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Original Paper

A Qualitative Study of the Theory Behind the Chairs: Balancing Lean-Accelerated Patient Flow With the Need for Privacy and Confidentiality in an Emergency Medicine Setting

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Abstract

Background: Many emergency departments (EDs) have used the Lean methodology to guide the restructuring of their practice environments and patient care processes. Despite research cautioning that the layout and design of treatment areas can increase patients' vulnerability to privacy breaches, evaluations of Lean interventions have ignored the potential impact of these on patients' informational and physical privacy. If professional regulatory organizations are going to require that nurses and physicians interact with their patients privately and confidentially, we need to examine the degrees to which their practice environment supports them to do so.

Objective: This study explored how a Lean intervention impacted the ability of emergency medicine physicians and nurses to optimize conditions of privacy and confidentiality for patients under their care.

Methods: From July to December 2017, semistructured interviews were iteratively conducted with health care professionals practicing emergency medicine at a single teaching hospital in Ontario, Canada. The hospital has 1000 beds, and approximately 128,000 patients visit its 2 EDs annually. In response to poor wait times, in 2013, the hospital's 2 EDs underwent a Lean redesign. As the interviews proceeded, information from their transcripts was first coded into topics and then organized into themes. Data collection continued to theoretical sufficiency.

Results: Overall, 15 nurses and 5 physicians were interviewed. A major component of the Lean intervention was the construction of a three-zone front cell at both sites. Each zone was outfitted with a set of chairs in an open concept configuration. Although, in theory, professionals perceived value in having the chairs, in practice, these served multiple, and often, competing uses by patients, family members, and visitors. In an attempt to work around limitations they encountered and keep patients flowing, professionals often needed to move a patient out from a front chair and actively search for another location that better protected individuals' informational and physical privacy.

Conclusions: To our knowledge, this is the first qualitative study of the impact of a Lean intervention on patient privacy and confidentiality. The physical configuration of the front cell often intensified the clinical work of professionals because they needed to actively search for spaces better affording privacy and confidentiality for patient encounters. These searches likely increased clinical time and added to these patients' length of stay. We advocate that the physical structure and configuration of the front cell should be re-examined under the lens of Lean's principle of value-added activities. Future exploration of the perspectives of

patients, family members, and visitors regarding the relative importance of privacy and confidentiality during emergency care is warranted.

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KEYWORDS

Lean health care; emergency medicine; privacy and confidentiality; work intensification; qualitative research

Introduction

Background

The provider-patient relationship is the foundation of medicine, and this relationship revolves around trust. As part of a trusting relationship, a patient must have faith that any information exchanged during their encounter with a physician or nurse will remain private and confidential [1,2]. Although privacy and confidentiality share some ideas, these 2 concepts have distinct definitions. Privacy has physical, decisional, and informational dimensions. Regarding these dimensions and medical care, a patient should not experience any unnecessary or embarrassing exposures of their body. A patient should also be free to make informed decisions regarding their care without facing undue pressure or interference from another individual, and they should entrust that any information collected during their medical care will be kept confidential [3-5]. Violations of confidentiality can be intentional or unintentional [3,6]. Intentional violations occur when a professional directly communicates a patients' information to an unauthorized person. Unintended violations arise when conditions are inadvertently created that enable an unauthorized individual to see or hear information about a patient. Intentional violations or failure to adequately protect a patients' personal health information may result in an investigation or audit from a professional regulatory organization, with potential consequences including disciplinary action [1,2].

An emergency department (ED) is considered to be one of the most complex environments in which to deliver patient care [5,7-10], and although reviews by Ulrich et al have highlighted a dearth of research in this area, there are some indications that the design and layout of an ED can increase the vulnerability of patients to breaches of their physical and informational privacy and confidentiality [11,12].

Mlnek and Pierce asked trained observers to record patients' names plus their diagnosis/reason for treatment while they were sitting in a triage chair or empty treatment areas of a hospital-based ED in the United States. From the triage chairs, observers recorded the names of 81% (26/32) of patients and the diagnosis/reason for treatment for 56% (18/32). Both elements were recorded for 53% (17/32) of triaged patients. Observers noted that when they were stationed in treatment areas with curtains, they were able to hear "almost everything" that occurred in adjacent areas. When curtains were left open in other rooms, observers were also able to craft detailed notes about medical procedures they saw being performed on patients. The authors noted that no privacy breaches were recorded when observers were stationed in empty patient rooms with solid walls [13].

In another American study, Zhang et al asked an observer to record the ambient conversation while they were seated near a nurses' station and in some empty patient rooms of hospital-based ED. Thematic analyses of transcripts prepared from the recordings revealed that nursing station conversations predominantly revolved around patient care (86% of content; 95% CI 68.7-94.7). Although patient names were not heard on the nurses' station recordings, other details including individuals' medical and social histories, physical examination results, and diagnoses were audible. The authors noted that although 44.8% (95% CI 17.7-62.2) of the conversations that were recorded from patient rooms revolved around clinical topics, these contained very little patient-related information [14].

Karro et al reported that 45.1% (106/235) of patients treated by an Australian ED had been involved in a privacy incident at an Australian hospital-based ED. Overall, 41% of patients (95% CI 35-47) revealed they had overheard information involving another patient, and 15% (95% CI 11-21) sensed other members of the public had overheard conversations related to their care. Overall, 10% (95% CI 06-14) admitted they saw another patient's body, and 4% (95% CI 02-07) felt their body was exposed. Patients treated within walled cubicles were significantly less likely to overhear information about another patient (P<.002) and felt their information would be less likely to have been heard by an unauthorized person (P=.06) [15].

Finally, patient surveys from Barlas et al in the United States and Lin and Lin from Taiwan explored whether patients' perceptions of privacy and confidentiality impacted how they interacted with members of their ED care team. Patients in both of these study cohorts admitted that due to a perceived lack of privacy and confidentiality, they withheld aspects of their medical history or had refused parts of their physical exam (Barlas, a total of 3.7% [4/108] of patients; Lin, 21.2% [23/108] of patients withheld aspects of history; and 19.4% [21/108] of patients refused parts of exam). These studies appeared to put forth different viewpoints regarding the degree of effort made by members of the care team to circumvent breaches. Although Barlas reported that 85.2% (92/108) of patients in their study perceived that ED staff showed respect for their privacy, Lin and Lin concluded, "in our opinion, the most important factor influencing patient privacy was lack of vigilance in the ED" [16,17].

Many EDs had used Toyota's Lean methodology to guide the restructuring of their practice environments and patient care processes [18,19]. As part of its focus on continuous improvement, Lean asks an organization to rethink how they are delivering what is of value to their customers [18,20-25]. Organizational processes are broken down and examined regarding whether they contribute value-adding activities

[18,19]. Value-added activities are those that work toward satisfying customer needs. Conversely, nonvalue activities detract an organization from achieving its goals and waste time and resources including personnel and physical space. By removing nonvalue activities, the Lean method asserts that an organization will be able to streamline its processes and deliver what customers want at a faster pace [5,20-22,25].

Objective

Given that Lean health care focuses on the enhancement of patients' experiences, it would seem to follow that when a Lean intervention is evaluated, it should include some examination of how it potentially affected patient privacy and confidentiality. However, reviews by Holden regarding the implementation of Lean interventions in EDs and reviews by Moraros et al of the effects of Lean interventions across multiple medical settings, have suggested that the topic of privacy and confidentiality has not been a priority in the Lean health care discourse [18,24]. None of the articles that were part of these 2 reviews looked at the potential impact of Lean-driven changes on patient privacy and confidentiality. Moraros' review also presented primary analyses of patient satisfaction data that were gathered by hospitals in the Canadian province of Saskatchewan. Saskatchewan is recognized to have undergone the largest Lean health care transformation in the world, and this included restructuring of provincial EDs [19]. Although the Saskatchewan analyses included multiple indicators of provider-patient communication, measures specifically tied to patients' privacy and confidentiality were not presented. Moreover, we were not able to locate a study about Lean and patient privacy and confidentiality through our searches of the published literature.

If professional regulatory organizations are going to require that physicians and nurses interact with their patients privately and confidentially, we need to examine the degrees to which their practice environment supports them to do so. The purpose of this study was to explore how a Lean intervention affected the ability of emergency medical professionals to optimize conditions of privacy and confidentiality for patients under their care.

Methods

Study Design

The findings reported by this study arose from data collected as part of a realist grounded theory study that examined the impact of a Lean intervention undertaken by 2 EDs from a single teaching hospital in Ontario, Canada [26]. The hospital has 1000 beds, and about 128,000 patients seek treatment from the 2 adult EDs annually. In 2013, in response to poor ED wait times, the hospital introduced extensive changes to the physical practice environments and patient care processes at both adult sites. The changes were anticipated to improve the efficiency of the ED, and in turn, this would reduce the wait times experienced by patients.

From July to December 2017, emergency nurses and physicians who practiced at either ED were sent emails inviting them to consider participating in a single, semistructured interview. These emails were sent on behalf of the study by the administrative office that manages the ED sites, and professionals were asked to reply to EMZ's confidential university email account. The administrative office was not made aware of the participants' identities. Interviews were audio-recorded for transcription into verbatim electronic documents by a professional transcription service. Participants received a Can $20 gift card as an honorarium. University and hospital-level research ethics boards approved the study's protocol.

The study followed a constant comparative approach that is consistent with grounded theory methodology [27-29]. Using a semistructured format, the interview probed the ED environment, both before and after the Lean intervention, including the physical configuration of space, organization of patient flow, clinical workflow for physicians and nurses, opportunities for professionals to collaborate during patient care, the motivation for restructuring the ED, and the processes that were involved in the Lean intervention.

Data Analysis

After each interview, field notes were prepared about the dialogue that occurred with the professional, and these notes were reviewed alongside the interview's prepared transcript. With the use of MAXQDA software (Version 11.2.5, VERBI Software, Sozialforschung GmbH, Berlin, Germany), information from the transcripts was first read line-by-line and was coded into a set of categorical topics. Categorical coding continued alongside data collection, and information from new interviews was successively compared with the existing set of codes. Through the repeated review of the interview transcripts and evolving coding, the categorical topics were organized into themes. Data collection continued to theoretical saturation of meaning at which point we felt that the amount of information that was gathered from the interviews was sufficient to support our exploration of participants' perspectives and that any additional interviews were not likely to introduce major modifications to our understanding of the data gathered in our study [30,31]. For our research, we sensed theoretical sufficiency after 20 interviews.

Results

Demographics

Overall, 15 nurses and 5 emergency physicians were interviewed, and 18 of these individuals had been practicing emergency medicine for at least 10 years. Interviews lasted, on average, 53.8 min (SD 11 min), and the corpus of transcripts contained a total of 171,592 words of content.

Themes

All of the health care professionals who were interviewed during this study spoke in detail about their experiences providing medical care to patients and interacting with their family members and visitors within a particular area of the restructured ED, the front cell. The construction of the front cell was a major element of the Lean redesign. The front cell tends to be a very busy area of the restructured ED because it receives all of the patients that are flowed forward from triage. The experiences of nurses and physicians in the front cell revolved around 3

themes: the theory behind the chairs, too many people in the front cell, and how we work (around) to try to preserve our patients' privacy. After a description of the physical configuration and patient care processes used in the front cell, the 3 themes will be unpacked with anonymized quotes to ground, and enrich, our findings with the voices of our study participants.

The Front Cell

The front cell of the ED was separated into 3 zones, and triaged patients were directed to one of these. Each zone had 3 stretcher beds and 6 chairs, and the primary assessment nurse, who manages patient flow, made the initial decision of whether a patient was sent to a stretcher bed or front chair. Although the stretcher beds had surrounding curtains, the chairs did not. Instead, the chairs were located together in an open concept configuration and were spaced in a side-by-side array. Before its restructuring, the ED did have some chairs available for patients, but these were situated away from treatment areas and spaces where nurses and physicians completed their charting.

The Theory Behind the Chairs

Participants explained that the theory behind equipping the front zone with sets of patient chairs arose from an accepted idea that ambulatory patients should remain ambulatory:

> *The point of chairs is to be able to keep upright patients upright. So, if you can walk and you do not need a stretcher, per se, because your medical condition does not need you to be on a stretcher, they would seat you in a chair. A patient who was young, healthy but just needs a quick exam, belly exam, something like that, or someone with an isolated orthopedic injury. They would be able to take the patient from the chairs into that first bed, see them there and then put them back into the chairs for a plan.* [N101]

> *If you were a gallbladder, you need a bed. If we triage you and the assessment nurse has done your blood work, and it comes back, and it is fine, you'll sit in the chair until you get to an examination table for the doctor to be able to do a full exam. If you were sweating profusely, pale, not doing well, we would have you still in one of those stretchers until we get you pain-free. We may be able to move you over to the Rapid Assessment Zone, or to the middle bubble, while we get ultrasounds and that. If you are doing really well and you look well enough to sit in a chair and weren't in crisis, then you would sit in a chair, continue to give you medication, and go from there.* [N112]

Too Many People in the Front Cell

Several participants clarified that the ED seemed to have drifted away from its original plan to designate the front cell as a patient-only area. In the original plan, under certain circumstances would a family member or friend be allowed to accompany a patient forward to the front cell after triage. For example, if a patient had a cognitive issue or they required an interpreter, 1 person would be allowed to remain with the patient. Although interviewees empathized with individuals' desire to be with a loved one or friend while that person was being cared for in the ED, they noted that over time, the front cell had become, in essence, a secondary waiting room. As this nurse noted, it was common for patients to bring one or more people with them into a front zone:

> *People get rather annoyed if family members can't stay with their loved ones, which I understand. I always try and say, "We don't need to have five family members for the one person."* [N107]

During times when family and visitors accumulated in the front zones, interviewees noted fewer chairs were available for patients, family members crowded around stretcher beds, hallways became congested, ambient noise levels increased, and as this nurse and emergency physician explained, it was often difficult for a health care professional to work in a front zone while their family members and visitors were also present:

> *I understand that they are worried, and they are concerned about their family members, but I have actually had put it to them, and I said, "If anything ever happened to your family member, I can't get to them. I'm not going to be tripping over chairs or you to do my job. Please trade off any time you like, but I can only have one [of you here].*" [N110]

> *It's become like a waiting room. And even at the [stretcher] bedside, it's a small geographical space. And there are many times I'll open the curtain to try to walk in, and there will be three or four visitors with the patient. In a small area where you're trying to provide such rapid care, you cannot do it with visitors there. It was initially intended that you would do your care in the front bubble [without visitors]. Once the patient was moved, visitors or family would be allowed to come into the areas where they have been moved. The general public hasn't accepted that. And that space has just never been designed to allow for that.* [P204]

Moreover, some participants noted that the public often ignored the hospital's request that they refrain from using mobile devices in the ED, and you could see people using their mobile phones while they waited in a front zone.

Interviewees explained that during periods of high patient volume and slowed access to the stretcher beds in the front zones plus the accumulation of patients, family members, and visitors in the front cell synergized to increase the likelihood that a patient would interact with a health care professional in the presence of other members of the public. Professionals were not comfortable with this situation as described by these 2 nurses:

> *I like the idea of either putting them in the chairs to wait to come into a spot [stretcher bed]. Say, all our spots are full, there are a few more people that are appropriate, trade them out. That is fine. Or they have had their lab work done, and they are just waiting for results, they are stable, put them into the chair and wait for the results. I am okay with that. It's the*

> *people that are getting seen by physicians or nurses in the chairs. I don't like that. I don't like assessing a patient in a room full of a bunch of other people, asking them personal information questions, things like that.* [N110]

> *You could have patients in chairs surrounded by strangers beside you inches away, and a doctor is asking you questions. Yeah, or even if it's just assessing your foot, people are watching that, they're right there. And even in the stretchers, you can hear everything that's going on behind those curtains. The historical set up though we've had curtains, so there's always been some lack of confidentiality, but with the cluster of chairs where they are out in the open now. Oh, it's terrible. I think about if I was a patient how I would feel with that and I would probably put a complaint in because there is no privacy there.* [N109]

Concerns were raised regarding the impact of the departments' push-forward model on the front chair environment. Physicians explained that as the model prioritized the continual flow of patients from triage, this meant that at any given moment, it was feasible for individuals with varied medical needs to be seated together. They cautioned that although a patient may be alert and mobile when they are assessed at triage, and therefore, would be eligible to be pushed forward into a chair, it should not be assumed that the individual was experiencing a minor medical complaint. Although some physicians recalled instances where they felt a triaged patient should have been directed to a stretcher bed rather than a chair, they also acknowledged there was not always an available alternative:

> *I honestly feel we have to put people in chairs that should not be in chairs. But the alternative is, they wait in the waiting room [by registration]. So, I'll say to patients, "I'm sorry that you have to be in that spot [a front chair], but it's either that or you don't get seen at all." And people understand that equation, but it doesn't mean they're happy about it, particularly if they're not feeling well.* [P202]

Further, as these 2 physicians highlighted, there were medical contexts where doctors anticipated it could be especially uncomfortable for a patient to have to interact with them while they were sitting among other people:

> *The chairs are where I have difficulty because there will be multiple patient types in chairs. You might have two psychiatry patients, you could also have someone waiting on blood work, and you could have someone that has a sore foot in the chairs. My perception is that most patients don't like to be talked to in front of a bunch of other people. Of course, it depends on why you are there in the first place. If you have a cut on your thumb, you may very well not mind talking about it in front of other people.* [P200]

> *Sometimes you're asking some pretty uncomfortable questions to people. Like, you [the emergency physician] need to know this, or you don't know this. So for them [patient] to, sort of, to be quizzed, or asked, or somewhat berated sometimes in front of a room, and then to have to go see that next person 10 feet away, that person knows exactly what's going on. Whereas in the old system, you had that privacy, and to discuss issues about patients that, you know, that person had chlamydia, gonorrhea, or something else. That's probably not the nicest conversation in a room full of 50 people.* [P201]

How We Work (Around) to Try to Preserve Patient Privacy

We have previously described that managing high patient volumes in the ED commonly involved moving patients around the 3 cells of the reconfigured ED [26]. When interviewees elaborated on reasons underlying these moves, they explained that they would often ask a patient to move out of a front chair and accompany them over to another area of the department to try to optimize a sense of privacy before they began communicating with that individual:

> *The chairs are great, but because there is no place for patients to be moving out of the stretcher, you have people in the chairs, and there is no privacy. You can't talk and ask people. Sometimes, they are there, I'll take people around the corner, and I'm talking to them in the hall, just so their neighbour doesn't hear them, which I personally don't think it's appropriate. If they were alone in the chair, I have no problem talking to them, but otherwise, there is no privacy. There is nowhere to sit.* [N110]

> *Hopefully, you're not assessed in the chair. Unless you're the only person in the chairs at the time, then we would talk to you there, just for privacy reasons. But if there are other people there, we've got to take you out of that chair to some corner where we can talk to you privately and then bring you back to the chair.* [P201]

Participants listed off various areas, wherein the moment, they had sought out a more private location to interact with their patient including a hallway or corner, trauma bay, the resuscitation room, or even another front zone:

> *Well, they put patients in the chairs when all the [stretcher] beds are full. So, you're going to see them in the chairs, but there are other people there. I'm not willing to have those conversations unless it's maybe an infected finger. Even that I really don't like having in case, there's something else about it. So, it can be hard to find the space that you can actually talk to somebody. I try to move them around. But you end up going into the quiet room or the resuscitation room or pull them off to the side, trying to see if somebody else's chairs are empty.* [P203]

Nurses also acknowledged that although it was an accepted practice to treat patients while they were sitting in a front chair, they were quite uncomfortable doing so when other members of the public were present. During these moments, some nurses admitted that they, too, felt like they were on public display:

> *I do find there's far less confidentiality [compared to our old model]. I have to now go into the small area*

> *where patients are more or less knee-to-knee with each other, and I have to disclose information or results or do vitals in front of everybody else, spike meds in front of everybody else. You're being watched, and the patient that you're doing this stuff to is now the centre focus of everybody in that area.* [N104]

Two of the nurses who were interviewed described incidents where they felt their privacy was disrespected:

> *I've been caught a couple of times where people are photographing you. That is the culture, and it irritates me because it's [a mobile device] supposed to be off. And how can we enforce that, when everybody else is on them?* [N107]

> *I was on the phone with [details regarding the conversation are anonymized], and then I was called into a patient room and another patient said, "I just wanted to let you know that I feel for you [details regarding what the individual said they overheard are anonymized] and I heard your conversation." And I'm like, "Oh no. Oh my god." There's just no privacy. We have no place to have private phone calls.* [N109]

Discussion

Principal Findings

To our knowledge, this is the first qualitative study to explore the impact of a Lean health care intervention on patient privacy and confidentiality. Although the Lean redesign was intended to make the ED work more efficiently, the results of this study illuminated that the physical configuration of the front cell often intensified the clinical work of emergency nurses and physicians because they needed to actively search for spaces that could better afford privacy and confidentiality for patient encounters.

Evidence-based design of health care facilities requires careful consideration, and anticipation, of the complexities that exist within the delivery of patient care [32]. Although published studies have cautioned against the use of open concept areas in ED settings, as these were associated with increased prevalence of breaches of patients' informational and physical privacy, the hospital embraced an open concept design for the sets of chairs located in each zone of the front cell. Although professionals did perceive value in having these chairs, they also cautioned that the chairs served multiple, and often competing, purposes. They were part of an active treatment area, they afforded an intermediary space for patients awaiting their results or further diagnostic testing, and as a result of public pressure, they had also become part of a secondary waiting room that housed patients along with their family members and visitors. At any time in the ED, members of the public could fill the front chairs for one or more of these purposes. Again, although previous research had demonstrated the superiority of walled patient areas over those separated by curtains [13,15], when the doctors and nurses in our study interacted with ED patients seated in the front chairs, they were doing so in an area that was absent of any curtains or walls.

