1] to select an appropriate color scheme of navy and orange. The navy was used to give the app a sleek, modern, and professional feel, while the orange was used to emphasize caution and confidence, a viable substitute for the harsh red associated with medical emergencies. The five tabs were re-oriented to align along the left-hand side for easier reach using the left thumb. The tab titles were replaced with newly created icons to represent the five sections of the checklist derived from the primary and secondary survey of the ATLS protocol. Various input types were tested, such as a number slider and an on/off switch. The original note-taking spaces were replaced with pen icons to decrease blank space. Custom icons include pre-arrival, primary survey, vitals, secondary survey, prepare for travel, settings, complete checklist, new checklist, log, notebook, new note, clear all, vitals update entry, draw, erase, text, trash, and undo buttons. The status screen concept (Figure 4), was drafted to explore how best to improve the user's understanding of checklist progress and navigation. iOS and Android design elements were used to increase user familiarity.

Online Survey to Obtain Feedback on Version-1

The online survey gathered anonymous qualitative and quantitative feedback on the v1 prototype (Figure 3). Four users responded, two physician team leaders and two medical researchers. The survey was administered using Google Forms and contained 22 questions, taking about 15 minutes to complete. The clickable v1 prototype was created using Adobe XD and was provided via an electronic link to the live build. Participants were asked to match icons for the five tabs to their titles. We also asked them about the purpose of the timer on the status screen and what the notebook icon represented. Remaining questions gathered feedback on the aesthetics and usability of the prototype. Participants were encouraged to leave written comments throughout the survey.

Participants responded positively to the v1 prototype re-design, saying, "*the layout is fairly intuitive and navigating seems simple*". The color scheme was appropriate from an aesthetic point of view, but one response pointed out "*it might be a bit dark, which could be hard to read*", and another added the design was "*too dim*". Three of four participants understood the function of the notebook icon (Figure 5). None of the participants found the status screen useful (Figure 4), feeling it was a nice addition to the design, but not necessary for use during actual resuscitations. Participants responded positively to the reduced length of each page, liking that there was "*no scrolling up and down on the screen*". Half of the participants found the various input styles (the number slider and the on/off switch) difficult, and preferred typed or written input fields. For the five tab icons, only responses for the secondary survey icon were all correct. The icons depicting the primary survey and the pre-arrival plan were confusing, and participants did not pair these icons with their correct titles.

Version-2 Prototype Design

A new prototype was designed and built after feedback from the v1 prototype was reviewed. The more extensive v2 prototype uses a lighter color scheme, brightening the interface to improve visibility (Figure 5). The text is a dark violet color for improved readability. The orange remains unchanged, paired with a complimentary light violet background to convey a pediatric environment [1]. White space was reintroduced to improve contrast. More functionality was added to the top navigation bar, including settings, an icon for the "complete checklist" function, and a history log. Icons were re-designed and re-colored. Scrolling capabilities were expanded, giving the user three options to navigate between the checklist sections: (1) switch between pages using the left-hand five-tab menu, (2) scroll continuously, or (3) tap arrows on the top and bottom of each page. The margin-note from the top of the original design was re-introduced, but designed to be collapsible to use when needed. The status screen was removed from the v2 design, but status progress circles were incorporated around the icons in the five-tab menu to show progress within each of the checklist sections (Figure 5). These progress circles were animated to change color in response to checking off items in each section. The circles cycle through red (least complete), to orange, yellow, and finally green (100% complete). To take notes, the user can switch between pen icons or thumbnails of individual item notes in settings. Individual item notes are displayed within the list when the pen icons or the thumbnails are tapped (Figure 6). Similar to the nested list items, the notepad expands from beneath its corresponding list item, and collapses once the user is finished taking a note. Notepad capabilities now include a pen tool, eraser, undo button, text tool, and clear button (Figure 6). The vitals tab was re-designed to allow multiple inputs: if vital signs change over the duration of the resuscitation, users can enter new values, keeping past entries ordered by timestamps. The most recent vital signs information is now also displayed in a highlighted bar at the absolute top of the screen. This change will help users reference vitals without switching to another section of the checklist. Upon review and completion of the checklist, the user is brought to the summary page that displays all items, timestamps, and notes taken during the session. This information is stored in a log for later reference.

Video-Based Usability Test to Evaluate Version-2

We ran the usability sessions with three of the four participants (including the surgical fellow and both research coordinators) via video conferencing (Skype) due to the geographical distance. We guided each of the three participants through a 30-minute video call to obtain feedback on the v2 prototype. Similar to the online survey design, we provided access to the prototype via a link to the live build in Adobe XD (Figure 7). The v2 prototype was displayed on a tablet, and participants were asked to turn their backs to the camera, allowing the designer to virtually look over their shoulder as they used the app. This arrangement was the closest we could come to observing our users in person. We gave users a list of ten functions to explore and asked them five open-ended questions. They were asked to explore (1) starting a new checklist, (2) checking off items, (3) taking a note in the top margin, (4) taking a note on an individual item, (5) expanding and collapsing list items, (6) scrolling between pages, (7) entering data on the vitals tab, (8) clearing checked items, (9) completing the checklist, and (10) accessing the checklist log. Questions included initial reactions to the new interface look and feel, navigation questions, and what they personally would like to see added to the design.

The three participants were pleased with the changes made to the color scheme. The first participant commented, "*I love [the color scheme], this is a good transition from the old design*". Another stated "*it is light, easy to see, and nice to look at*" and "*you don't have to squint at hard-to-read text*". Most icons were intuitive, with confusion surrounding only the note and the log icons. One participant noted, "*The buttons are larger and easier to click, especially when using the stylus*". Participants reacted positively to the progress circles and the color changes reacting to the checklist being completed. One participant stated, "*The app will have a natural learning curve, but [physicians] will easily get used to it*". Concerns involved software issues, such as the scrolling glitches, note taking, and having items automatically checked off if numerical information is entered. A participant suggested to include an, "*are you sure?*" pop-up box before clearing information, to prevent data deletion by mistake. The participants agreed that the multiple entries under vitals should be displayed graphically to show changes over time, instead of a text-based list.

Conclusion

This design revision was a necessary part of creating and deploying an app that will improve protocol compliance during trauma resuscitations. Careful consideration of UX/UI was critical to increase the checklist adoption and ease of use. Design may sometimes be viewed as a second-priority in healthcare, but technology that prioritizes visual design of its interfaces will be more successful in being adopted by users. It is rewarding to see our users, actual physicians, engaged and effortlessly navigating through the app. The initial checklist design was used over the past year, but design and development flaws frustrated physicians who ran into issues. Designing the new version with and for the physicians who will use it in the future helped us address problems that may have been overlooked. The biggest challenge was the geographic distance from our research site and gathering feedback without the ability to observe user interactions in real life. A video-mediated usability test was the closest we could be to watching users in person. As users tap through digital prototypes of

the checklist, they become more comfortable with using the new design, and provide advanced insight and ideas. The users will continue to be a valuable resource to our research team. Because of the new design, users will experience improved ease of use, streamlined tasks, and an overall more dynamic tool built for improving trauma teams' performance.

Future Applications

The new design lays the groundwork for future testing *in situ* by trauma team leaders, as we plan to deploy the new app in the hospital in early 2018. Our team is working to implement the needed changes to ensure seamless transition between the two checklist designs. We will be training users on the new system and explaining the new features. We will continue to collect data from the new design after implementation. For the future, improvements made to the design will help this app become a necessary tool for years to come.