Unlike Lin and Lin [17], we found that the ED staff was very vigilant of threats to the ongoing informational and physical privacy of their patients . Although nurses were more limited in their ability to work around issues brought on by the configuration of front chairs, professionals were aware that during any given shift, they might need to search for a quieter, more confidential location to engage with their patient. Locating this space was not an easy task to perform when the ED was experiencing a high volume of patients, and physicians noted that their searches for private space could involve temporarily encroaching on another patient treatment area, another front zone, or moving the patient out into a hallway or corridor. Although the conditions that optimized privacy and confidentiality were viewed as being essential for all patients, physicians made a point of highlighting their concerns regarding the vulnerability of individuals who sought medical care from the ED for stigmatized conditions including mental health, addictions, and sexually transmitted diseases. An ED can be the primary source of medical care for patients with stigmatized conditions [33], and although in the moment, an attending may feel that moving a patient out from a front chair into a hallway or corridor may be advantageous to the individuals' privacy and confidentiality, doing so may actually bring some risk into that encounter. A survey by Stoklosa et al found that 89.5% (206/230) of American emergency physicians believed they deviated from their usual way of performing a physical exam, and 77.5% (286/369) felt they altered how they took a history when they assessed a patient in a hallway. When asked about the impact of these disruptions, over one-third of physicians surveyed admitted they had delays or failures in the diagnosis of hallway-assessed patients, including cases involving psychiatric conditions, substance abuse, and domestic/intimate partner violence [34].

Our study did not focus on change management, and we do not know how closely hospital management has been working with its frontline health care professionals to monitor the ongoing impacts of the restructured ED. Although we do not believe that ED wait times were intentionally privileged over patient privacy, our finding that medical professionals felt the need to move their patients around the department to better afford conditions for their patients' privacy and confidentiality highlights an important, unintended consequence. Given that Lean assumes that an organization will seek continuous improvement through their examination of whether activities are adding value [20,25], it would seem reasonable that the hospital reflects on how the front chairs have been impacting their ED patients and the nurses and physicians who care for them. We do not know if the hospital is achieving its targets for improved ED wait times, but our participants expressed that during a given shift in the ED, it was common for them to go through the following sequence of activity: request that a patient move out from the front chair area and then ask the patient to accompany them in a search for more private space within the ED; once a suitable spot was located, then the professional interacted with the patient as intended, and then they returned the patient to the front chair area. Professionals viewed this workaround as a way to prevent unintended violations of their patients' privacy, and thus in the moment, it was viewed by them as being a value-added activity. However, through the lens of the Lean intervention, it may not

be a value-added activity. The workaround is likely adding several minutes to the clinical time spent by the professional on that case as well as adding on to the patients' length of stay in the ED. Our study did not involve discussions with patients, and we cannot make statements regarding their experiences nor perceptions of the quality of medical care they received from the ED. Previous research has shown that although time is important to ED patients, so are other subjective experiences beyond waiting. Patients can show tolerance for waiting when other aspects of their experience were perceived as being well met [35-38]. The question of whether patients value shorter ED wait times over privacy and confidentiality in an ED setting warrants future attention.

The issue of health care professionals being recorded while they provide patient care has been raising concerns within the medical community. About 86% of Canadian households own a cell phone [39], and many members of the public bring these devices with them when they seek medical care [40]. In Canada, hospital policies on cell phone use by the public vary, and there do not appear to be any federal guidelines in place [41].

In terms of patients' perceptions of, and experiences with, making a cell phone recording in a hospital setting, Oyedokun et al surveyed 110 patients who were treated for a laceration potentially requiring suturing at one of the 3 EDs located in the Canadian province of Saskatchewan [42]. To contrast patient perspectives about recording with the opinions of health care providers, 156 ED professionals (19 nurses and 37 physicians) who practiced at one of the 3 sites were also recruited into this study. Over 80% of patients (81.8%, 90/110) indicated that they had brought a cell phone capable of making a video or audio recording with them to the ED, and 30.8% (33/107) had admitted they contemplated making a video on the day they were surveyed.

Statistically significant differences were found between the proportions of patients versus providers who felt that video recording should be allowed in the ED. Although 61.7% (66/107) of patients were in favor of allowing patients to video record while they were in an ED, 49.5% (51/103) of nurses and 42% (15/35) of physicians indicated that they would allow the patient to do so (chi-square test; $P<.001$). When asked, hypothetically, why they would want to make a video while they were having a suturing procedure performed on them, 43% (24/55) of patients indicated that they would want to do so to be able to share that experience with others, and 38% (21/55) said it would be for a memento of their experience. None of the patients surveyed felt that they would want to video their sutures because they were unsatisfied with the care they had received. Fear of legal action, loss of control over the use and distribution of the video, and feeling that it was generally inappropriate for a patient to make a video during their treatment were among the reasons why providers indicated they would decline their patients' requests to record.

Although we do not know the contexts under which these incidents occurred, 2 of the nurses in our study spontaneously recalled, respectively, that a patient overheard a conversation that they should not have been privy to and also that another nurse sensed they had been filmed by a member of the public. Both of these nurses felt uncomfortable about what had occurred, and with the findings by Oyedokun et al [42], these incidents continue to raise the question of what degree of informational and physical privacy should be afforded to health care providers. Future research is warranted. At one time, the hospital we studied was noted to have a policy that restricted family members and visitors from being in the front cell. In light of the issues that have been voiced in our study about privacy and confidentiality, it may be time for the ED to revisit the number of members of the public that can be safely, and comfortably, accommodated within patient treatment areas.

Limitations

This study is not without limitations. As with all studies involving qualitative methodologies, our findings are not generalizable beyond our local context. Exploring the transferability and resonance of our results to other ED settings will require additional research. Given that our study involved discussions with nurses and physicians who provided frontline medical care to patients, we cannot make statements regarding the experiences and opinions of patients who received medical care at the ED nor about the family members and visitors who may have accompanied them. Future research on patients', family members', and visitors' perspectives is needed.

Conclusions and Implications

To our knowledge, this is the first qualitative study to explore the impact of a Lean health care intervention on the ability of emergency medicine physicians and nurses to optimize conditions for patient privacy and confidentiality. The changes made in the ED included the construction of a three-zone front cell that received all of the patients flowed forward from triage. Each front zone housed an open concept area outfitted with a set of chairs. Our research illuminated that although, in theory, physicians and nurses perceived that the chairs were viewed as adding value to the ED environment, in practice, the chairs served the multiple, and often, competing uses by patients, family members, and visitors. In an attempt to work around the limitations they encountered and keep patients flowing from triage, physicians and nurses revealed that they often needed to move a patient out from a front chair and then go to actively search for another location in the ED that better protected the individual's informational and physical privacy. These searches involved clinical time and likely impacted the length of stay experienced by some ED patients. We advocate that the physical structure and configuration of the front cell should be re-examined under the lens of Lean's principle of value-added activities. Future exploration of the perspectives of patients, family members, and visitors regarding the relative importance of privacy and confidentiality during ED care is warranted.

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Authors' Contributions

EMZ conceptualized the study, managed the recruitment process, interviewed participants, and was the primary data analyst. LS and RB provided feedback on the interview guide and reviewed ongoing data analyses. EMZ wrote the initial manuscript, and the other authors provided feedback and edits of the manuscript toward the final version.

Conflicts of Interest

None declared.

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Abbreviations

ED: emergency department

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Original Paper

Supporting Older Adults in Exercising With a Tablet: A Usability Study

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Abstract

Background: For older adults, physical activity is vital for maintaining their health and ability to live independently. Home-based programs can help them achieve the recommended exercise frequency. An application for a tablet computer was developed to support older adults in following a personal training program. It featured goal setting, tailoring, progress tracking, and remote feedback.

Objective: In line with the Medical Research Council Framework, which prescribes thorough testing before evaluating the efficacy with a randomized controlled trial, the aim of this study was to assess the usability of a tablet-based app that was designed to support older adults in doing exercises at home.

Methods: A total of 15 older adults, age ranging from 69 to 99 years old, participated in a usability study that utilized a mixed-methods approach. In a laboratory setting, novice users were asked to complete a series of tasks while verbalizing their ongoing thoughts. The tasks ranged from looking up information about exercises and executing them to tailoring a weekly exercise schedule. Performance errors and time-on-task were calculated as proxies of effective and efficient usage. Overall satisfaction was assessed with a posttest interview. All responses were analyzed independently by 2 researchers.

Results: The participants spent 13-85 seconds time-on-task. Moreover, 79% (11/14)-100% (14/14) participants completed the basic tasks with either no help or after having received 1 hint. For expert tasks, they needed a few more hints. During the posttest interview, the participants made 3 times more positive remarks about the app than negative remarks.

Conclusions: The app that was developed to support older adults in doing exercises at home is usable by the target audience. First-time users were able to perform basic tasks in an effective and efficient manner. In general, they were satisfied with the app. Tasks that were associated with behavior execution and evaluation were performed with ease. Complex tasks such as tailoring a personal training schedule needed more effort. Learning effects, usefulness, and long-term satisfaction will be investigated through longitudinal follow-up studies.

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KEYWORDS

frail elderly; aged; activities of daily living; exercise; health behavior; telemedicine; mobile devices; tablet computers; usability testing; mobile phone

Introduction

Physical Activity Interventions for Older Adults

Physical activity is vital for a healthy life. A sedentary lifestyle is associated with numerous health-related problems such as obesity, diabetes, cardiovascular diseases, various forms of cancer, and depression [1,2]. Furthermore, for older adults, physical activity can prevent or delay the onset of functional impairments and prolong the ability to live independently [3]. Provided by these well-acknowledged health benefits, community-based physical activity programs have spawned across the world [4,5]. A prototypical example of such a program that has been running for over 35 years in the Netherlands is "More Exercise for Seniors" (*Meer Bewegen voor Ouderen*, abbreviated as MBvO in Dutch). Weekly, 400,000 older adults exercise in a group under the guidance of an instructor. Despite the popularity of this program, however, its effects on physical health appear to be insufficient [6]. In particular, studies show a need for higher frequency and longer exercise duration to capitalize on the health benefits of physical activity [7,8].

To achieve the recommended frequency and duration, a home-based exercise program could prove a useful addition to a community-based program such as MBvO. With the convenience of their home, older adults can continue the exercises they have learned during the weekly community classes. A focus-group study showed that the MBvO participants believed additional home exercises would be useful but also had worries about the safety, self-efficacy, and adherence to such an intervention [9].

Technology Use

Mobile health (mHealth), that is, the use of mobile devices and wireless technology for medical and health practices [10], is increasingly being used to attain health goals, for instance, increasing physical activity, weight loss, stress reduction, or chronic disease management like diabetes. In 2017, over 325,000 health apps were available for the general public through the various app stores [11]. Health professionals, policy makers, and researchers recognize the opportunity to reach a large audience through developing technology-enhanced interventions for various target populations and health outcomes. Increasing physical activity in older adults is one of such intended health outcomes [12-16]. In contrast to popular belief that older adults are not inclined to use technology, the ownership of tablet computers among older adults is growing rapidly [17-19]. The popularity of tablets stems possibly from its usability. Studies show that older adults are able to operate tablets better than personal computers [20,21] or smartphones owing to their large touchscreen [22]. It is not surprising that recent health interventions for older adults choose tablets as the primary mode of delivery [23-27].

Development of a Tablet-Based Intervention

To increase the physical activity in older adults and capitalize on the potential of mHealth, a technology-enhanced intervention was developed as part of the Motivating Technology for Older Adults' Behavior (MOTO-B) and VITal Amsterdam elderly IN the city (VITAMIN) projects. The aim of these projects was to develop an mHealth intervention that can be used in conjunction with existing community-based exercise programs. By supporting older adults to perform exercises at home as well, it helps them to achieve the recommended exercise duration and frequency [7,8].

To develop the intervention, the Medical Research Council (MRC) framework was used [28,29]. This framework describes the process of developing, pilot-testing, assessing the effectiveness, and implementing complex health interventions. As part of the development stage, focus groups were conducted with prospective users, and relevant literature was identified, which led to 3 design considerations [9,30]. First, physical activity should be supported by functional exercises that can be executed safely within a home environment. Second, to facilitate behavior change, the intervention should support self-regulation. Third, a blended approach allows the convenience of a home-based exercise program and the ability to tailor the intervention to individual needs to be combined with the effectiveness of rich feedback and social support.

These design considerations were implemented in a tablet-based app called VITAMIN that delivered a home-based exercise program in conjunction with coaching. Key components were goal setting, the ability to tailor the program to individual needs, video demonstration of functional exercises, rating of exercises, and progress tracking and feedback of a personal coach that could remotely monitor performance. See Mehra et al. [30] for a detailed account of how behavior change principles were translated into the blended intervention.

Prior to evaluating the efficacy of the intervention in terms of health outcomes, the feasibility should be assessed. This stage is often overlooked, leading to efficacy studies of interventions that have not matured yet and problems that could have been prevented with sufficient pilot testing [29]. Usability issues are one of the key factors that determine the success of mHealth interventions [31,32]. Usability is defined as the extent that devices can be operated by users to achieve the specified goals with effectiveness, efficiency, and satisfaction in a specified context of use [33]. In line with the feasibility stage of the MRC framework, this study sets out to investigate the usability of the tablet-supported intervention. The aim was to assess whether first-time users could operate the VITAMIN app that was designed to support older adults in doing home-based exercises. First-time users are older adults that have no prior experience of using the app.

Methods

Study Design

Zapata et al [32] conducted a systematic review on how the usability of mHealth apps is being evaluated. The majority of the studies use either interviews or questionnaires to investigate usability. These methods rely on self-report of prospective users after having used the device. These methods are suitable to gauge user satisfaction but in lesser degree effectiveness and efficiency. In contrast, other studies investigate the usability by observing users as they try to complete prescribed tasks on the device. This method is a reliable estimate of effectiveness and efficiency but not user satisfaction. Combining various methods to evaluate usability is therefore the recommended approach, although only a few studies do so [32].

This study used mixed methods to investigate the usability of the VITAMIN app. To evaluate effectiveness and efficiency, user performance was recorded and assessed as they executed tasks in a laboratory setting. Satisfaction was evaluated by asking the participants to "think aloud" during the execution of tasks. This is a common technique used in usability studies where users are requested to verbalize their ongoing thoughts as they execute a task [34]. After performing the tasks, participants were interviewed about their overall impression of the app.

Participants

A total of 15 older adults, 4 men and 11 women, were recruited from local community centers that offer weekly exercise programs. Inclusion criteria were that the participants be at least 55 years old, living independently at home, and taking part in the weekly exercise classes offered by the community center. Exclusion criteria were mental or physical health conditions that could prevent them of operating a tablet, such as the presence of tremors or cataract. Both the inclusion and exclusion criteria match those of a future randomized controlled trial (NTR5888) and the intended implementation of the intervention as an addition to existing community-based exercise programs [35].

Materials

Tablet Application

The app was designed for a 10-inch Android tablet. The main functions of the VITAMIN app were delineated by 5 distinct tabs in the home screen: (1) Exercises, (2) Profile, (3) Weekly Schedule, (4) Today, and (5) Video Calling. *Exercises* is a library that contained 16 functional exercises, designed by human movement scientists, that were devised to be executed in a home setting with ordinary household objects as aids. Each exercise consisted of 3 versions that varied in difficulty. For each variation, a custom-made video with a voiceover was shot (48 in total) that depicted how the exercise could be executed safely (modeling). The video was accompanied by a factsheet that contained background information about the exercise (Figures 1 and 2). *Profile* is the possibility to formulate personal goals and a step-by-step wizard that helped users to set up a weekly schedule with suitable exercises (goal setting & tailoring). *Weekly Schedule* is an overview with icons depicting which exercises were planned for each day of the week (Figure 3). Users could checkmark exercises that had been performed and see, in a glance, what still had to be done (progress tracking). *Today* is a reel of exercises that were planned for that day. To aid the execution, a countdown timer depicted the remaining seconds. Prior to the execution, the user could customize each exercise using 3 parameters: the duration of the exercise, the amount of repetitions of the exercise, and the difficulty level (Figures 4-6). After the completion of each exercise, the user could rate the exercise using 3 scales on difficulty, effort, and fun (Figure 7). *Video Calling* is the option to video call an appointed coach that could motivate and assist the user from distance (motivational interviewing). This coach could also remotely monitor the weekly schedule and the user ratings of each exercise (Figure 8).

The typical use of the app would be exploring the available exercises (1) and setting personal goals (2) during the initial use. The Weekly Schedule (3) and Today (4) tabs are used on a daily basis to assist users in performing their scheduled exercises. Finally, the Video Calling (5) tab is to be used when users want to evaluate and discuss their progress with their personal coach.

Usability Tasks

In order to test typical scenarios for novice users that have no to little experience using the app, a series of basic tasks were defined. The tasks were grouped around the 4 tabs: Exercise, Today, Weekly Schedule, and Video Calling described above. The Profile tab could not be tested because it was still in development at the time.

The basic tasks were designed with the novice user in mind. Three additional "expert tasks" were added to the testing procedure as a "back-up option" in case participants completed the basic tasks early. The expert tasks were defined as tasks that would be indicative for advanced users that have been using the app for an extended period of time (see Textbox 1 for a description for the basic and expert tasks that were tested).

Figure 1. Exercise library.

Figure 2. Selecting an exercise variation.

Figure 3. Personal training schedule.

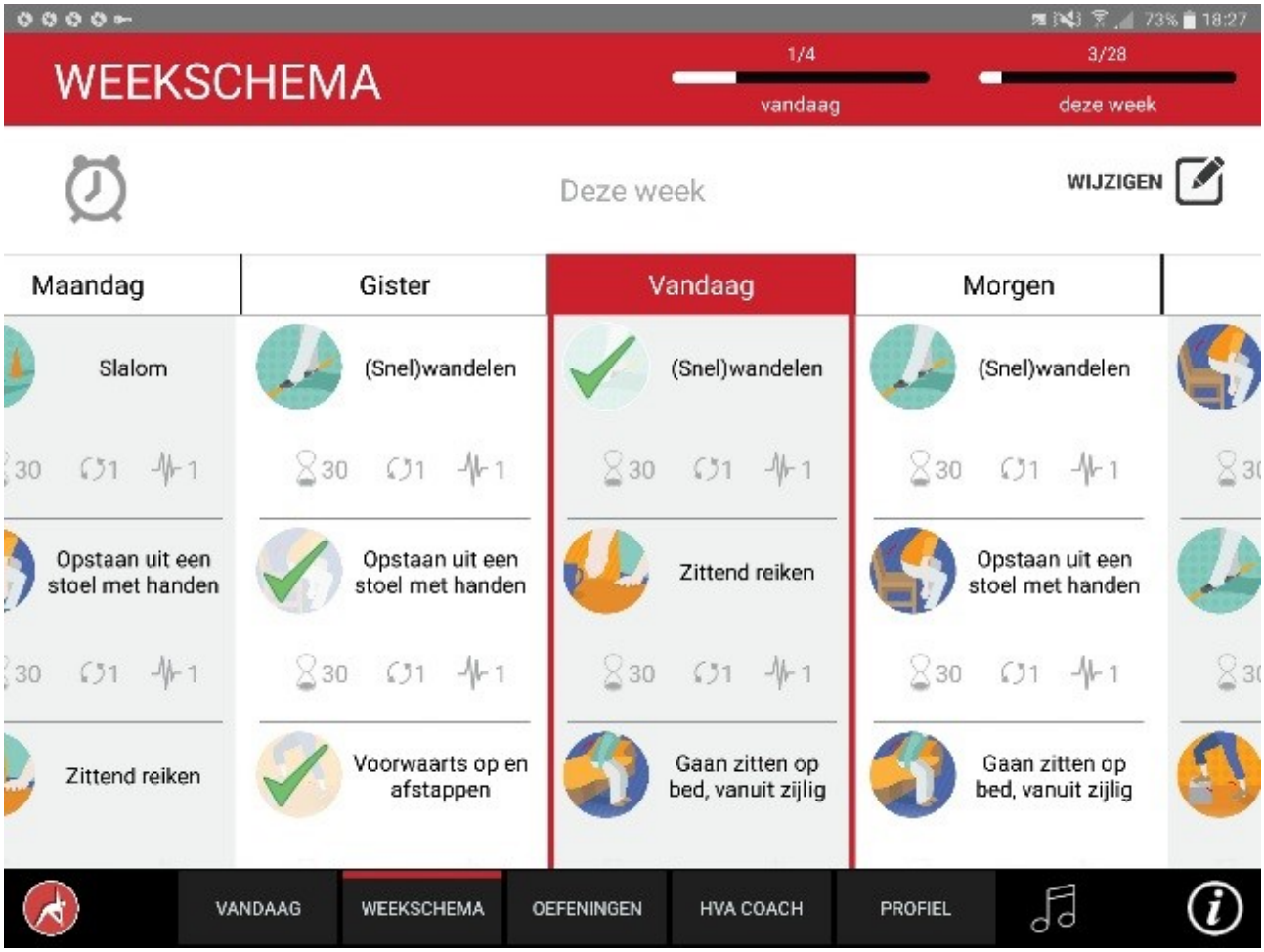


Figure 4. Today's program.

Figure 5. Modifying execution parameters.

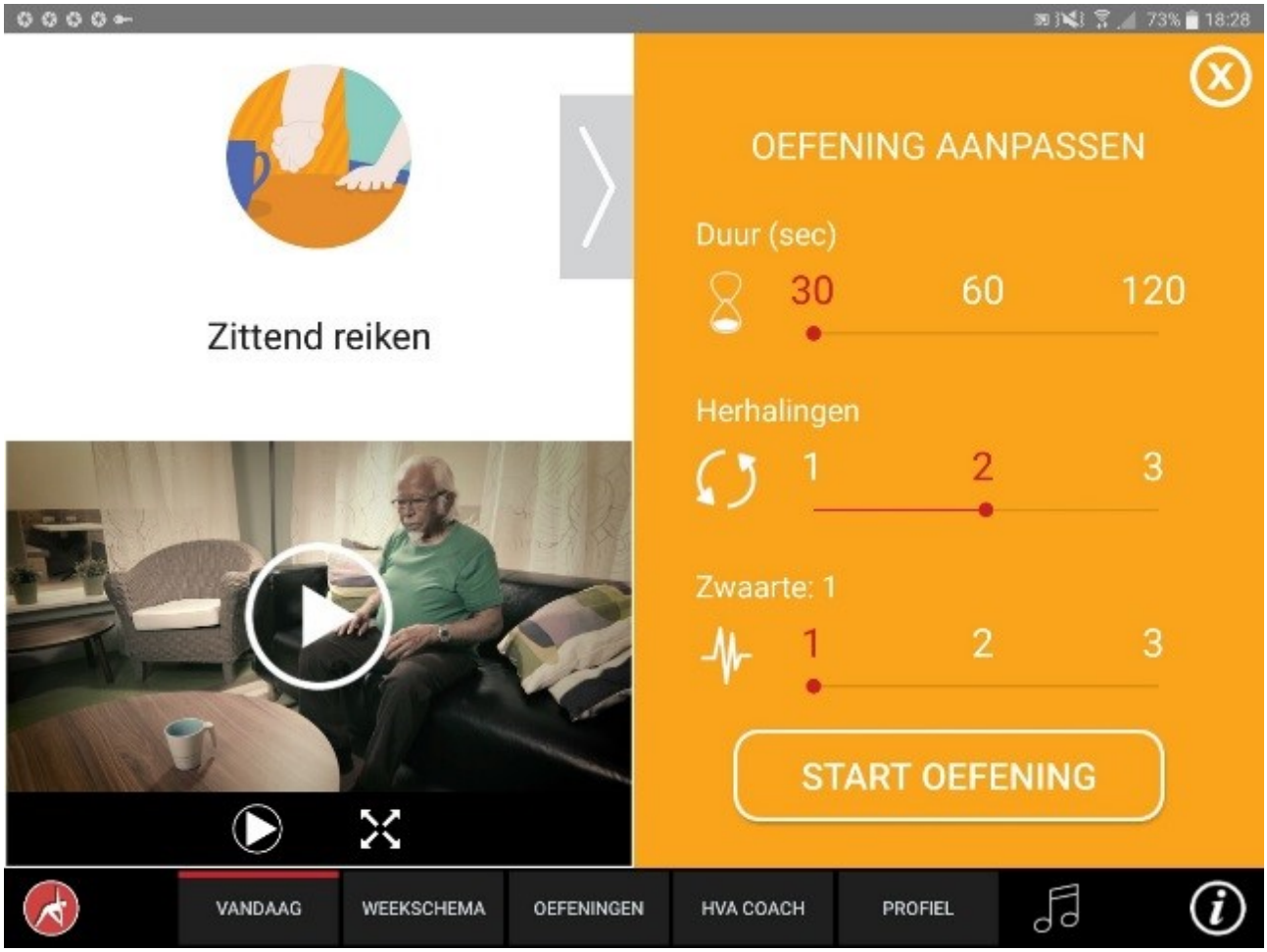


Figure 6. Countdown timer during execution.

Figure 7. Rating an exercise.

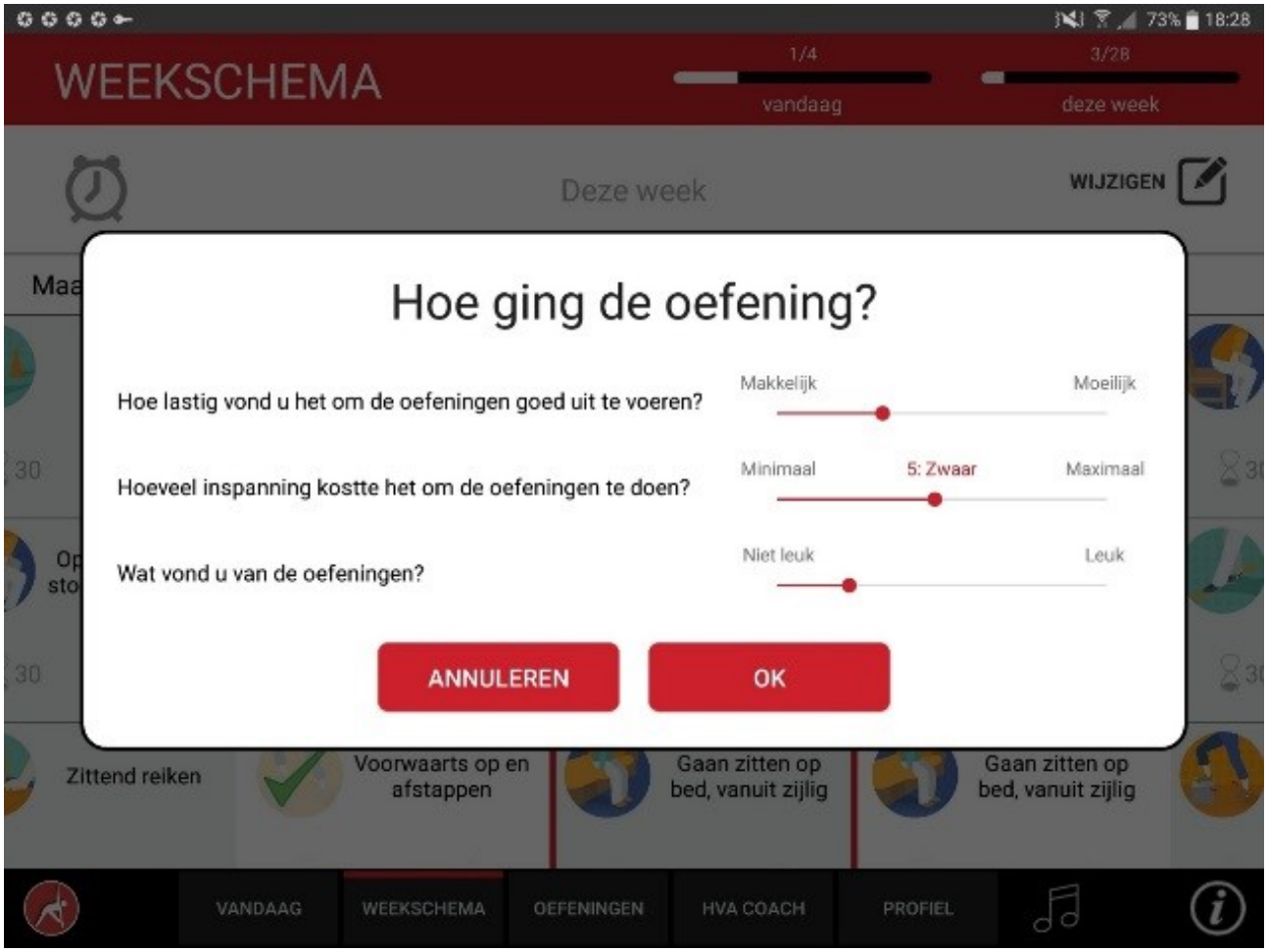
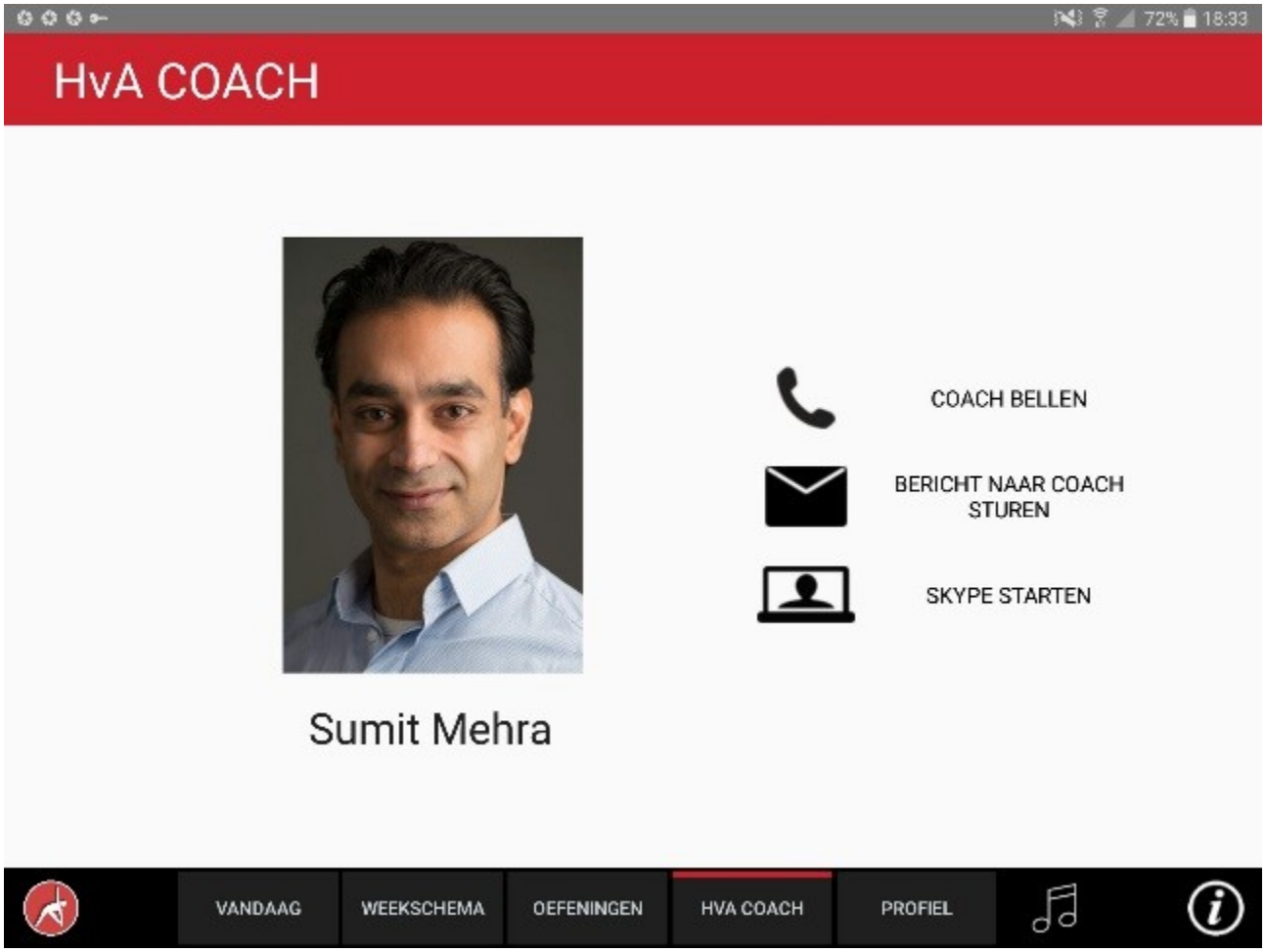


Figure 8. Initiating a video call to the coach.



Textbox 1. Description of the tasks that were performed by the participants.

- Today:

Today1: Execute the exercises that are scheduled for today. Adjust the duration to 10 seconds and set the repetition to 1.

Today2: After completing an exercise, rate the difficulty, effort and fun using three scales.

Today3: Find and watch the instructional video of exercise X.

Today4 (expert): During the execution of an exercise, pause the countdown timer.

- Weekly Schedule:

Schedule1: Look up which exercises are planned for Friday.

Schedule2: Add an exercise to your weekly schedule that will increase your capacity to pick up objects from the floor.

Schedule3: In the weekly schedule, remove exercises so that the maximum exercises for that day is three.

Schedule4: Set an alarm so that you will get a daily reminder at 12.00.

Schedule5 (expert): Yesterday you forgot to mark your exercises as completed. Do this in retroaction.

- Exercises:

Exercise1: Look up information about exercise X.

Exercise2 (expert): Study the different variations of exercise X.

- Video Calling:

Video1: Make a video call to your coach.

Procedure

Participants were received in the usability lab of the university by an experimenter and an assistant. After signing an informed consent document and receiving a short verbal introduction, they were seated behind a desk. The participants were instructed to think aloud as they performed each task. If needed, they were encouraged to do so by asking "what do you see?" or "what are you trying to achieve?" during the experiment. If participants were stuck during the execution of a task, they were given a verbal hint by the experimenter after 30 seconds, for instance "the button you are looking for can be found in the top left-hand corner." In this manner, the participant could continue with the rest of the task.

After practicing the procedure with a trial run, they were asked to perform the tasks as described in Textbox 1. The order of the tasks was fixed in principle, but some tasks were skipped if the experimenter felt this was appropriate. Occasionally, some participants deviated from the goal and explored the functions of the app. In some cases, this situation made certain future tasks irrelevant. For instance, if a participant already deliberately removed exercises from the weekly schedule during the task Schedule2, performing Schedule3 was skipped for that specific participant. Furthermore, the expert tasks were given only to the participants whose pace was high and when the experimenter believed that the participant would be able to complete all the tasks within the allocated time.

After completing the tasks, the tablet was put aside and the participants were shortly interviewed about their general impression of the app. The sessions lasted 45 minutes in total and were video recorded. Furthermore, the user's interaction with the tablet was recorded by screen capture software.

Data Analysis

All recordings were transcribed and coded using software for qualitative analysis (MaxQDA). Two researchers independently coded 4 metrics of the aggregated dataset:

1. Time-on-task: the average time the participants spent on executing a task.
2. Hints: the average number of hints that were given during the execution of a task.
3. Success rate: the proportion of participants that completed the task successfully without any hints, completed the task successfully with hints, and could not complete the task.

Errors: the average amount of errors that were made by participants during the execution of a task. A distinction was made between the following: strategy errors: not knowing how to approach the task (eg, not knowing how to add exercises to the weekly schedule); interaction errors: not knowing how to execute the strategy (eg, unable to find the play button); and operating errors: being unable to operate the device (eg, swiping).

Furthermore, the remarks of the participants during the execution of a task (think-aloud protocol) and posttest interview were classified as either positive, neutral, negative, or a suggestion for improvement.

After both coders annotated the data independently, they compared the results. Differences were resolved via discussion. If no consensus was achieved, the first author settled the rare dispute.

Results

Participant Characteristics

The ages of the 15 participants varied from 69 to 99 years old with an average of 77 years (SD 8.5). The majority indicated they had no prior experience operating a tablet.

Time-on-Task, Success Rate, and Satisfaction of Basic Tasks

The results of 1 participant were excluded from the study because she turned out to be insufficient in Dutch to understand the assigned tasks, and her responses could not be coded reliably. The remaining participants spent 13-85 seconds time-on-task for the basic tasks that were indicative for novice users. Depending on the task, 79% (11-14)-100% (14/14) of the participants completed the tasks successfully with either no help or after having received 1 hint.

Despite the fact that the tasks could be completed successfully by the majority of the participants, their performance varied greatly across different tasks. Executing an exercise (Today1), watching an instructional video (Today3), and video calling a coach (Video1) were conducted relatively easy, as demonstrated by the high success rate without any help. In contrast, adding an exercise to the weekly schedule (Schedule2) appeared to be a more difficult task, indicated by the relatively high failure rate (see Table 1 for the average time-on-task, amounts of hints given, and success rate for the basic tasks). The type of errors that were made ranged from strategy and interaction errors to operating errors (Table 2).

In addition to task performance, the satisfaction per task was assessed with the think-aloud protocol. The majority of the basic tasks elicited more positive remarks than negative remarks during the execution (see Table 3 for the type of remarks per task). Participants were most positive about performing the daily exercises from the Today tab (Today1). This task elicited 3 times more positive remarks than negative remarks. Examples are "I think this is great. A short break. A[n] interval," "...yes, very easy," and "...this is very convenient" or "it is quite orderly." In contrast, the participants were not enthusiastic about looking up information in the Exercise library (Exercise1). During this task, participants could read background information about an exercise. This task elicited 2 times more negative remarks than positive remarks. Examples are "I think this is a lot of text" or "...this is not of much use." The suggestions made by the participants were "...look, you call it domain. I would use a different term for this" or "I think the text should be shorter." Also, for watching an instructional video (Today3), participants had several suggestions about enlarging the video to full screen, for example, "enlarging with two fingers would be useful" or "a different symbol for enlarging the video would perhaps be better."

Table 1. Participants who performed the task (N), average time-on-task, number of hints given, and success- and failure rates for basic tasks.

Basic task	Participants, n	Time-on-task (s)	Hints	Success without hints, n (%)	Success with hints, n (%)	Failure, n (%)
Today1	14	78	1.0	10 (71)	3 (21)	1 (7)
Today2	14	59	0.9	6 (43)	8 (57)	0 (0)
Today3	12	20	0.8	7 (58)	4 (33)	1 (8)
Schedule1	12	33	0.8	5 (42)	5 (42)	2 (17)
Schedule2	14	85	0.9	2 (14)	9 (64)	3 (21)
Schedule3	11	60	0.9	0 (0)	10 (91)	1 (9)
Schedule4	13	85	1.1	6 (46)	6 (46)	1 (8)
Exercise1	13	19	0.8	6 (46)	6 (46)	1 (8)
Video1	11	13	1.1	6 (55)	5 (45)	0 (0)

Table 2. Participants who performed the task (n) and the average number of errors made for basic tasks.

Basic task	Participants, n	Strategy errors	Interaction errors	Operation errors
Today1	14	0.8	0.2	0.4
Today2	14	0.2	0.0	0.5
Today3	12	0.0	0.2	0.2
Schedule1	12	0.4	0.1	0.0
Schedule2	14	0.5	0.5	0.7
Schedule3	11	0.5	0.5	0.4
Schedule4	13	0.4	0.4	0.1
Exercise1	13	0.8	0.0	0.2
Video1	11	0.1	0.0	0.0

Table 3. Participants who performed the task (n) and the total number of remarks evaluated as either positive, negative, neutral, or a suggestion for basic tasks.

Basic task	Participants, n	Positive	Negative	Neutral	Suggestions
Today1	14	18	6	2	1
Today2	14	3	1	3	0
Today3	12	8	4	0	5
Schedule1	12	1	2	1	0
Schedule2	14	3	1	1	1
Schedule3	11	3	1	0	3
Schedule4	13	9	9	0	7
Exercise1	13	4	8	1	8
Video1	11	3	2	0	2

Time-on-Task, Success Rate, and Satisfaction of Expert Tasks

Besides the basic tasks, a few participants also completed the expert tasks. The time-on-task varied from 14 to 58 seconds. The success rate varied from 75% to 100%. As could be expected, more hints were needed to complete the tasks successfully compared with the basic tasks described earlier. Marking an exercise retroactively as completed, which required the participant to tap and hold down for a certain amount of time, proved to be an especially difficult task. This task had the highest time-on-task, failure rate, and errors. The verbal remarks of the participants indicated that they appreciated the possibility of retroactively marking exercises as complete but found its operation difficult (see Tables 4 and 5 for details of the expert task performance; see Table 6 for the type of remarks per task).

Table 4. Participants who performed the task (n), average time-on-task, number of hints given, and success and failure rates for expert tasks.

Expert task	Participants, n	Time-on-task (s)	Hints	Success without hints, n (%)	Success with hints, n (%)	Failure, n (%)
Today4	4	14	3.5	2 (50)	1 (25)	1 (25)
Schedule5	8	58	1.5	1 (13)	5 (63)	2 (25)
Exercise2	4	18	3.5	1 (25)	3 (75)	0 (0)

Table 5. Participants who performed the task (n) and average number of errors made for basic tasks.

Expert task	Participants, n	Strategy errors	Interaction errors	Operation errors
Today4	4	0.0	0.5	0.0
Schedule5	8	0.4	0.4	0.6
Exercise2	4	0.8	0.0	0.0

Table 6. Participants who performed the task (n) and the total number of remarks evaluated as either positive, negative, neutral, or a suggestion for expert tasks.

Expert task	Participants, n	Positive	Negative	Neutral	Suggestions
Today4 (expert)	4	5	1	0	0
Schedule5 (expert)	8	3	2	1	2
Exercise2 (expert)	4	1	1	0	1

Overall Satisfaction

During the posttest interview, the participants were overall positive; 31 positive remarks were made against 10 negative remarks. The number of participants in the posttest interview (n) was 14. In this interview, 31 remarks were validated as positive, 10 as negative, 10 as neutral, and 22 as suggestions. Typical positive remarks were “Nice. I found easy to operate and fun,” “it was pretty clear and straightforward,” and “it’s nice to do different exercises now and then.” Examples of negative remarks were “I am not sure if I would use this app, because it seems to me as an invasion of privacy if every time you have to enter what you have done” or “it wasn’t always clear.” The participants also made several suggestions, often in the line of giving more extensive instructions prior to the first use. A typical remark was “maybe you could provide some more information. Like it works so and so. Perhaps a manual or something.” This bore relevance to the brief verbal introduction they received about the app.

Discussion

Principal Findings

Overall, the app that was designed to support older adults in doing exercises at home appears to be usable for first-time users. After a brief introduction, the vast majority of the participants could complete the assigned tasks. They did this not only effectively (as indicated by the high success rate) but also efficiently. Mostly within 1-2 minutes, they successfully performed the tasks. Furthermore, the think-aloud remarks and posttest interview revealed that the users were satisfied with the app in general.