Acknowledgements

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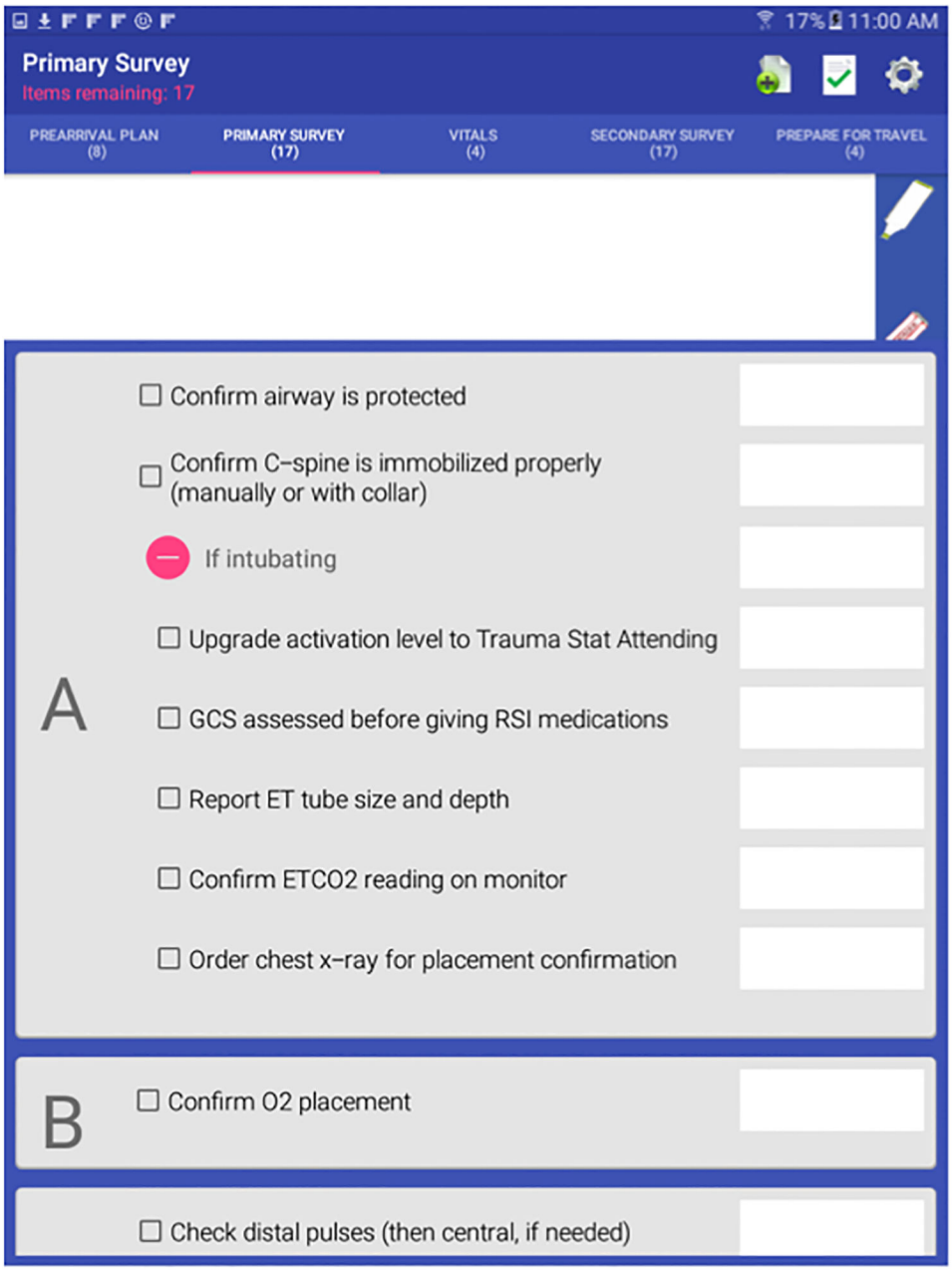

Figure 1:
Current digital checklist design targeted for optimization.