The performance varied from task to task. Basic tasks that were associated with supporting behavior execution (Today and Exercise) and evaluation (Video Calling) were completed successfully by the majority of the participants, whereas tasks that were associated with tailoring (Weekly Schedule) were more difficult for the users, as indicated by the longer task completion times and higher rate of errors.

The fact that the older adults in this usability study needed some minor help with performing the assigned tasks is not considered to be a major issue by the authors. First of all, the average age of the participants was 77 years old. The majority had never operated a tablet before and only received a short introduction of a few minutes before they had to perform the assigned tasks under the scrutiny of 2 observers. Observer effects and the think-aloud protocol are known to decrease performance for complex tasks in usability studies [36-38]. It is plausible that the participants would have performed better in the privacy of their own home where they feel more free from prying eyes. Second, the expert tasks were developed with an experienced “power user” in mind. It was designed in an unobtrusive manner not to clutter the interface for first-time users. Therefore, it was not surprising that the participants in the study, as first-time users, had more difficulties executing those tasks. Third, the app is designed to be implemented in a blended intervention in which a coach will be appointed. This coach will give hands-on support, face-to-face and remotely. Thus, in this particular case, receiving help to operate the app is not an artefact of the usability study but reflects the actual context of use.

Limitations and Future Work

The app is part of a blended intervention in which older adults participate in weekly group-based classes, perform tablet-supported exercises at home, and receive feedback by a personal coach. This study only evaluates if the app that is part of the blended intervention is usable for older adults. It does not evaluate other aspects of the intervention. Furthermore, the

usability study was conducted in a lab where users interacted with the app for a short period of time. It provides an indication of the usability for first-time users but not for long-term users. Learnability and user acceptance can only properly be studied when older adults have used the app for an extensive period of time. To investigate these matters, follow-up studies are planned. A randomized controlled trial will evaluate the efficacy of the blended intervention in terms of health outcomes [35]. Parallel to this randomized controlled trial, participants that have been using the app for 6 to 12 months will be questioned about the perceived usefulness, ease of use, learnability, and satisfaction on the long term [39]. To optimize reliability and validity, both questionnaires and interviews will be used.

Conclusion

In line with the MRC framework, an evidence-based blended intervention was developed to support older adults in performing functional exercises at home. The feasibility of the tablet-based app that was designed for this purpose has been validated by a usability study with mixed methods. Older adults were able to use the app in an effective and efficient manner. They were mostly also satisfied with the app. These findings pave the way to implement and evaluate the intervention in practice.

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Conflicts of Interest

None Declared.

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Abbreviations

MBvO: Meer Bewegen voor Ouderen (Dutch for More Exercise for Seniors)
mHealth: mobile health
MOTO-B: Motivating Technology for Older Adults' Behavior
MRC: Medical Research Council
VITAMIN: VITal Amsterdam elderly IN the city

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Original Paper

Advancing Cardiac Surgery Case Planning and Case Review Conferences Using Virtual Reality in Medical Libraries: Evaluation of the Usability of Two Virtual Reality Apps

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Abstract

Background: Care providers and surgeons prepare for cardiac surgery using case conferences to review, discuss, and run through the surgical procedure. Surgeons visualize a patient's anatomy to decide the right surgical approach using magnetic resonance imaging and echocardiograms in a presurgical case planning session. Previous studies have shown that surgical errors can be reduced through the effective use of immersive virtual reality (VR) to visualize patient anatomy. However, inconsistent user interfaces, delegation of view control, and insufficient depth information cause user disorientation and interaction difficulties in using VR apps for case planning.

Objective: The objective of the study was to evaluate and compare the usability of 2 commercially available VR apps—Bosc (Pyrus Medical systems) and Medical Holodeck (Nooon Web & IT GmbH)—using the Vive VR headset (HTC Corporation) to evaluate ease of use, physician attitudes toward VR technology, and viability for presurgical case planning. The role of medical libraries in advancing case planning is also explored.

Methods: After screening a convenience sample of surgeons, fellows, and residents, ethnographic interviews were conducted to understand physician attitudes and experience with VR. Gaps in current case planning methods were also examined. We ran a usability study, employing a concurrent think-aloud protocol. To evaluate user satisfaction, we used the system usability scale (SUS) and the National Aeronautics and Space Administration-Task Load Index (NASA-TLX). A poststudy questionnaire was used to evaluate the VR experience and explore the role of medical libraries in advancing presurgical case planning. Semistructured interview data were analyzed using content analysis with feedback categorization.

Results: Participants were residents, fellows, and surgeons from the University of Washington with a mean age of 41.5 (SD 11.67) years. A total of 8 surgeons participated in the usability study, 3 of whom had prior exposure to VR. Users found Medical Holodeck easier to use than Bosc. Mean adjusted NASA-TLX score for Medical Holodeck was 62.71 (SD 18.25) versus Bosc's 40.87 (SD 13.90). Neither app passed the mean SUS score of 68 for an app to be considered usable, though Medical Holodeck (66.25 [SD 12.87]) scored a higher mean SUS than Bosc (37.19 [SD 22.41]). One user rated the Bosc usable, whereas 3 users rated Medical Holodeck usable.

Conclusions: Interviews highlighted the importance of precise anatomical conceptualization in presurgical case planning and teaching, identifying it as the top reason for modifying a surgical procedure. The importance of standardized user interaction features such as labeling is justified. The study also sheds light on the new roles medical librarians can play in curating VR content and promoting interdisciplinary collaboration.

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KEYWORDS

virtual reality; cardiac surgery; usability study; system usability score; NASA-Task Load Index; medical libraries; case planning; presurgical planning

Introduction

Background

Cardiac surgery is quite often a complex task. Valvular heart surgery (eg, mitral valve repair) and surgical management of adult congenital heart disease require detailed knowledge of patient-specific pathological and anatomical characteristics of the heart and great vessels to ensure patient safety and optimal surgical outcomes [1,2]. Three-dimensional anatomical reconstructions using two-dimensional data from radiographs, computerized tomography (CT) scans, or ultrasounds help surgeons previsualize a surgical intervention to define the surgical approach and navigation in the context of cardiothoracic surgery [3,4]. This is often accomplished with a headset, creating an immersive experience [5]. The use of virtual reality (VR) for clinical apps started in the early 1990s and has become more widespread with the availability of inexpensive computing power.

Significance

Surgical errors can be reduced through the effective use of VR [6]. The ability to properly visualize complex spatial anatomy can potentially reduce operating room time and ensure better surgical outcomes. Planning the placement of surgical cannulae, incision length and position, placement of baffle, sizing the conduit, placement of a surgical patch, and choosing between a minimally invasive procedure versus an open procedure are all patient specific. Interactive VR visualizations of patient anatomy can benefit case planning and better inform patients to alleviate anxiety and provide consent for the procedure. The same VR model can also be used to train fellows, residents, and medical students [4,5,7,8]. Previously published literature has shown that trainees using VR simulators complete their surgical curriculum faster [4]. High-fidelity three-dimensional models are generally available for interactive visualization. However, there is a paucity of formal usability research on VR apps themselves for case planning purposes.

Study Goals

We designed and implemented a study plan to compare VR software for use in presurgical case planning with cardiovascular surgeons. First, we identified gaps in current case planning approaches for elective cardiac procedures. Second, we evaluated the usability and utility of 2 commercially available VR interfaces for surgical case planning purposes. Finally, we explored how medical librarians and informaticians can play a role in graduate medical education and clinical information management.

Methods

Study Design and Setting

Through a mixed-methods qualitative study, we evaluated 2 commercially available VR apps: Bosc version 4.5 (Pyrus Medical systems) and Medical Holodeck version 2.0 (Nooon Web & IT GmbH). Semistructured individual ethnographic interviews were conducted before and after the usability study to understand the context of our findings. We employed a concurrent think-aloud protocol for the usability study, conducted in the University of Washington (UW) Health Sciences Library [9]. Surgeons, fellows, and residents were invited to participate in our study. The UW institutional review board approved the study.

Our usability study was an effort to help medical libraries to create their own VR and augmented reality services to help clinicians plan surgical cases and train residents and fellows. We collaborated closely with faculty and researchers affiliated with the UW Center for Cardiovascular Innovation (CCVI) laboratory. Through them, we were able to generate sufficient interest in the cardiology and cardiothoracic surgery departments at our institution, UW Medicine. The feedback we received from designing and implementing an innovation lab in a library space for VR app testing informed our usability study.

The VR usability testing was conducted in the UW Health Sciences Library's Translational Research and Information Lab (TRAIL). The room and testing set up included the Textbox 1.

Participant Selection

Recruiting volunteers to test VR was accomplished by posting an email to the resident listserv and departmental listserv at UW Medicine. Volunteers were invited to participate via email in a 1-hour usability session in TRAIL. Our recruitment window was open for 1.5 months (May to mid-June 2018), with 8 physicians taking part in the study. Our exclusion criteria included a history of epilepsy or motion sickness exacerbated by exposure to virtual environments. However, none of our respondents fit the exclusion criteria.

Textbox 1. The room and testing set up.

- HTC Vive virtual reality (VR) headset and controllers
- VR-capable gaming laptop (MSI GT73VR Titan Pro laptop, Intel i7, 16 GB RAM, 1 TB hard disc drive, 128 GB solid-state drive, NVIDIA GeForce GTX 1080)
- 14 ft × 12 ft dedicated standing VR play area
- Six-screen ultra-high-definition data wall
- High-speed Wi-Fi connection to stream content, as required

Study Protocol

After taking informed consent, the study team invited the participant to fill out a prestudy questionnaire in TRAIL to build out a user profile about activities related to case planning and issues faced during case presentations. The prestudy questionnaire included questions such as:

- Have you played computer games or participated in virtual simulations before? If yes, how many times in the past 2 years?
- Have you modified your surgical plan after you started operating on a patient recently? If yes, why?
- Could this information have surfaced during a case presentation?
- What do you want Virtual Reality to do for you?
- What are some other gaps you see during case presentations?

A habituation session (5 min) was conducted to familiarize the user with the VR interface around how to use the trackpad, navigate the play area, and ask for help if necessary. The goal of habituation was not to test the discoverability of a feature. It was to see how users combine basic interactions to achieve the endpoint of a scenario. A medical librarian observed the session to understand how to incorporate information into VR experiences in the future. Once the user was habituated, a 30-min usability study was conducted, with the time evenly split between first Bosc and then Medical Holodeck. A visual representation of our study protocol is provided in Figure 1.

User scenarios were sketched out keeping in mind all user tasks that need to be performed to complete the scenario. We had the following scenario for Bosc:

> Scenario: You were given the CT scan of this patient with a lung tumor. Replicate this image and annotate the mass saying “Tumor.”
>
> Hint: The patient image is on the last one on the lower right. Notice the density and opacity settings.

For a screenshot of the Bosc interface please refer to Figure 2.

The tasks to accomplish the endpoint of this scenario were selecting an image, selecting the square tool, moving the sliders into optimal position, and selecting the annotation tool and marking the tumor.

The following was the scenario with 2 different endpoints for Medical Holodeck:

> Endpoint 1: Two cut planes
>
> Scenario: You are trying to visualize different structures in the chest cavity using the volumetric images provided to you by the radiology department. Can you replicate the following images?

The tasks to accomplish Endpoint 1 of this scenario were selecting the heart model, rotating the heart model, finding and using 1 cut plane, removing cut plane and using 2 cut planes.

> Endpoint 2: Visualizing structures
>
> Hint: Use −400 to −600 on the outermost filter ring and turn the rest off.

The tasks to accomplish Endpoint 2 of this scenario were: selecting the lung model, turning on and off ring filters, and adjusting the resolution on the outermost ring filter and turning off other filters.

For a screenshot of the Medical Holodeck interface please refer to Figure 3.

An observer noted verbal user feedback and task completion times. After each interface was tested, a questionnaire was administered to evaluate user satisfaction via 2 standardized tools: the system usability scale (SUS) and the National Aeronautics and Space Administration-Task Load Index (NASA-TLX). The questionnaires took approximately 10 min to complete. At the end of the study, users filled out a poststudy questionnaire, which included the following questions:

- Can VR make your case presentations easier? (Yes/No/Unsure) Why?
- What did you like about your experience?
- What did you think was missing?
- How would you prefer to use VR for case presentation? Single person mode (where you operate and present) or Presenter operator mode (where you present, and a colleague operates the VR)? Why?
- What else do you think VR can do for you?

The whole session lasted for 1 hour. Participants had the option to opt out of answering any question and the ability to opt out of testing at any time.

Figure 1. Study protocol. SUS: system usability scale; TLX: Task Load Index.

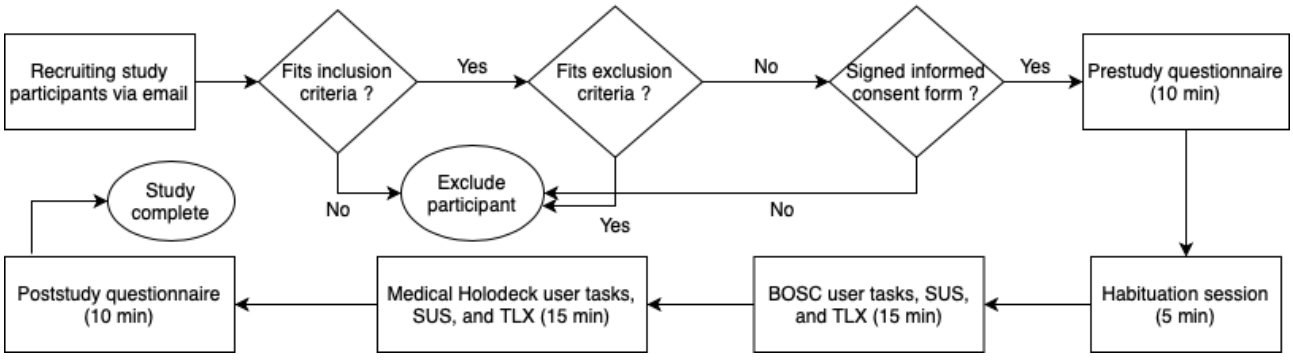


Figure 2. User interface of the BOSC.

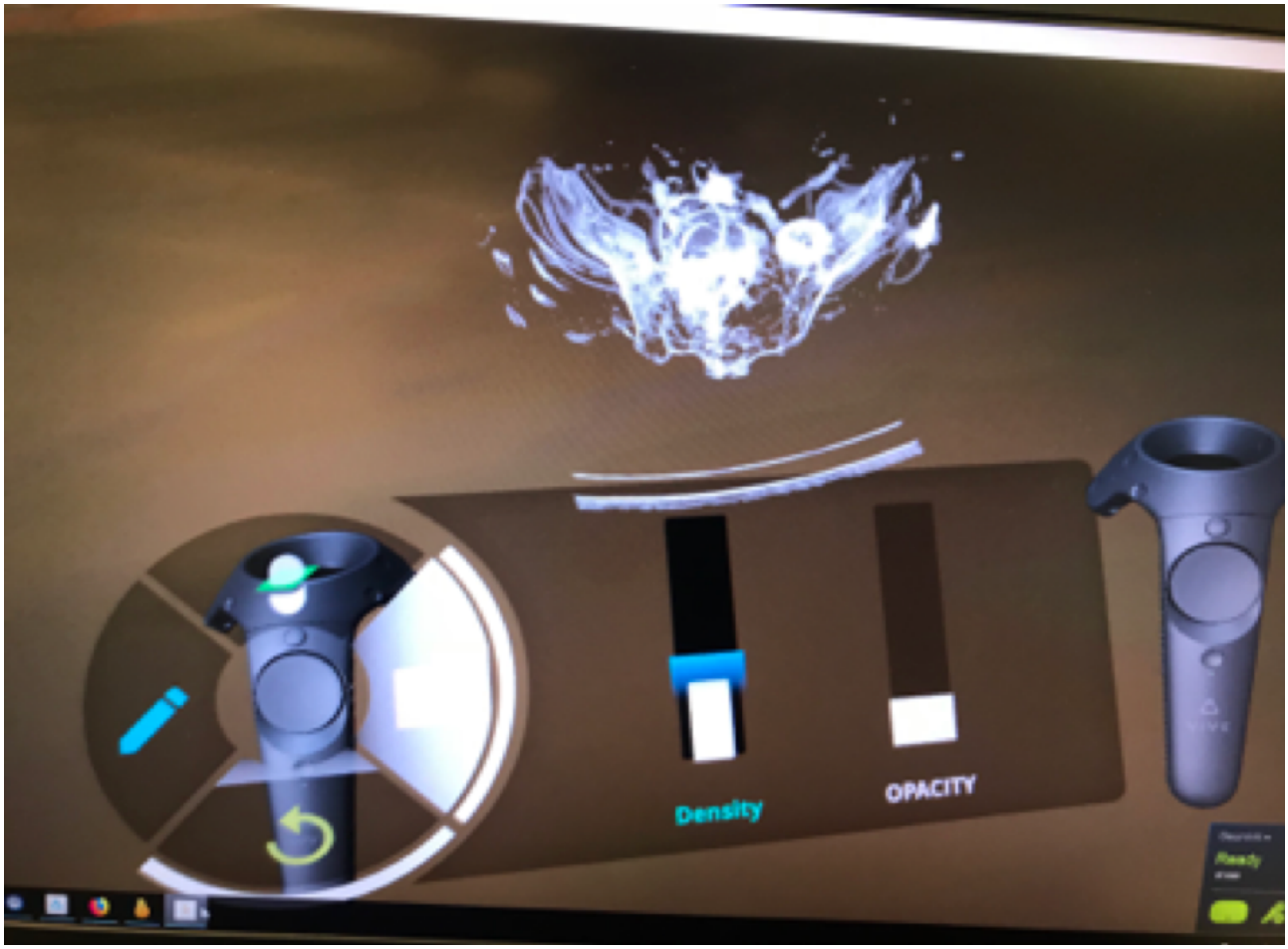
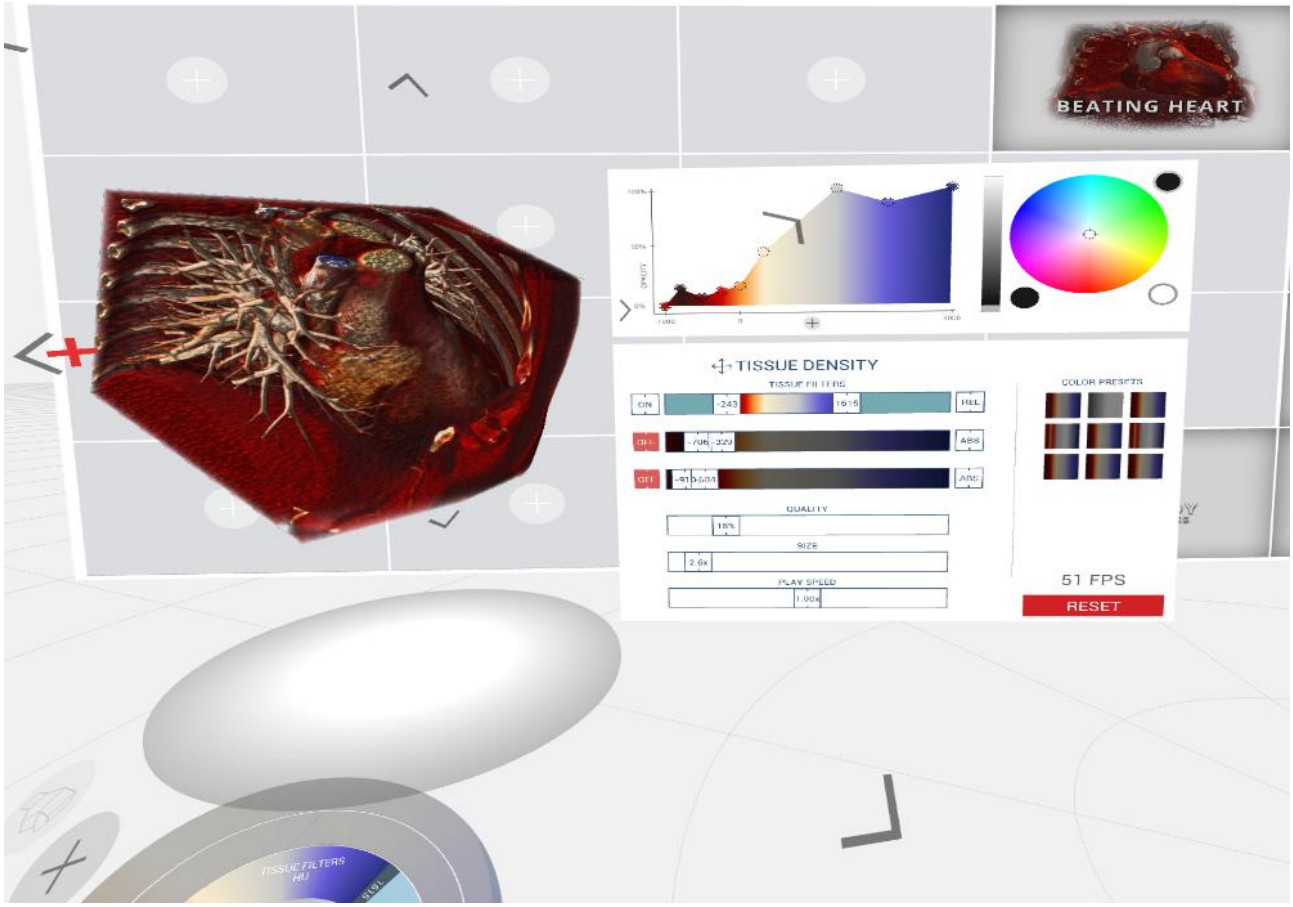


Figure 3. User interface of the Medical Holodeck.



Outcome Measures

We were interested in the usability and the utility of the VR apps and the role medical libraries could play to ease adoption of VR in clinical settings. Through prestudy questionnaires we identified gaps in current case planning approaches for elective cardiac procedures.

Through a poststudy questionnaire and a semistructured interview we explored the role of medical librarians and informaticians in graduate medical education and clinical information management.

Analysis Approach

We presented participant characteristics and the 3 dimensions of usability (effectiveness measured by completion rate, efficiency measured by task completion time, and satisfaction measured by SUS and NASA-TLX). We also presented a qualitative analysis of responses to our prestudy and poststudy questionnaires, addressing the 3 aims of our study. Content analysis was performed on the ethnographic interviews. In addition, 2 of the investigators (SN and MM) reviewed notes and video recordings to identify key phrases. Both investigators performed this task independently and then met to agree upon the categories of feedback. Quotes were extracted to ensure accuracy. Task completion rate is defined as the proportion of users completing the task without assistance from the moderator. Task completion time is defined as the time it took in seconds for a certain task to be completed. Task completion parameters were defined, and the moderator confirmed user comprehension, before the participants started a task. Qualitative data were managed using Microsoft Excel (Microsoft Corporation). Quantitative data were managed using a Web-based app called Plotly (Plotly Technologies Inc, Montreal).

Results

Study Participant Characteristics

We reached out to approximately 60 faculty, fellows, and residents of whom 11 responded (11/60, 18%). We were able to schedule 8 users in our recruitment window. There were 63% (5/8) male participants and 38% (3/8) female participants. Our user sample had 6 faculty, 1 resident, and 1 fellow. We had a varied range of ages (29-69 years) and clinical experience (3-25 years) in our user group. On an average, 5 cases were presented per week per user (Table 1).

Table 1. Characteristics of study participants (n=8).

Characteristics of participants (surgeons)	Statistics
Physician training level, n (%)	
Resident postgraduate year 1-4	1 (13)
Fellow	1 (13)
Physician	6 (75)
Gender, n (%)	
Female	3 (38)
Male	5 (63)
Age in years	
Mean age, (SD)	41.5 (11.67)
Median age, (min-max)	39.5 (29-69)
Clinical experience in years	
Mean clinical experience, (SD)	13 (9.82)
Median clinical experience, (min-max)	11.5 (3-35)
VR[a] technology comfort level or exposure (past experience with three-dimensional computer games or VR simulations), n (%)	4 (50)
Case conference presentation frequency	5 cases/week

[a]VR: virtual reality.

Usability Test

Effectiveness is a dimension of usability that can be measured using task completion rate, and efficiency is measured using task completion time. Certain subtasks such as selecting an image (a model), selecting a tool, marking a tumor, and using cut planes had 100% task completion rate and a short task completion time. Moving slider elements to an optimal position and selecting the annotation tool in Bosc had the worst task completion rate (0%) and the highest mean task completion time (154.57 seconds and 133.5 seconds, respectively). The same pattern was observed in Medical Holodeck. The subtasks with the worst completion times (25%) were specific to the app (eg, removal of cut planes and turning filters on and off) and had the longest mean completion times (42.88 seconds and 86.13 seconds, respectively). Another task that had a poor completion rate (50%) was the adjustment of filters to a certain window, which also had a long mean task completion time of 60.75 seconds (Table 2; Figures 4 and 5).

User Satisfaction

We used the TLX to measure cognitive burden and the SUS to measure usability of each app. These are considered good measures of user satisfaction [10-12]. Subjective workload depended on the frustration the user faced with each app. In detail, there were 3 elements of the scale that contributed to most workload among users. “Frustration” was the most common (“How insecure, discouraged, irritated, stressed, and annoyed were you?”), followed by “Performance” (“How successful were you in accomplishing what you were asked to do?”), “Temporal demand” (“How hurried or rushed was the pace of the task?”), and “Mental demand” (“How mentally demanding was the task?”). No users found the apps physically demanding, as evident in the low weights it received (Table 3).

Bosc had a higher cognitive burden mean TLX score (62.71 vs 40.87) and a lower mean SUS score (37.19 vs 66.25). However, neither app passed the mean SUS score of 68 for an app to be usable [10]. Medical Holodeck was found usable by 3 users, whereas Bosc was rated usable by a single user (Table 4).

Table 2. Task completion times and task completion rate.

Task	Mean (SD), in seconds	Unassisted completion rate, %
Bosc		
Selecting the image	4 (1.12)	100
Selecting the square tool	6.36 (3.84)	100
Moving sliders to optimal position	154.57 (46.89)[a]	0
Selecting the annotation tool	133.5 (55.10)[a]	0
Marking the tumor	17.5 (17.14)	88
Medical Holodeck		
Selecting the heart	8.13 (8.33)	75
Rotate the model using touch	15.83 (9.32)	96
Find and use 1 cut plane	23.13 (17.31)	75
Remove cut plane	42.88 (22.91)	25
Using 2 cut planes	22.5 (11.73)	100
Turn on and off ring filters	86.13 (45.74)	25
Adjust resolution to 400-600 on the outermost ring filter and turn off other ring filters	60.75 (54.38)	50

[a]Completed with assistance.

Figure 4. Task completion times for BOSC.

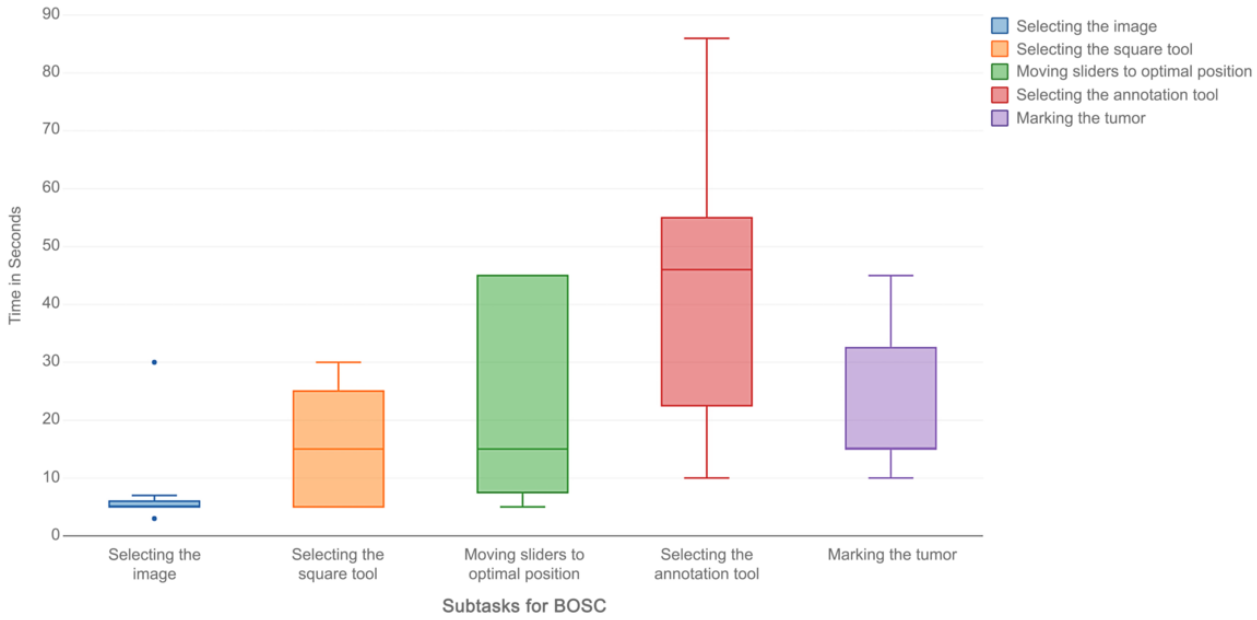


Figure 5. Task completion times for Medical Holodeck.

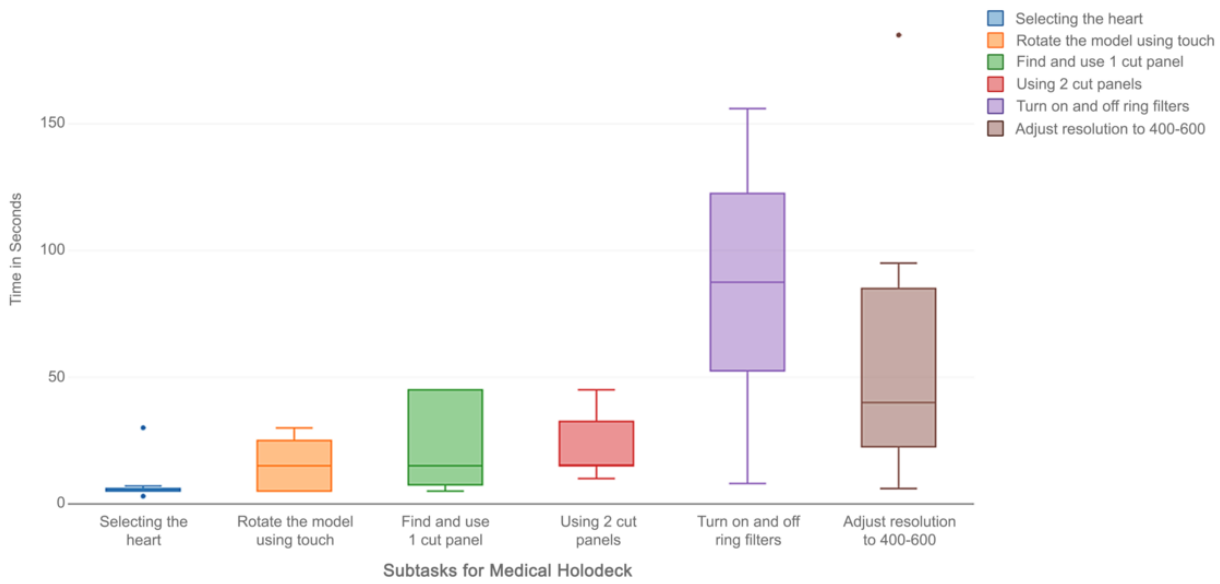


Table 3. Weighted dimensions of the National Aeronautics and Space Administration-Task Load Index (NASA-TLX).

User	Mental demand	Physical demand	Temporal demand	Performance	Effort	Frustration
User 1	2	0	1	4	3	5
User 2	3	1	4	5	2	0
User 3	2	0	4	4	1	4
User 4	4	0	1	2	3	5
User 5	5	1	2	4	3	0
User 6	4	1	4	0	2	4
User 7	4	1	1	1	3	5
User 8	2	0	5	3	2	3
Mean	3.25	0.5	2.75	2.875	2.375	3.25

Table 4. Results from the system usability scale (SUS).

SUS[a] (out of 100)	Bosc	Medical Holodeck
Score, mean (SD)	37.19 (22.41)	66.25 (12.87)
Users who rated the app usable (SUS >67), n (%)	1 (13)	3 (38)

[a]SUS: system usability scale.

Usability Problem Breakdown

Sliders were considered well-known interface elements because all of our users use mobile devices and were familiar with the slider interface to change a setting. Using a cut plane or ring filter, for example, had no parallels in everyday user interfaces so we considered them less commonly known. Frequency represents the fraction of the number of users who faced a certain usability problem over all users (n=8) (Table 5).

Ethnographic Interviews

The most commonly voiced issues in case presentation were inaccurate or unclear communication of patient anatomy (3/8, 38%), difficulties in teaching (2/8, 25%), and varying image interpretations (2/8, 25%) (Table 6). Intraoperative findings or anatomical considerations were the most common reason to modify surgical plans (4/8, 50%). Users were unclear about the perceived impact of surgical plan modification (3/8, 38%) and were not sure if the information that led to these modifications could have surfaced during case planning (7/8, 88%). The most commonly perceived gap in case presentation was communicating anatomical details (50%). The most desired benefits from implementing VR were improving imaging of complex cases (3/8, 38%), improving communication (2/8, 25%), and the ability to afford better planning (2/8, 25%) were both high on the list.

Our poststudy questionnaire explored the utility of VR and how librarians could play a role in curating and collaborating around VR. Users liked learning about VR (5/8, 63%) and knowing what is new out there (3/8, 38%). Some users found it difficult to understand the clinical context of VR apps (3/8, 38%) and whether they gave us useful information (2/8, 25%). Most users wanted a single operator-presenter system (4/8, 50%) instead of a dual separate operator and presenter setup. There was overwhelming emphasis on using VR for training (7/8, 88%) and patient education (4/8, 25%). The role of librarians, as our user group suggested, should be around providing a teaching resource via a repository of VR images collected by clinicians (3/8, 38%), providing space, apps, and equipment (3/8, 38%). However, most users were unsure (4/8, 25%) about the role librarians can play in clinical information management.

Table 5. Analysis of usability problems.

Usability problem type	Description	Frequency	Severity[a]
Bosc			
Using a well-known interface element in a virtual environment	Selecting and moving sliders to desired position	7/8	Medium
Using a well-known interface element in a virtual environment	Using the annotation tool	7/8	Medium
Software errors	Delayed slider movements	1/8	Low
Slider sensitivity	Higher sensitivity requires users to be cautious	3/8	Medium
Medical Holodeck			
Using a well-known interface element in a virtual environment	Rotating the heart model	3/8	Low
Using a less commonly known interface element	Creating and removing cut planes	6/8	Medium
Using a less commonly known interface element	Turning ring filters on and off	6/8	Medium
Using a less commonly known interface element	Adjusting ring filter resolution to specification	6/8	Medium

[a]Severity scale: low: task was delayed; workaround unnecessary; medium: task was delayed, workaround was necessary, or moderator helped the user; high: task was delayed or left incomplete, user couldn't complete the task even with moderator's assistance.

Table 6. Results of the ethnographic interviews (n=8).

Characteristic	Statistics, n (%)
Issues in case presentation	
Inaccurate or unclear communication of patient anatomy	3 (38)
Teaching difficulties for new learners	2 (25)
Varying image interpretations	2 (25)
Conveying the acuity of the clinical situation	1 (13)
Ease of bringing up relevant imaging in clinic or operating room	1 (13)
Not knowing what anatomy will look like in real time	1 (13)
Special training and software requirement for assessing MRI[a]	1 (13)
Limited applicability of some technologies	1 (13)
Reason to modify surgical plans	
Anatomy or intraoperative findings	4 (50)
Imaging inputs or new information from old surgical records	1 (13)
Need to be innovative	1 (13)
Perceived impact of surgical plan modification	
Unclear	3 (38)
Increased operating room time	3 (38)
Greater morbidity	1 (13)
Anticipated improved outcome	1 (13)
Could this information have surfaced during case planning?	
Maybe	7 (88)
Yes	1 (13)
No	0 (0)
Gaps during case presentation	
Communicating anatomical details	4 (50)
Case presenters unaware of priorities	1 (13)
Lack of retrievable mental imagery	1 (13)
Imaging limitations	1 (13)
Equipment readiness and reliability	1 (13)
Lack of clear problem statement and next steps	1 (13)
Potential apps for VR[b]	
Improve imaging of complex cases	3 (38)
Improve communication	2 (25)
Better planning	2 (25)
Dynamic and accurate measurements of anatomy	1 (13)
Display anatomy of complex cardiac repairs	1 (13)
Educate patients on complex cases	1 (13)
Things liked about the VR experience	
Learning about new technology	5 (63)
Knowing what is new out there	3 (38)
Interesting interface	1 (13)
Interesting anatomical models	1 (13)

Characteristic	Statistics, n (%)
Clear instructions and specific tasks	1 (13)
Interactive learning as you go	1 (13)
Relaxed atmosphere	1 (13)
Things missing in the VR experience	
Clinical context or applicability to respondent's scope of practice	3 (38)
Unsure if investigators were provided with useful information	2 (25)
Benefit of VR over current systems	2 (25)
Lack of understanding of controller setup before starting task	1 (13)
Nothing	1 (13)
Preferences for VR interface control	
Single person mode	4 (50)
Both	2 (25)
Only as an adjunct	1 (13)
No answer	1 (13)
Alternative apps of VR	
Trainee education	7 (88)
Patient education	2 (25)
Plan for appropriate devices necessary for treatment	1 (13)
Warm up or practice	1 (13)
Team communications	1 (13)
Role of librarians in graduate medical education	
Teaching resource via repository of VR images collected	3 (38)
Provide space, apps, and equipment	3 (38)
Serve as part of the team	1 (13)
Inform and educate the community	1 (13)
Train on VR environment	1 (13)
Invest in VR	1 (13)
Role of library in graduate medical education	
Unsure	3 (38)
Increase access to case materials for presentations	2 (25)
Find more apps	1 (13)
Provide strategies for research into clinical topics	1 (13)

[a]MRI: magnetic resonance imaging.

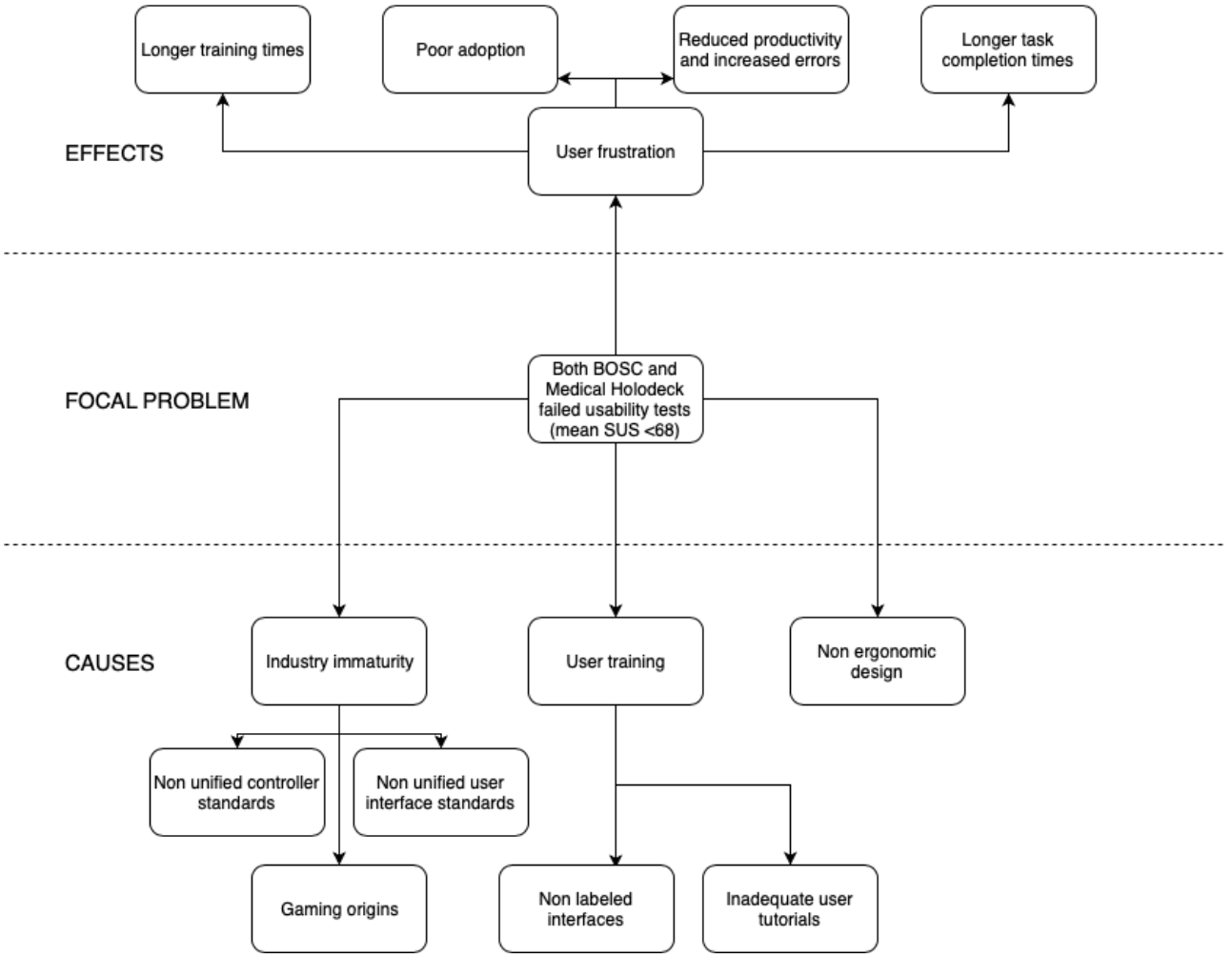
[b]VR: virtual reality.

Discussion

Principal Findings

In a usability study with 8 surgeons, resident physicians, and fellows at the UW, each user spent 60 min testing 2 VR apps—Bosc and Medical Holodeck. Users reported a general sense of frustration using the apps, but were appreciative of the role VR could play in case planning. Subtasks such as selecting a tool, marking a tumor, and using cut planes had high task completion rates, short task completion times, and less variation among users. This is likely because of these interactions being borrowed from daily life apps. When users were unaware of how to use a feature or when the interaction was app specific with no parallels to real-life apps, we observed poor task completion rates, higher inter-user variations, and long task completion times (Figure 6). Some users found the gesture-based controls confusing. User comments that demonstrate the frustration with these controls are quoted verbatim in Textbox 2.

Figure 6. Problem tree analysis. SUS: system usability scale.



Textbox 2. User comments that demonstrate the frustration with the controls.

- "Draw. That should be obvious. *tries to draw* But it's not actually doing what it says."
- "The direction in scrolling doesn't always match where the slider is going."
- "I'm trying to figure out how to move between the bars. I haven't figured out how you control it."
- "Did you guys do that or did I? I didn't do anything, and it moved. Is somebody else doing something?"
- "It's moving both. I can't control one without the other."