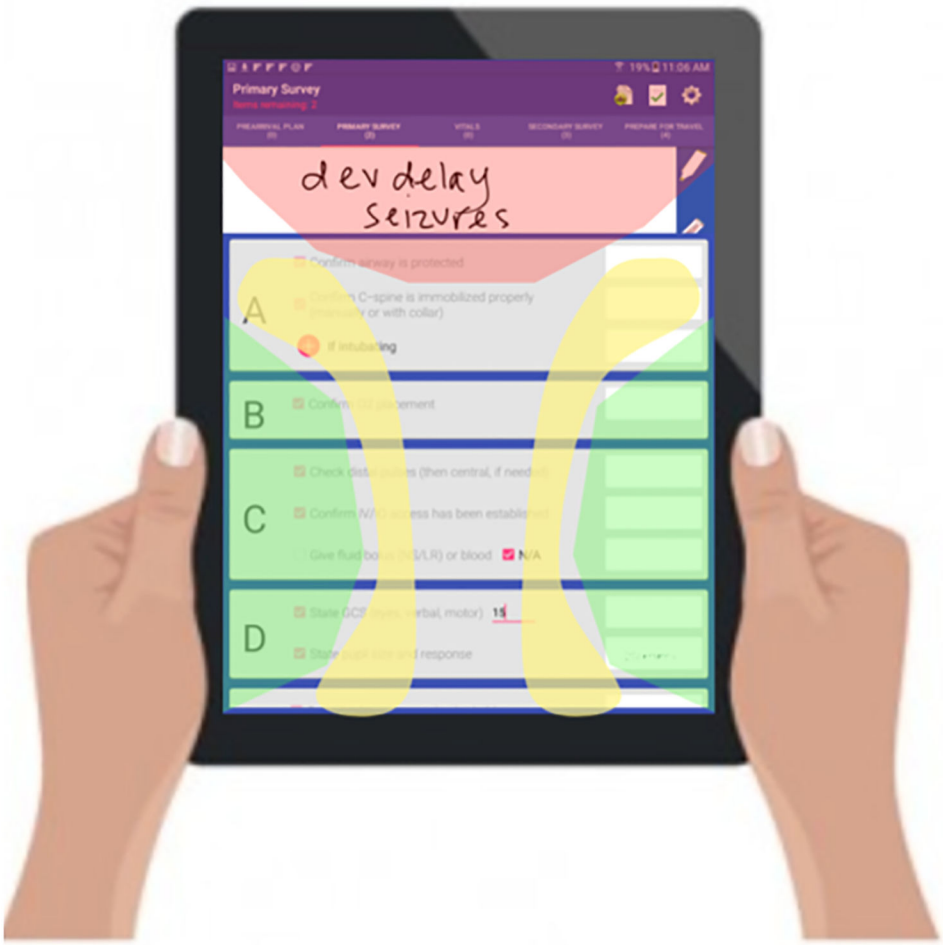

Figure 2:
Touchscreen heat map overlay over existing design.

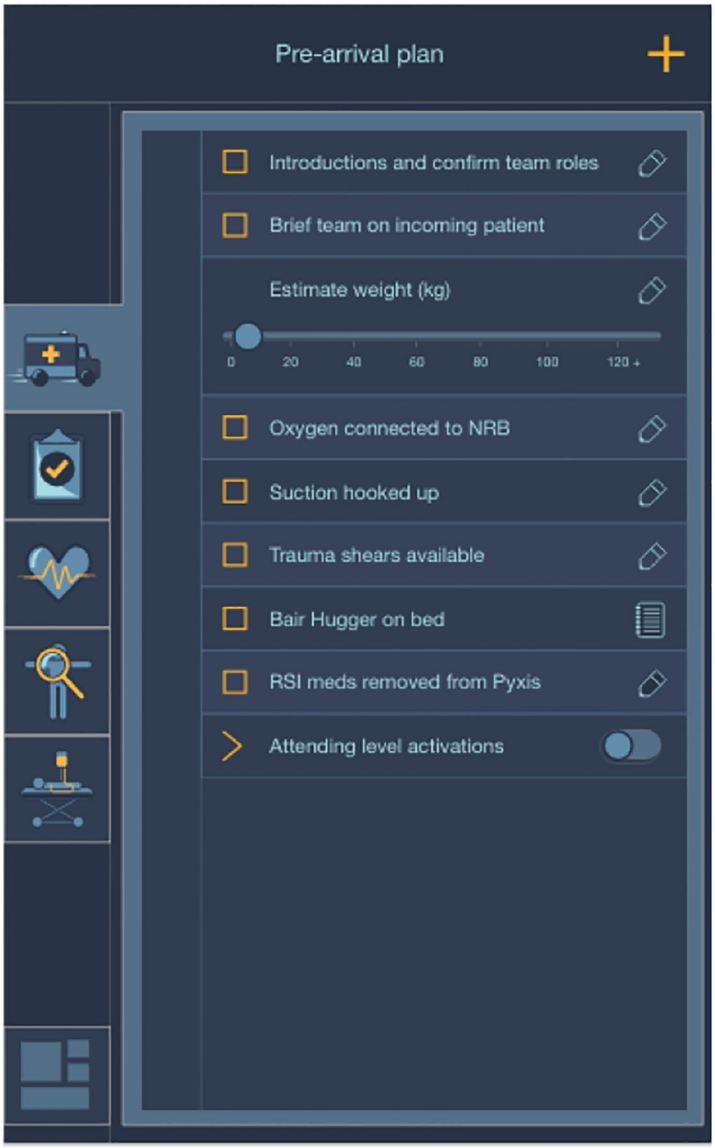

Figure 3:
Version-1 design.

Figure 4:
Version-1 status screen design.

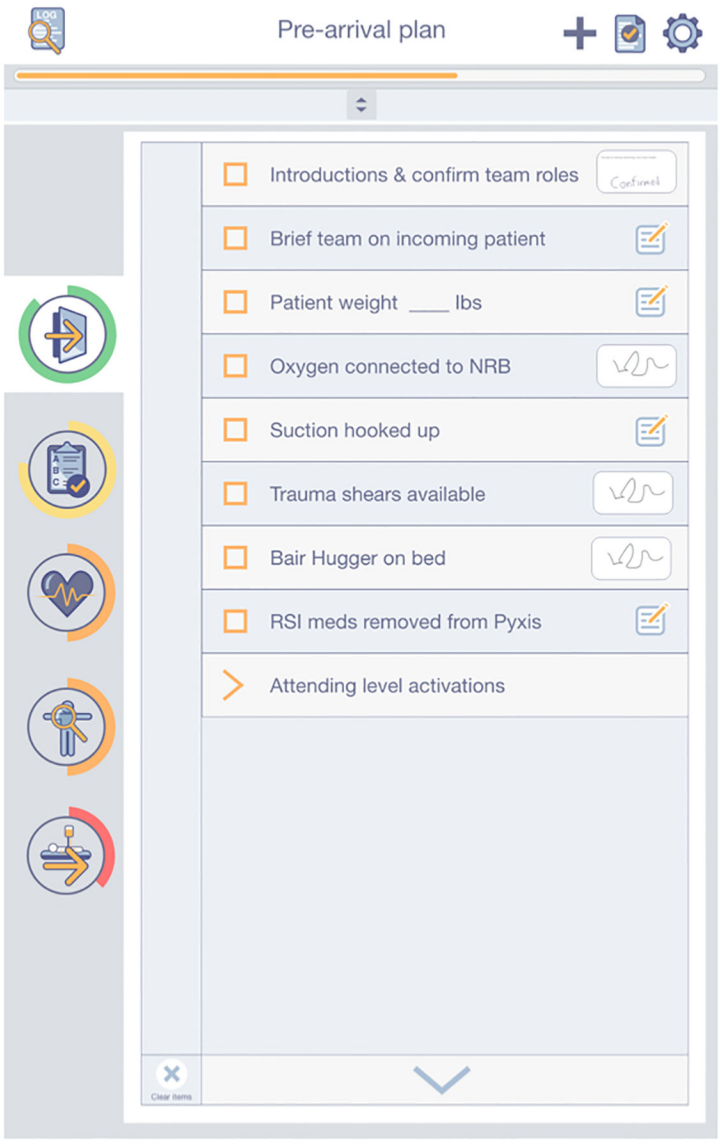

Figure 5:
Version-2 design.