The same pattern was observed with Medical Holodeck. However, unlike Bosc, the model selection interaction was not understood by all users. The subtasks with the worst completion times were specific to the app with no parallels to interactions users have in daily life, such as removal of cut planes and turning on and off the filters. These also had the longest completion times. Frustrations with the app are quoted verbatim in Textbox 3.

The app also required the user to hold his or her hands above waist level to continue visualizing the image, frustrating 1 user who said:

> *I can't really drop my hands to my sides. That would be nice to be able to stand here looking at model [without having to hold up my hands].*

Sensitivity of the controls and a slight lag in the user interaction was an issue identified by multiple users as shown in Textbox 4.

The user comments for Medical Holodeck were similar and are provided in Textbox 5.

The apps were not considered physically demanding by any users, as evident in the low weights it received.

User Satisfaction

In general, users found Medical Holodeck easier to use (Textbox 6).

Users appreciated Bosc as well, but commented on its limitations (Textbox 7).

Textbox 3. Frustrations with the app.

- "It's hard to tell in the visualization where I'm clicking."
- "If I click it just creates more planes."
- "It's very clunky."

Textbox 4. Sensitivity of the controls and a slight lag in the user interaction.

- "You just touch it and it switches [from opacity to density or vice versa]."
- "There's a lag."
- "I don't understand why it's moving at this point."
- "Maybe I just have to push longer harder? I feel like I should just have to push on the trackpad, but it isn't working."
- "Very confusing. It was tough to figure out what the buttons did. It seemed like I could never figure out what I was doing while it was happening."
- "That's less than ideal."

Textbox 5. User comments for Medical Holodeck.

- "Now I'm getting a little frustrated."
- "I have the panel but I'm not sure how to change it."
- "This is where I would expect the function on the left to stay lit up."

Textbox 6. User satisfaction comments on Medical Holodeck.

- "It's good that it has labels, even if they don't do what they say."
- "I like the second app [Medical Holodeck]. I like the labeling that shows you what does what."
- "It was easier to figure out what to do. The only thing was the laser; I wasn't sure how far you have to be [to have it 'catch']."
- "It seemed crisper and a better viewing experience."
- "It seemed more straightforward. It was clearer in terms of what each button does. It seemed more responsive."
- "You didn't have the sense that the pointer had as much power until [the moderator] told me it was what you had to use. Once you understand that it is easy to use."

Textbox 7. User satisfaction comments on Bosc.

- "I thought the app was pretty good, I just thought the scroll pad was awkward."
- "It would be good if there were labels to say what things did."

Textbox 8. Overall user impressions: positives.

- "Once I got a sense of what you wanted me to do, and you're not used to toys, it's a left-brain, right-brain thing where you're trying to do two things at once."
- "I conveniently see instructions [labels], which is a step in the right direction."

Textbox 9. Overall user impressions: negatives.

- "The question is what can it do that I can't do on my desktop?"
- "I'm not sold personally on this use of VR. That's my own personal bias."
- "It's all about picking the right audience."
- "From a practical point we'd really like to see where the blood vessels are."

We observed that TLX and the SUS provide user satisfaction information in different dimensions, and that a mixture of metrics in the context of user interviews provides us better insights into user perception of these apps. For example, 1 user rated both apps similarly in the SUS. However, on comparing the frustration score in the TLX, we were able to uncover which specific interaction was the most challenging, which we could clarify in the poststudy interview. This approach would be of benefit to interaction designers for VR apps. One user said:

> *There's no uniform approach to the button [in the HTC Vive]. Every time you go into a program you need to figure out what the buttons do.*

Building a standardized user interface for VR requires time, just as the decade that smartphone interactions took to reach maturity.

Questionnaire Analysis

Our prestudy questionnaire revealed interesting insights. The importance of precise anatomical visualization in presurgical planning and teaching is underscored by the fact that the most common issue in case presentation is not knowing how the patient anatomy will look like during the procedure. Similarly, intraoperative anatomical considerations were the most common reason to modify a surgical plan.

Our initial assumption was that users would prefer a 2-person mode of VR operation, where a surgeon presented the case and an operator (a fellow or resident) would navigate the VR system. However, most users wanted a single operator-presenter system. Considering the overwhelming emphasis on using VR for training and patient education and the relative immaturity of currently available VR apps, these are more viable apps than case planning for VR. As most users were unsure (3/8, 38%) about the role librarians can play in clinical information management, the librarians must make an active effort to communicate the value they bring to the table in curating clinical content and promoting interdisciplinary collaborations. One user suggested:

> *All surgeons require a retrievable system on which to think. Build a set of imagery they can recall. If you are training a team, you have to build that collection of images.*

Overall User Impressions

Although surgeons and resident physicians experienced individual challenges in using the 2 VR apps tested, the overall impression was positive (Textbox 8).

Working at an academic institution and teaching hospital, incorporating VR into ongoing and future teaching methods was of high interest to our faculty. Said 1 user:

> *We do not teach three-dimensional topics well. Almost all of our imagery is in 2 dimensions. Three dimensions make complexity better.*

Not all users were excited about the prospects for VR, feeling that the apps were irrelevant or the immersiveness distracting (Textbox 9).

Our study results suggest that VR can be a useful adjunct in traditional presurgical planning methods, an observation also echoed by other studies in this domain which highlight the potential for group-based approaches, user-defined interactive views, and cost-effectiveness over 3D printing [13,14].

Limitations

There are several limitations to the study. First, the study participants were self-selecting. A total of 37.5% of our participants had been exposed to immersive VR since they also worked with the CCVI. This may not be representative in other similar departments. Second, we only evaluated VR apps available to us. There are many other apps that are designed for specific purposes that we were unable to test. However, we have consolidated feedback to acknowledge user-friendly features of each app that serves as a benchmark to evaluate other such apps. Third, we had used existing VR models in these apps to avoid using actual patient data. Users, therefore, questioned the utility of these apps while identifying possible future research directions. Fourth, generating stereolithography models for VR apps requires high-resolution CT images, which we find difficult to acquire at our institution for most patients. This may impact future studies conducted at our institution. Finally, it is also possible that Medical Holodeck received higher usability ratings because it was the second app users tried. Multiple users indicated that they struggled or were frustrated earlier on in the testing but found it easier as they grew more accustomed and experienced to VR and the controllers, which coincides with their testing in Medical Holodeck. To preserve uniformity, however, we did not randomize which app the user tried first. In addition, we did not have enough users to draw statistically significant conclusions, even if we had randomized the order.

Conclusions

We evaluated the usability and utility of 2 commercially available VR apps (Bosc and Medical Holodeck) for cardiothoracic case planning. We found that, on an average, neither app passes the minimum mean usability score of 68 on the SUS. Although users found Medical Holodeck less cognitively demanding (mean TLX score of 40.87 vs 62.71), more work is needed to make both apps usable. We also identified ways to make VR apps more useful in the clinical setting and for teaching. As we explore new apps, the role of medical librarians in curating VR content and promoting collaboration is evolving. Our hope is that medical libraries around the world benefit from our work and develop VR studios of their own for clinical apps.

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Conflicts of Interest

None declared.

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Abbreviations

CCVI: Center for Cardiovascular Innovation
CT: computerized tomography
NASA-TLX: National Aeronautics and Space Administration-Task Load Index
NIH: National Institutes of Health
SUS: system usability scale
TRAIL: Translational Research and Information Lab
UW: University of Washington
VR: virtual reality

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Original Paper

High-Fidelity Prototyping for Mobile Electronic Data Collection Forms Through Design and User Evaluation

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Abstract

Background: Mobile data collection systems are often difficult to use for nontechnical or novice users. This can be attributed to the fact that developers of such tools do not adequately involve end users in the design and development of product features and functions, which often creates interaction challenges.

Objective: The main objective of this study was to assess the guidelines for form design using high-fidelity prototypes developed based on end-user preferences. We also sought to investigate the association between the results from the System Usability Scale (SUS) and those from the Study Tailored Evaluation Questionnaire (STEQ) after the evaluation. In addition, we sought to recommend some practical guidelines for the implementation of the group testing approach particularly in low-resource settings during mobile form design.

Methods: We developed a Web-based high-fidelity prototype using Axure RP 8. A total of 30 research assistants (RAs) evaluated this prototype in March 2018 by completing the given tasks during 1 common session. An STEQ comprising 13 affirmative statements and the commonly used and validated SUS were administered to evaluate the usability and user experience after interaction with the prototype. The STEQ evaluation was summarized using frequencies in an Excel sheet while the SUS scores were calculated based on whether the statement was positive (user selection minus 1) or negative (5 minus user selection). These were summed up and the score contributions multiplied by 2.5 to give the overall form usability from each participant.

Results: Of the RAs, 80% (24/30) appreciated the form progress indication, found the form navigation easy, and were satisfied with the error messages. The results gave a SUS average score of 70.4 (SD 11.7), which is above the recommended average SUS score of 68, meaning that the usability of the prototype was above average. The scores from the STEQ, on the other hand, indicated a 70% (21/30) level of agreement with the affirmative evaluation statements. The results from the 2 instruments indicated a fair level of user satisfaction and a strong positive association as shown by the Pearson correlation value of .623 (P<.01).

Conclusions: A high-fidelity prototype was used to give the users experience with a product they would likely use in their work. Group testing was done because of scarcity of resources such as costs and time involved especially in low-income countries. If embraced, this approach could help assess user needs of the diverse user groups. With proper preparation and the right infrastructure at an affordable cost, usability testing could lead to the development of highly usable forms. The study thus makes recommendations on the practical guidelines for the implementation of the group testing approach particularly in low-resource settings during mobile form design.

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KEYWORDS

high-fidelity prototype; group user testing; mobile electronic data collection forms; usability evaluation

Introduction

Background

Usability implementation in many design scenarios, even in user-centered designs (UCDs), is still unsatisfactory [1]. This leads to unusable interfaces especially for nontechnical users [2], and such interfaces contribute to the failure of most interactive systems [3]. Of the reasons for this failure, 1 is that developers of open-source software (OSS) such as the mobile electronic data collection forms (MEDCFs) are not prioritizing the use of the UCD approach in their software development projects. They instead develop software targeting particular features [4]. This approach often leaves out the end users in the design and evaluation of these systems, whose major role is to interact with the finished products. As a result, in low- and middle-income regions, several data collection systems exist, but these are often difficult to deploy, hard to use, complicated to scale, and rarely customizable [5], hence grossly decreasing their usability.

The mobile user interface designs are usually based on the desktop paradigm whose designs do not fully fit the mobile context [6], which in turn breeds usability challenges. Other challenges may also be hardware related, for example mobile phones have limited disk space, memory, processor speed, and battery life, among others. In addition, the mobile networks on which they depend are highly variable in performance and reliability [7]. Furthermore, the limited screen size makes efficient presentation of information and navigation to the users difficult [8,9]. In fact, some of the electronic forms have multiple questions, which may make presentation on the screen quite complicated. In some phones, the display resolution may not favor good presentation of tables and images on the screen. Additionally, the keyboard size or character setting is limited irrespective of the users' finger size [10,11] and the content. This leads to incorrect choice selection and wastage of time in additional scrolling activities, which is also common with smaller interfaces [10,12].

Literature Studies and Justification

Usability is mainly concerned with the exhibited design features of interactive products in relation to how easy the user interface is to use [13], as well as the user satisfaction as a result of such use [14]. Usability is, therefore, defined by characteristics such as the cognitive perception, the ability to interact with the system, and the perception of the response from the system [3], which may vary across individuals. Important to note is that the usability of MEDCFs relies on the capabilities of the software provided by the software developers [15]; however, a number of developers have a limited understanding of usability [1,2] and how it can be implemented. This is because despite the fact that the developers' goal is usability, they tend to follow engineering criteria, which results in products that seem obvious in their functioning for the developers but not for general users, and this often leads to negative results after evaluation [16,17]. Evaluation is one of the primary stages in the UCD and in design science research (DSR), which can be used to improve the quality of any system or prototype during and after its development. Evaluation is essential in conducting rigorous DSR as it provides evidence that a newly created artifact achieves the purpose for which it was designed [18]. However, evaluating usability alone may not be sufficient to improve the quality of the system, without considering the emotions and feelings of the users as they interact with the systems or applications [19]. This brings in the aspect of user experience (UX), which is concerned with getting a more comprehensive understanding of the users' interactive experiences with products or systems [20]. UX includes all the users' emotions, preferences, perceptions, behaviors, and accomplishments that occur before (preinteraction experience), during (actual interaction experience), and after use (postinteraction experience) of the product [19-21].

User testing is one of the usability evaluation methods where the assessment of the usability of a system is determined by observing the users working with that system [22]. Here, a representative number of end users perform a set of tasks using a prototype system, and the usability challenges are presumably identified by user observations during the exercise [23]. Group usability testing, on the other hand, also involves several participants individually but simultaneously performing the given tasks, with one or more testers observing and interacting with the participants [24]. The motivation for testing is based on the assumption that any system that is designed for people to use should be easy to learn and remember, contain the functions that people really need in their work, and also be easy and pleasant to use [25]. Evaluating user design preferences is not a common approach in the development of mobile data collection forms partly because of time and financial constraints. In fact, this is the first study in Uganda where this kind of testing has been conducted, and we do not have knowledge of any such study from the published literature.

Objectives

This study therefore assesses a set of design guidelines using the group testing approach and records the end users' experience after interacting with the high-fidelity prototype. It also recommends some practical ways of implementing group testing during mobile form design, particularly in low-resource settings. To achieve this, a high-fidelity prototype was developed based on the end users' design preferences and evaluated by the research assistants (RAs) for usability and UX after interaction using SUS and STEQ. We report the level of satisfaction and the features from the prototype the RAs are satisfied with.

Methods

Participants

The study participants were 30 RAs, and all of them were collecting data on a maternal and child health project (the Survival Pluss project) in northern Uganda, which is funded by the Norwegian Programme for Capacity Development in Higher

Education and Research for Development (NORHED) [26]. Of the RAs, 3 were certificate holders and 9 were diploma holders, whereas 18 were degree holders in various fields, which included accounting, agriculture, social work, laboratory services, and nursing. Of these, 23 RAs had been collecting data for a period of 2 years or less, whereas 7 had collected data for a period ranging from 4 to 6 years. All the RAs had used open data kit (ODK) [5,27] to collect data; however, 3 reported to have used tangerine, Survey Monkey, and OpenMRS, in addition to ODK [28].

Prototype

A Web-based high-fidelity prototype for MEDCFs was developed between January and February 2018. This prototype was meant to demonstrate the RAs' design preferences having collected them earlier using a mid-fidelity prototype [29,30]. It was also used as a basis for evaluating to what extent these design preferences contribute to the usability of the data collection forms. A high-fidelity prototype is a computer-based interactive representation of the product with a close resemblance to the final design in terms of details and functionality. The high-fidelity prototypes not only test the visuals and aesthetics of a product but also the UX aspects in relation to interaction with the product [31]. The prototype (see Multimedia Appendix 1) was created in Axure RP 8 without any backend functionality and was created to fit on Samsung Galaxy J1 Ace phones that were being used to collect data on the Survival Pluss project, and they had a view port size of 320 by 452.

The prototype had 3 main sections structured based on the project's content. These consisted of the demographic section where participants were required to fill the participant ID, interviewer name, and interviewer telephone number. Section I had list pickers and section II showed different table designs capturing a child's sickness record. We explained to the RAs the potential value of the user testing exercise before giving them access to the prototype and to the tasks they were supposed to do. A summary of the entered data on the child sickness was available for the users to crosscheck and *agree* or *disagree* to its correctness, after which they were prompted to submit. Before submission, the users were warned of the inability to edit the data once they have been submitted. At this point, the progress bar indicated 100%, meaning that the form had been filled to completion and submitted.

Group Testing Exercise

The group testing exercise was conducted in February 2018 in Lira, Uganda. The RAs were required to complete some tasks (Multimedia Appendix 2) during the group testing exercise. This was meant to create uniformity in the prototype evaluation and also to be able to measure the time it took for each of the RAs to complete the same tasks. In addition to carrying out the tasks, they were also meant to read the feedback given as a result of the actions carried out and to respond appropriately until they correctly submitted the form. It was a requirement to complete all the tasks before submission of the form, and the participants were expected to record their start time before and finish time after the testing exercise. A total of 2 observers were present to record the exercise and to attend to the questions when asked to. The start time and end time were recorded for each participant in each session.

Prototype Evaluation

The prototype evaluation happened immediately after the group testing exercise. This was an ex-post naturalistic evaluation because we were evaluating an instantiated artifact in its real environment, that is, with the actual users and in the real setting [18,32]. The artifact was a high-fidelity prototype, and the actual users were the RAs who were collecting data on mobile phones using ODK, an OSS software.

Instruments Used in the Prototype Evaluation

A total of 2 instruments were used to evaluate the prototype usability, one was the SUS, a standardized questionnaire, and the other was STEQ. By combining the two, we expected to gain more detailed insight and also to test our generated questionnaire against the standardized one. These 2 posttest questionnaires were administered after the participants had completed the tasks in a bid to show how users perceived the usability of the data collection forms [33].

The STEQ comprised 13 statements and was developed based on the literature with a purpose of making an alternative instrument, other than the SUS. The statements were based on features such as form progress, simplicity in use, error correction and recovery, and visual appeal, among others. The RAs were required to indicate their level of agreement with the evaluation statements by selecting options, which included *strongly disagree*, *disagree*, *somewhat agree*, *agree*, *strongly agree*, and *don't know* and were tallied to a score of 1, 2, 3, 4, 5, and 6, respectively. The evaluation statements were selected from 4 usability evaluation questionnaires, namely the Computer System Usability Questionnaire [34], Form Usability Scale [35], Questionnaire for User Interaction Satisfaction [36], and statements from the Usability Professional Association [37]. The selected statements were based on the fact that they could be used to assess usability in mobile data collection forms as defined by the design preferences of the RAs and were all affirmative statements with positive valence. It is alleged that participants are less likely to make mistakes by agreeing to negative statements [38] similar to the case of a balanced questionnaire consisting of positive and negative statements [39]. However, and for the sake of simplicity, we used only affirmative statements adopting the style of the 4 abovementioned usability evaluation questionnaires.

The SUS is a balanced questionnaire that is used to evaluate the usability of a system and comprises 10 alternating positive and negative statements [40]. The SUS acted as a complementary scale to the STEQ. The SUS has been experimentally proven to be reliable and valid [33] because of its ability to control against acquiescence bias and extreme response bias [38,39]. In acquiescence bias, respondents tend to agree with all or almost all statements in a questionnaire, whereas the extreme response bias is the tendency to mark the extremes of rating scales, rather than the points near the middle of the scale [38,39]. These biases greatly affect the true measure of an attitude. The word *system* was replaced with the word *form* for some of the statements in both questionnaires.

Table 1. The 13 statements in the tailormade evaluation questionnaire and the number of respondents (n=30) in each category from *strongly disagree* to *strongly agree*.

Evaluation statement	Strongly disagree, n (%)	Disagree, n (%)	Neutral, n (%)	Agree, n (%)	Somewhat agree, n (%)	Don't agree, n (%)	Total (N)[a]
The form informs about its progress during interaction	0 (0)	0 (0)	2 (6)	8 (27)	20 (67)	0 (0)	30
The information, for example, onscreen messages provided in this form were clear	1(3)	0 (0)	3 (11)	4 (14)	18 (64)	2 (7)	28
It was easy to move from one page to another	3 (10)	2 (6)	1 (3)	8 (27)	15 (50)	1 (3)	30
The overall organization of the form is easy to understand	1 (3)	0 (0)	2 (6)	13 (43)	12 (40)	1 (3)	30
I knew at every input what rule I had to stick to (possible answer length, date format, etc)	2 (6)	3 (10)	7 (23)	5 (17)	13 (43)	0 (0)	30
Reading of characters on the form screen is easy	1 (0)	3 (10)	9 (30)	17 (57)	0 (0)	0 (0)	30
The form gave error messages that clearly told me how to fix the problems	3 (10)	1 (3)	1 (3)	2 (6)	21 (70)	2 (6)	30
I was able to fill in the form quickly	2 (6)	4 (13)	3 (10)	8 (27)	13 (43)	1 (3)	30
It was simple to fill this form	1 (3)	1 (3)	5 (17)	10 (33)	13 (43)	0 (0)	30
Whenever I made a mistake when filling the form I could recover easily and quickly	0 (0)	1 (3)	2 (6)	5 (17)	21 (70)	1 (3)	30
This form is visually appealing	0 (0)	2 (6)	6 (20)	10 (33)	10 (33)	2 (6)	30
Overall, the form is easy to use	1 (3)	2 (6)	1 (3)	8 (27)	17 (57)	1 (3)	30
Overall, I am satisfied with this form	0 (0)	0 (0)	7 (21)	8 (27)	14 (41)	1 (3)	30

[a]Some respondents did not reply to all statements.

Results from the 2 instruments were compared. Previous studies have shown that irrespective of the questionnaires used being balanced or affirmative, the scores from the 2 questionnaires are likely to be similar [38]. This is because there is little evidence to show that the advantages of using balanced questionnaires outweigh the disadvantages, some of which include misinterpretation of the scales leading to mistakes by the users [38]. The STEQ was summarized using frequencies in an Excel sheet where the evaluation statement with majority *agreeing* to it was taken as the option which RAs were most satisfied with (Table 1). On the other hand, SUS scores are calculated based on the statement being scored [40], and we did the same in this study. For the positive statements 1, 3, 5, 7, and 9, the score contribution was what the user had selected minus 1. For the negative statements 2, 4, 6, 8, and 10, the score contribution was 5 minus what the user had selected. The total sum of the score contributions was obtained and multiplied by 2.5 [40]. This gave the overall result of the form usability from each participant.

Results

This section presents the results after evaluation of the high-fidelity prototype using the tailor-made evaluation questionnaire and the SUS.

End-User Experience in Relation to System Usability Scale and Study Tailored Evaluation Questionnaire Scores

Of the data RAs, 80% (24/30) *agreed* that the form progress was visible, form navigation and organization were easy, and that the error messages clearly indicated how to fix problems. The same number also *agreed* that the form was simple, that it was quick and easy to recover in case of a mistake, and that overall the form was easy to use. In addition, half of the participants also *agreed* that they knew the rules to stick to when inputting the data and also found reading characters on the form easy.

However, more than 23% (7/30) of the participants *disagreed* to the form being easy to navigate and to the ability to fill the form quickly. Still some of the participants were neutral to some of these evaluation statements, that is, they neither *agreed nor disagreed*. For example, 36% (11/30) of the participants were neutral about easy reading of characters on the screen and 27% (8/30) of the participants were neutral about knowledge of the rules to stick to when inputting data. In addition, 23% (7/30) were neutral about the form being visually appealing and with their satisfaction with the form. We calculated the quantities and the respective percentages of those who *agreed*, *disagreed*, and those who *did not know* or were *neutral* to the evaluation statements during the evaluation exercise (Figure 1). The figure shows that about 70% of the RAs were satisfied with the form prototypes.

The individual SUSs ranged from 50 to 90 (Figure 2), with an average score of 70.4 (SD 11.7). This value was above the recommended average SUS score of 68, which showed that the RAs were fairly satisfied with the usability of the prototype. However, over 20 of the RAs felt that the form was easy to use and would like to use it more frequently, there was proper integration of various functions in the form, and they felt very confident about using the form. The same number of participants did not find the form unnecessarily complex, and neither was there any inconsistency in the form. For some of the statements, the number of participants who were *agreeing* and *disagreeing* was almost equal. For example, 12 felt they would need a technical person to use the form, whereas 16 did not, 12 felt the form was cumbersome to use, 15 felt otherwise, and 18 participants felt they needed to learn a few things first before using the form whereas 15 *disagreed* to that. Finally, 9 of the participants would opt not to use the form more frequently.

We plotted a graph to compare the association between the time it took to complete the form and the SUS scores (Figure 3). The results indicate that the time the participants took to fill the form also varied ranging from 5 to 35 min across the participants, which gave an average of 19 min overall. The direction of the relationship between the SUS score and the time is negative as shown in Figure 3. Results from the bivariate Pearson correlation we conducted indicated that the SUS score and the time taken did not have a statistically significant linear relationship because P=.699 which is greater than .01 for a 2-tailed test.

Comparison of Results From the System Usability Scale and the Study Tailored Evaluation Questionnaire

Using these instruments concurrently turned out to be important because we were able to test for both usability and UX using the 2 instruments. In this study, the SUS is meant to measure usability, whereas the evaluation questionnaire is more detailed and meant to capture more of the UX after including the new design preferences.

Figure 4 indicates a positive relationship between the 2 variables, for example, the participants who were satisfied with the prototype (scored 4 or 5) according to the STEQ had high SUS scores and the ones who were not satisfied (scored 1 or 2) had relatively low SUS scores. The results from the bivariate Pearson correlation indicate that this relationship is significant at the .01 level for a 2-tailed test because the P-value is less than .01. The Pearson correlation value of .62 further signifies a strong association between the SUS score and the STEQ score.

The participants with the lowest SUS scores all found that the form was not simple to fill, easy to use, and were also not satisfied with it as depicted in the STEQ. These results could be attributed to the fact that there was a general comparison between the forms they had been using (ODK) and the high-fidelity prototype. It felt that the prototype was limiting their usage because due to missing functionality they could not freely do what they were used to doing with ODK. In general, the results from these 2 instruments are proof that the 2 evaluation methods or instruments are meant to complement each other and not to compete against each other [41].

Figure 1. The percentage of participants who agreed, disagreed or were neutral to the evaluation statements.

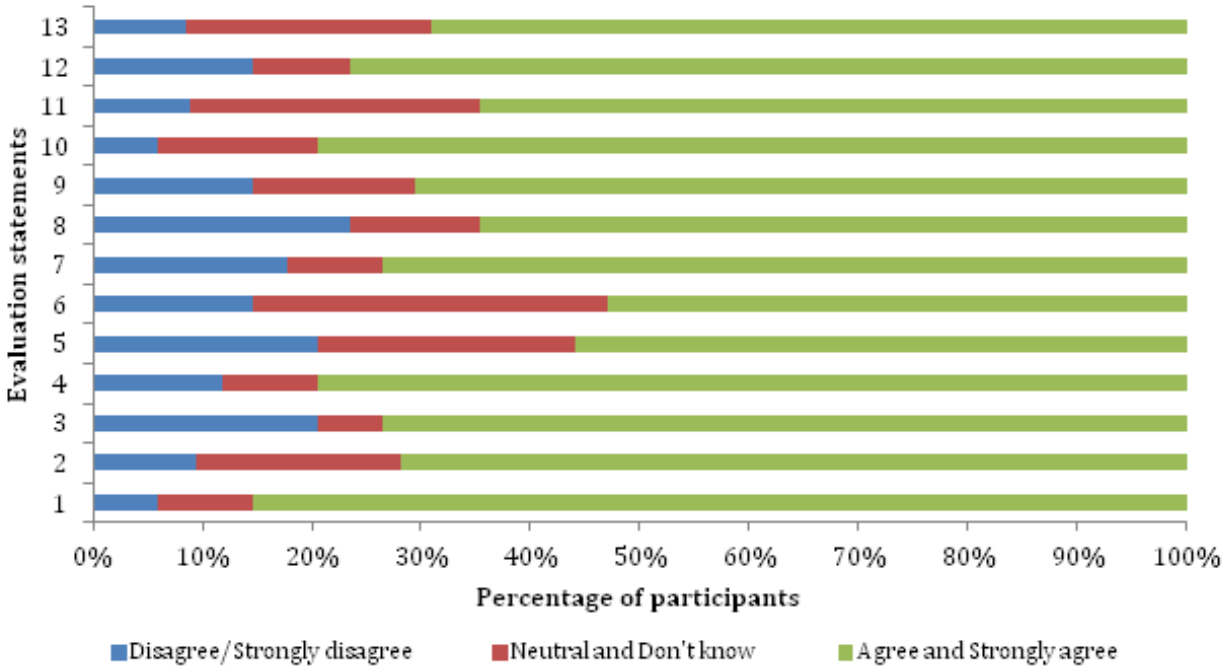


Figure 2. Results from the research assistants' (RAs) evaluation using the System Usability Scale (n=30).

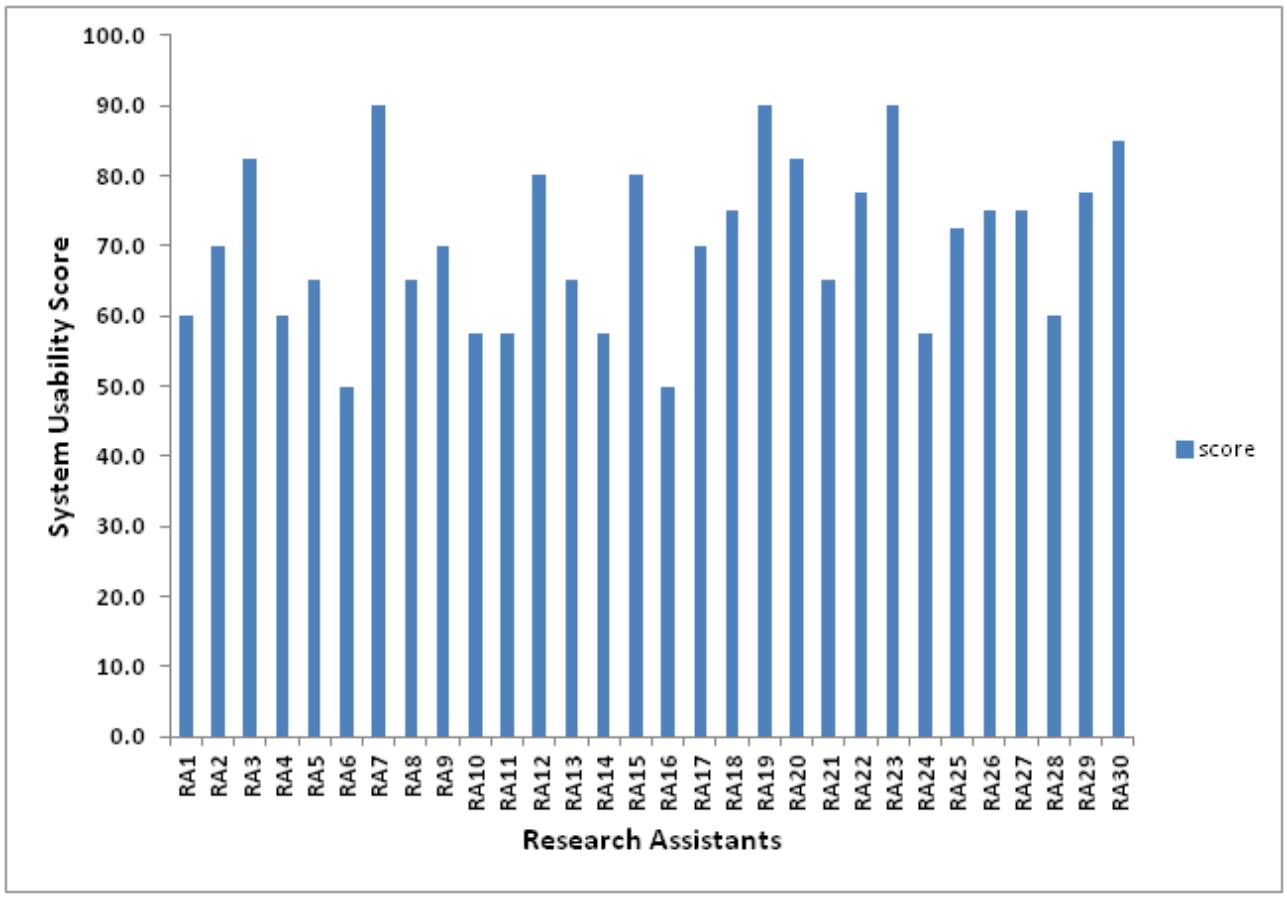


Figure 3. System Usability Scale compared with form completion time (minutes).

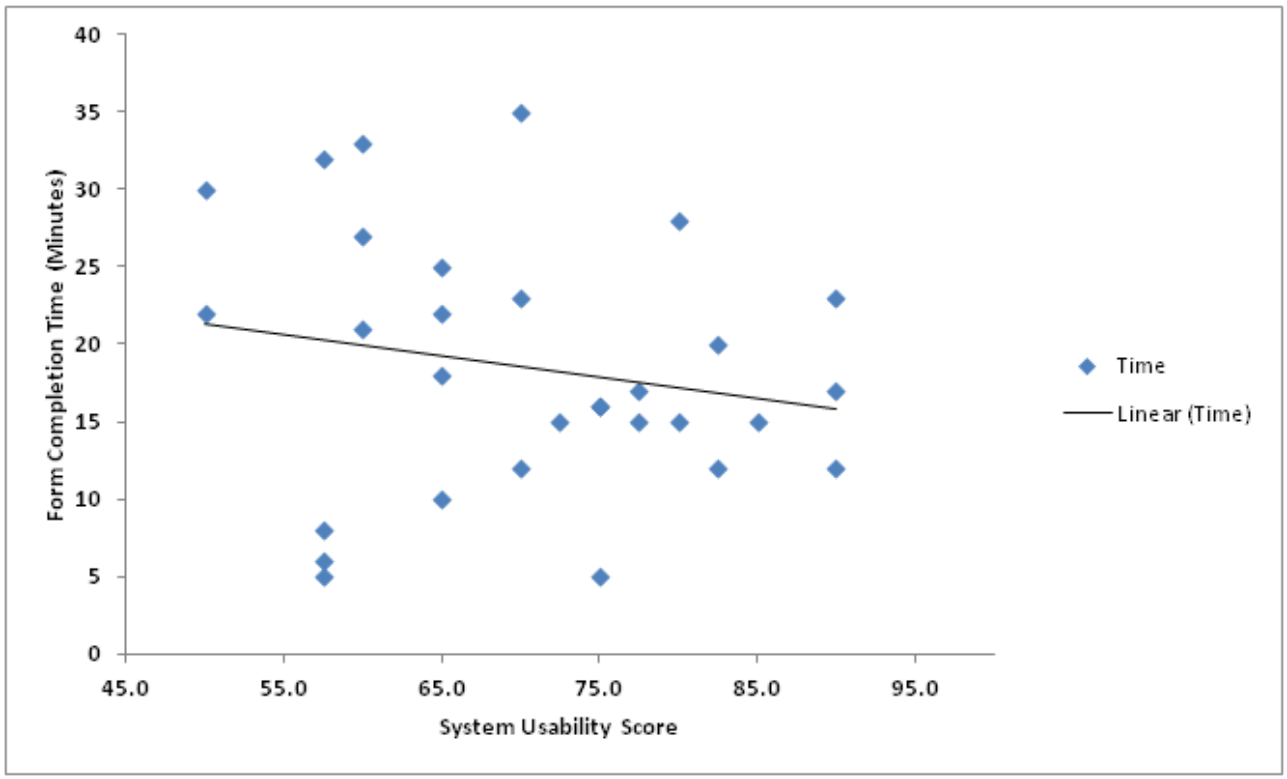
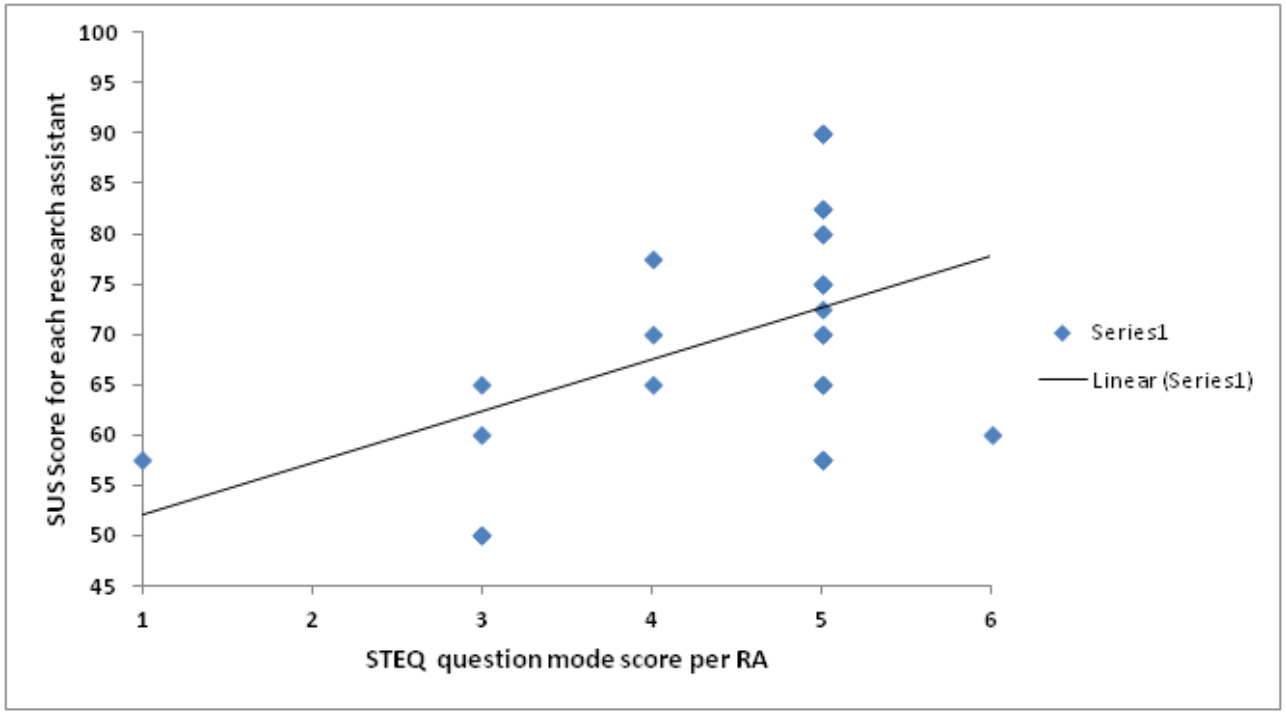


Figure 4. System Usability Scale (SUS) score compared with the Study Tailored Evaluation Questionnaire (STEQ) score. RA: research assistant.



We also note that the results for our generated affirmative STEQ do not depict any acquiescence bias because there were variations in the number of participants who *agreed* to a specific evaluation statement, meaning that not all the participants simply agreed to the evaluation statements. The percentage of participants with agreeable responses ranged from 60% (18/30), which was the lowest number, to 85% (29/30) the highest percentage (Figure 4). We also did not experience extreme response bias because the participants' responses did not only target the extreme options on the scale but also included neutral responses as shown in evaluation statements 5, 6, 11, and 13 where the percentage of respondents were 26% (8/30), 36% (11/30), 30% (9/30), and 76% (23/30) respectively. Thus, from this questionnaire, we were still able to get what the participants felt about the data collection form.

Discussion

Principal Findings

Our findings from the STEQ indicated that about 70% of the responses were *agreeable* to the affirmative statements, and the alternative average SUS score was 70.4, which showed that the participants were generally satisfied with the data collection forms. The results also indicated a strong positive association between the 2 evaluation questionnaires. Using 2 evaluation methods turned out to be important because it provided an opportunity to test for both the usability of the forms and the UX. This is based on the fact that a product with good usability can generate negative UXs, hence leading to dissatisfaction, whereas a product with bad usability can generate positive experiences or satisfaction [42]. In other words, good usability will not always lead to a good UX and the reverse is true.

We used 30 participants in this study, contrary to the recommended 5 by some researchers. The justification of the number of use testers varies and is usually linked to the benefit per cost ratio [43], whereas some researchers also intimate that 5 test users are enough to detect 80% of the usability problems [44]. However, Pablo [17] suggests selecting as many users as would be representative of the target audience provided it does not affect the usability data analysis.

Usability is not an absolute concept, but is relative, dependent on the task and the user [17]. In this study, the variations in the levels of agreement with the different design features and the time taken to complete the tasks by the participants support this. The time the users spent in the evaluation process ranged from 5 to 35 min. The participants had never been involved in such an activity before, and at times found it difficult to follow the tasks while filling the form, which affected their time specifically during consultation. Some of the vocabulary particularly in the SUS may have been a bit complex to the participants, considering that usability was a new discipline to the participants.

Prototype evaluation as a means of usability testing may not necessarily identify comprehensively all the design problems in the prototype [17] because it may be hard to observe the participants diligently, attend to all their queries, and at the same time record the sessions all in one go. Thus, using prototype evaluation can be a time-consuming and error-prone task that is dependent on subjective individual variability [17]. However, errors can be managed by ensuring that there are enough observers during the exercise to support the participants where necessary, and also the tasks chosen should cater for the variability of all the participants. Using a prototype that can be accessed in an offline state would also be useful especially in areas where internet access and speeds are a problem.

Study Limitations

Metrics from posttest evaluations do not indicate why users struggle with any design and also do not provide insight on how the design can be improved because their main focus is on tracking how users feel about using a given product [33]. Their main focus is on producing a usability score for the system rather than the identification and remediation of the specific usability issues [45]. This was true for this study as well because the RAs were not required to elaborate on why they had scored the way they did, which then leaves a gap on how best to improve the MEDCF design. There is therefore a need to identify these usability issues and remediation and give them the attention they deserve.

It is important to note that the SUS questionnaire was given after the first evaluation questionnaire, when some of the participants were probably tired and had lost their concentration, which may have had an influence on the SUS score. It was evident in some questionnaires that the users did not give much thought to what they were evaluating but ticked the same score across all the statements, for example, 1 participant who scored 50 selected *agreed* to 8 of the 10 SUS statements. This kind of evaluation certainly affects the results of the SUS score because of the alternating positive and negative statements that comprise this instrument. The SUS was deliberately designed to obtain reliable scores by alternating positive and negative statements on the same thing, that is, the UX dimension.

It was not possible to attach the users' experience to their individual scores, because we collected the demographics data during the evaluation of the mid-fidelity prototype [29] and we did not collect it again, and yet the participants did not have unique identifiers.

The results also indicate that the participants were not satisfied with the size of the screen characters and visual appeal. One would argue that the phone had a small screen size as in some cases, one had to scroll up and down several times on the same page to fill up the content on that screen. This could have had an impact on the scores from the RAs and the subsequent results.

A reasonable amount of time was spent trying to secure an internet connection, and on getting it, the internet speed was rather slow hence affecting the prototype loading time. As a result, the participants had to work in shifts because the internet could support 5 people at a go, meaning that some of the participants had to wait for longer hours before they could finally begin the exercise. Second, Survival Pluss project has a follow-up component of their recruited mothers, and some of these RAs had prior appointments to meet these mothers at the time when we were carrying out the evaluation. This also prolonged the time taken to carry out the evaluation because some of the RAs were not available on particular days or particular times.

Recommendations and Future Work

Tailoring OSS solutions to user-specific needs and preferences at reasonable costs is worth the effort. We thus recommend that data collectors worldwide are involved in form design and evaluation as early involvement could also help understand the potential of the group, their preferences, and the group's appropriate design solutions.

It is also important to consider the infrastructure and the user groups in such group testing activities, for example in this case, it would be advisable to have the prototype accessible in an offline state especially in areas where internet accessibility is a challenge.