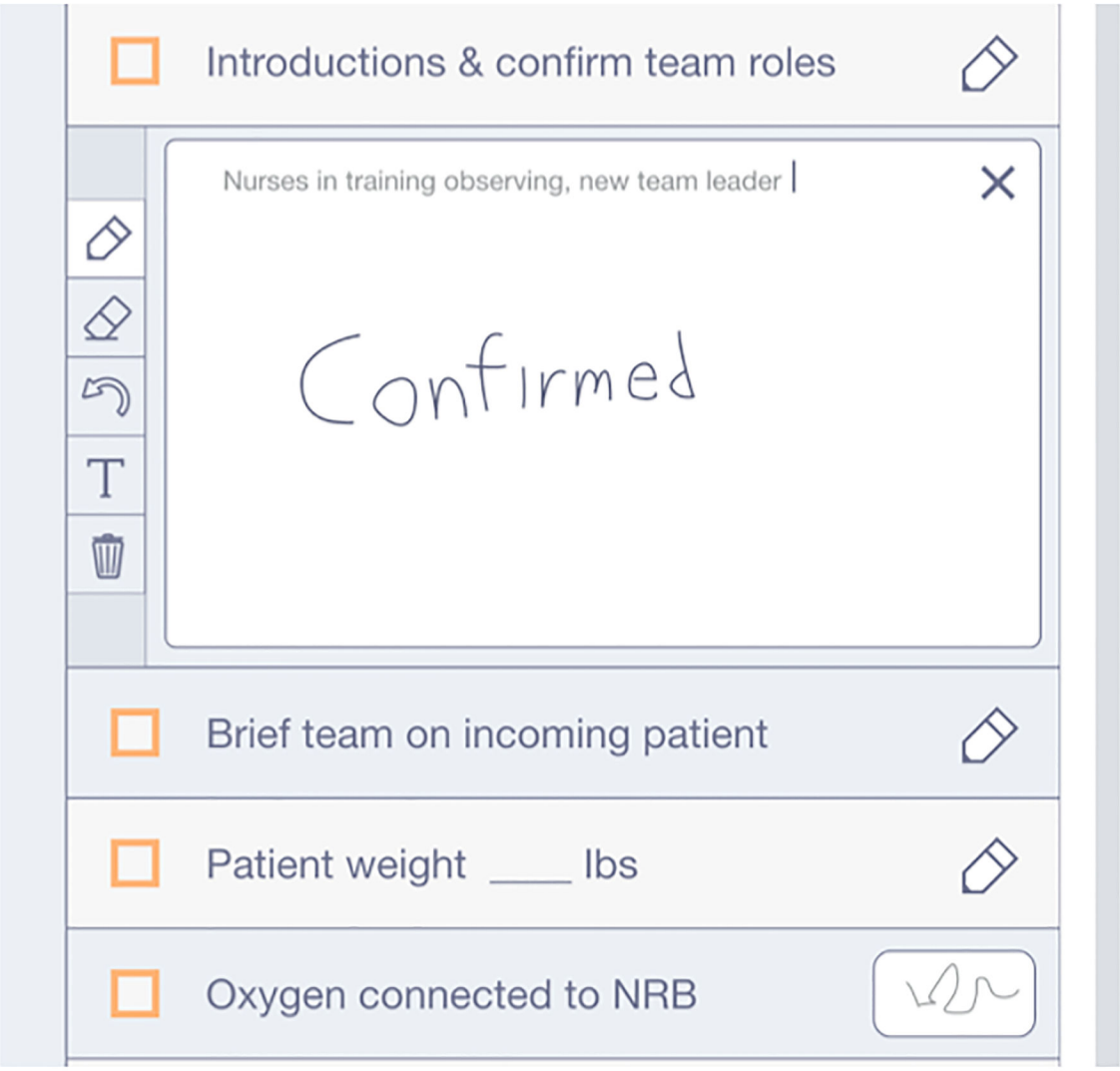

Figure 6:
Version-2 checklist notes detail.

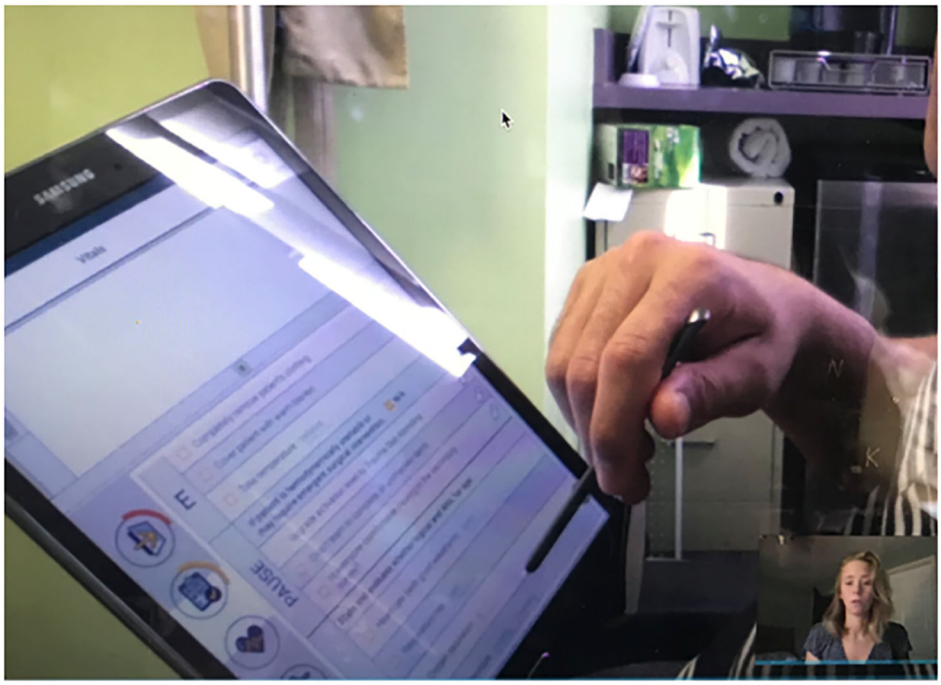

Figure 7:
Version-2 video interview screen capture via Skype.