It is not always feasible for software developers to include more resource-demanding features such as rich graphics, and perhaps some elements of gamification, but it is important to note that the RAs will always have some expectations that are worth exploring and considering.

Conclusions

Evaluating user design preferences to determine the UX using the group testing approach is not a common approach in the development of mobile data collection forms, and yet this could be one way of tailoring design to the user needs so as to cater for the diversity in context and user groups especially in rural Africa [46]. Using high-fidelity prototyping to demonstrate the design variations turned out to be a feasible and affordable form development option irrespective of the time it consumed during the evaluation process. The design features in the high-fidelity prototype that were evaluated can be a good basis when designing mobile data collection forms to improve usability and UX. In addition, adopting 2 evaluation instruments could be considered during user testing for purposes of comparing and complementing findings.

Acknowledgments

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Authors' Contributions

AM wrote the protocol and participated in data collection and analysis. TT participated in data collection. AB participated in data collection and analysis. All authors participated in the preparation of paper and approval of its final copy.

Conflicts of Interest

None declared.

Multimedia Appendix 1

Screenshots showing the high-fidelity prototype.

[PDF File (Adobe PDF File), 1MB - humanfactors_v6i1e11852_app1.pdf]

Multimedia Appendix 2

Tasks carried out during interaction with the prototype.

[PDF File (Adobe PDF File), 251KB - humanfactors_v6i1e11852_app2.pdf]

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Abbreviations

DSR: design science research
MEDCF: mobile electronic data collection form
NORHED: Norwegian Programme for Capacity Development in Higher Education and Research for Development
ODK: Open Data Kit
OSS: open-source software
RA: research assistant
STEQ: Study Tailored Evaluation Questionnaire
SUS: System Usability Scale
UCD: user-centered design
UX: user experience

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Original Paper

Nurses' Perceptions of a Care Plan Information Technology Solution With Hundreds of Clinical Practice Guidelines in Adult Intensive Care Units: Survey Study

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Abstract

Background: The integration of clinical practice guidelines (CPGs) into the nursing care plan and documentation systems aims to translate evidence into practice, improve safety and quality of care, and standardize care processes.

Objective: This study aimed to evaluate nurses' perceptions of the usability of a nursing care plan solution that includes 234 CPGs.

Methods: A total of 100 nurses from 4 adult intensive care units (ICUs) responded to a survey measuring nurses' perceptions of system usability. The survey included 37 rated items and 3 open-ended questions.

Results: Nurses' perceptions were favorable with more than 60.0% (60/100) in agreement on 12 features of the system and negative to moderate with 20.0% (20/100), to 59.0% (59/100) in agreement on 19 features. The majority of the nurses (80/100, 80.0% to 90/100, 90.0%) agreed on 4 missing safety features within the system. More than half of the nurses believed they would benefit from refresher classes on system use. Overall satisfaction with the system was just above average (54/100, 54.0%). Common positive themes from the narrative data were related to the system serving as a reminder for complete documentation and individualizing patient care. Common negative aspects were related to duplicate charting, difficulty locating CPGs, missing unit-specific CPGs, irrelevancy of information, and lack of perceived system value on patient outcomes. No relationship was found between years of system use or ICU experience and satisfaction with the system (P=.10 to P=.25).

Conclusions: Care plan systems in ICUs should be easy to navigate; support efficient documentation; present relevant, unit-specific, and easy-to-find information; endorse interdisciplinary communication; and improve safety and quality of care.

(JMIR Hum Factors 2019;6(1):e11846) doi:10.2196/11846

KEYWORDS

usability; patient care planning; evidence-based practice; nursing; documentation; information technology; survey

Introduction

Background

Usability of health information technology (IT) is essential yet an overlooked aspect that drives system fitness to care context, adoption, and quality and safety of care [1-5]. Usability is "the effectiveness, efficiency, and satisfaction with which specific users can achieve a specific set of tasks using a specific system in a particular environment" [6]. Methods for usability evaluation of health IT include questionnaires, chart review,

log file analysis, and observation of user-system-task-environment interaction [7]. Questionnaires are commonly used in usability studies to understand end-user perception of IT, are easy to administer, and serve as a basis for subsequent rigorous usability testing using techniques such as user-system-task-environment interaction. In this study, we assessed nurses' perceptions of a care plan IT solution within the nursing documentation system in intensive care units (ICUs). The solution allows nurses to integrate the recommendations from hundreds of clinical practice guidelines (CPGs) into the plan of care.

CPGs are documents that synthesize recent research findings and recommend a plan of care to diagnose, treat, and manage disease conditions and symptoms. CPGs are essential treatment components for standardized evidence-based practice (EBP), better patient outcomes, cost reduction, and compliance with national safety standards [8-13]. On the other hand, CPGs are lengthy complex documents and vary in their trustworthiness, specificity, strength of evidence, and clarity of recommendations, thus hindering their adaption in intensive care environments with urgent and complex medical conditions [14-16]. Promising strategies for implementation and adoption of CPGs have focused on automating essential components (ie, the recommendations) of the CPGs and integrating them into the electronic health record (EHR) using interactive clinical decision support systems in the forms of alerts and reminders, care protocols, and bundles [12-17]. Although these approaches were successful in some contexts, they allow automating a limited number of CPGs and in many cases produce a small adoption and adherence rate in addition to alert fatigue [15-18]. Although the integration of CPGs' recommendations into an EHR is complex and multifaceted, in many cases and based on end users' perspectives, poor adherence to automated CPGs is attributed to poor usability of the IT system [17-21].

To improve adoption of CPGs, Elsevier Clinical Practice Model Resource Center developed *Care Planning*, a comprehensive interdisciplinary care plan and documentation solution that provides clinicians instant point-of-care access to recommendations from hundreds of CPGs for assessment, diagnosis, treatment, and evaluation [22]. Care Planning is developed based on the Elsevier Clinical Practice Model Framework. The framework places the patient as the center of care and focuses on the core beliefs, principles, and theories of EBP, health and healing, interdisciplinary integration, partnership, health informatics, and international consortium. The Care Planning CPGs, which were developed by interdisciplinary clinicians, are updated periodically and are tested by the Elsevier Clinical Practice Consortium that includes more than 400 hospitals [22]. Care Planning is currently used by many health care institutions across the United States and Canada [22]. The integration of an IT solution such as Care Planning into the nursing documentation system in complex environments such as ICUs is likely to have mixed effects on care processes and quality and safety outcomes. Despite the rise in system adoption, little information is available about the value and usability of the system from a nursing perspective.

Objective

In our facility, Care Planning is known as Knowledge-Based Charting (KBC) and is a major part of the nursing documentation system used to plan and document standardized and evidence-based nursing care. This study describes nurses' perceptions of the usability of the KBC solution within the nursing documentation system in terms of ease of use and documentation, usefulness, efficiency, system safety features, help resources, and training on system use.

Methods

Design, Setting, and Sample

This descriptive study took place in 4 adult ICUs in a 705-bed university teaching hospital with a large referral base in the southwest of the United States. ICUs included neuro (NeuroICU), medical (MICU), surgical trauma (STICU), and transplant and cardiac (TCICU), and had a total of 206 nurses and 950 annual discharges and transfers. After obtaining the approval of the institutional review board, 100 nurses were invited to respond to a questionnaire measuring their perceptions of the usability of the KBC solution. Recruitment was stopped after the target sample of 100 nurses was reached.

Description of the Knowledge-Based Charting System

In our facility, KBC (release 3.2) was integrated into the nursing documentation system in the EHR (Sunrise, Allscript). KBC consists of the index and flowsheets of CPGs. The CPGs' index is a database that includes 165 medical and surgical CPGs (eg, acute coronary syndrome and postoperative) and 69 behavioral or human response CPGs (eg, pain and anxiety). The CPGs' flowsheets are seamlessly integrated into the nursing documentation system only when a CPG is selected from the CPGs' index as described below. Nurse unit educators and superusers support individual training needs on KBC use. All ICUs were sufficiently equipped with hardware for EHR use.

The EHR provided nurses complete access to patient information. One of the main fields used by nurses in Sunrise is the plan of care (left-side list, Figure 1). Nurses can add a CPG by clicking on the list that appears under the plan of care (Figure 1). This allows nurses to access the CPGs index (Figure 1 —"Add Parameter"). From this index, nurses select CPGs that are pertinent to the patient condition. Once added, CPG recommendations appear as two main flowsheets under the plan of care list: CPGs flowsheet and CPGs education (Figure 1). Each of these flowsheets has subscreens to be completed by nurses once clicked. For example, the CPGs flowsheet has the following 4 subscreens (Figure 2): signs and symptoms of potential problems assessed, signs and symptoms of potential problems present, progress to goal, and plan of care. When nurses click any of these subscreens, a side list is presented for nurses to select what they assessed (problems assessed); what exists (problems present); if the goal to progress is improving, declining, or had no changes (progress to goal); and if the interventions related to present problems are ongoing or need to be discontinued or changed (plan of care; see Figure 2).

Figure 1. Accessing the clinical practice guideline (CPG) index and adding CPGs from the CPGs' index.

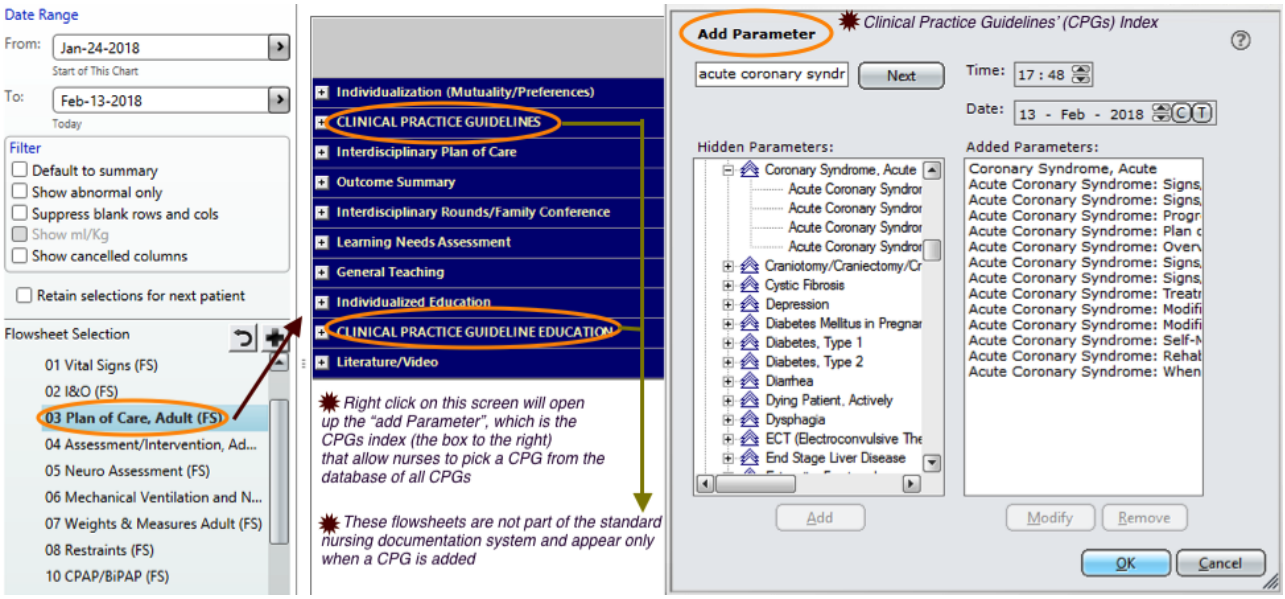
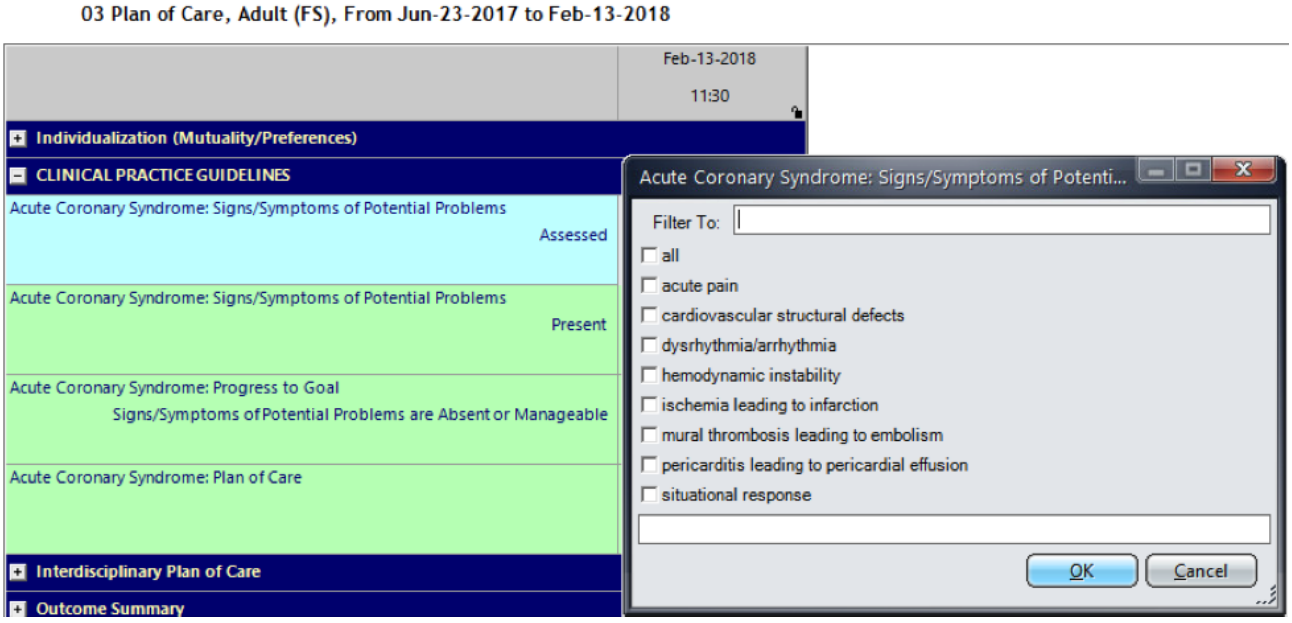


Figure 2. Screens under the clinical practice guidelines' flowsheet with a side box for "problems assessed".

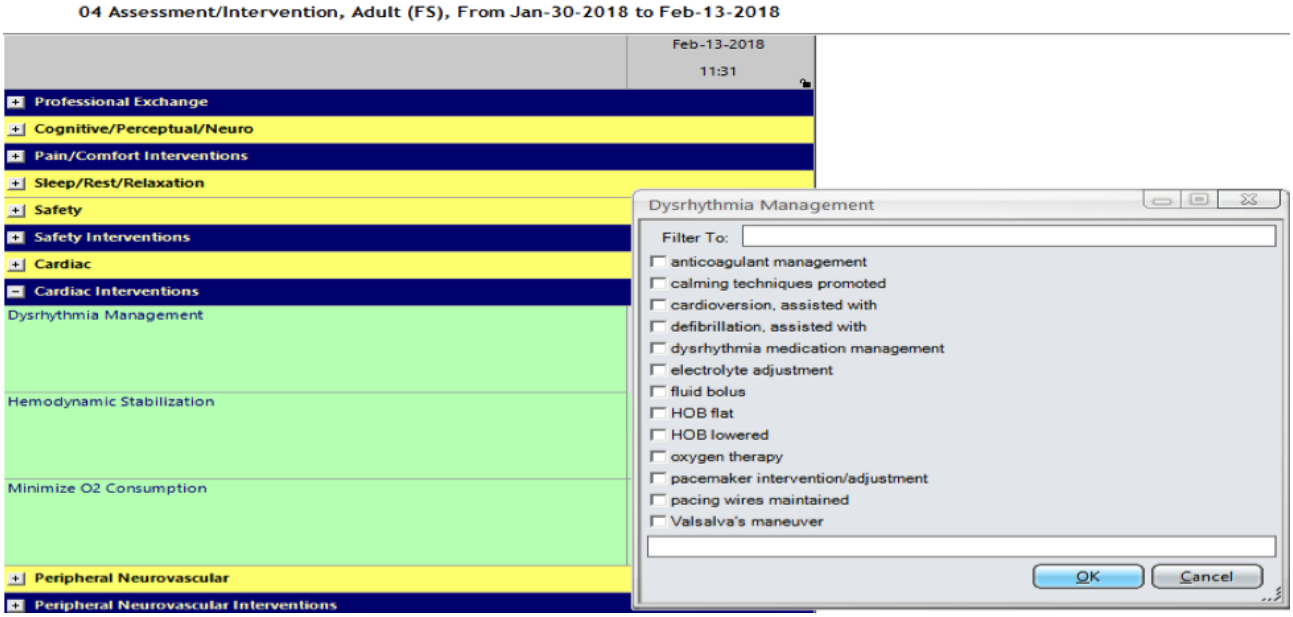


In addition to the CPG-related flowsheets integrated under the plan of care in Sunrise, 2 other flowsheets are also automatically added to the assessment and intervention field in the nursing documentation system in Sunrise (Figure 3) once a CPG is added to the nursing documentation system. The tabs provide nurses with lists of assessment points and interventions to pick from (see Figure 3, a side screen for dysrhythmia management interventions). As the lists can be lengthy, nurses were trained to choose wisely from these lists to provide manageable care, especially when multiple CPGs apply to the patient condition.

Under the assessment and intervention field, standard of care–related fields are highlighted in a different color (yellow and blue) than the CPG-related flowsheets (green).

After a hand-off report, nurses can verify, modify, add, or discontinue CPGs based on the chief medical diagnosis, physical examination, assessment findings, problems list, vital signs, and intake and output. Nurses may also access the complete document of any CPG to confirm the appropriateness of the selected CPG or to learn more about the health condition.

Figure 3. Dysrhythmia management interventions suggested by the dysrhythmia clinical practice guideline.



The complete document of a CPG is similar to a CPG summary published by the Guideline Central [23] in which it provides a summary of the recommendations based on the latest evidence for assessment and interventions along with the strength of the recommendation. However, unlike the CPG summary from the Guideline Central, our complete document in the KBC was limited to 3 of the following main parts: the name of the CPG and the target population (ie, asthma, adult patients); goals and outcomes; and assessment, intervention, clinical reasoning, and decision making. The 2 components under goals and outcomes are (1) signs and symptoms of manageable potential problems (ie, hypoxia, pneumonia, and depression) and (2) educational outcomes (ie, symptoms of asthma, medication treatment plan, modifiable risk factors, and self-management strategies). The assessment, intervention, clinical reasoning, and decision-making section of a complete CPG document in KBC includes the following information under each potential problem: definition; assessment strategies; recommended interventions; citation of the evidence; and the strength of the recommendation for each intervention.

Instrumentation and Procedures for Data Collection

Nurse Perception of the Usability of the KBC Solution Questionnaire was developed after extensive review of usability literature and IT issues identified in critical care settings [1-7,24-33] and was guided by the Davis Technology Acceptance Model [34], Nielsen usability heuristics [35], and Zhang and Walji usability principles [36]. The questionnaire includes 3 sections: (1) demographic data (eg, age, gender, employment status, and years of experience); (2) 37 rated items of a 5-point Likert-type scale of agreement; (3) and 3 open-ended questions to understand missing CPGs that nurses wish the system included and advantages and negative aspects of the KBC. Rated items reflect the following usability aspects of the KBC: perceived ease of use, usefulness (ie, KBC effect on workflow, safety, quality of care, communication, and supporting interdisciplinary care), inclusiveness of the KBC to most important CPGs necessary for ICU conditions, system safety, efficiency, adequacy of training and help resources, and nurse satisfaction with the KBC system. The questionnaire was validated by 5 expert ICU nurse educators, 3 KBC superusers, and informatics experts for appropriateness and adequacy of items and was administered via SurveyMonkey.

To improve the response rate, 2 stations with 4 computers each were set outside the ICUs and nurses were invited to respond to the survey when they were coming to their shifts or leaving the unit. Data collectors also rounded in ICUs before and after shift change to encourage participation. A small cash token for participation was given to each respondent. To foster voluntary participation, some data collectors were non-ICU nurses and data collectors who were ICU nurses administered the questionnaire in ICUs other than their units.

Analysis

Demographics and survey items were presented using descriptive statistics. The relationship between demographic variables and survey items were examined using correlation tests such as chi-square and Spearman rho, with a significance level of .05. Content analysis was used to categorize narrative data into themes.

Results

Nurse Characteristics

All nurses provided complete questionnaires (N=100). As shown in Table 1, the majority of the nurses were from STICU (28/100, 28.0%), aged more than 30 years (60/100, 60.0%), females (65/100, 65.0%), and full-time employees (69/100, 69.0%). Most of the nurses worked in ICUs for 3 years or fewer (59/100, 59.0%) and rated their computer skills as moderate or above moderate (85/100, 85.0%). Of the nurses, 27.0% (27/100) had less than 1-year experience of KBC system use.

Table 1. Nurse characteristics (N=100).

Characteristic	n (%)
Intensive care unit	
Surgical trauma	28 (28.0)
Transplant/cardiac	26 (26.0)
Medical	26 (26.0)
Neuro	20 (20.0)
Age (years)	
Less than 30	40 (40.0)
More than 30	60 (60.0)
Gender	
Female	65 (65.0)
Male	35 (35.0)
Employment status	
Full-time	69 (69.0)
Part-time	31 (31.0)
Experience with KBC[a] system	
Fewer than 6 months	14 (14.0)
6-11 months	13 (13.0)
1-3 years	38 (38.0)
More than 3 years	35 (35.0)
Years in intensive care units	
Fewer than or equal to 3 years	59 (59.0)
More than 3 years	41 (41.0)
Years working as a nurse	
Fewer than or equal to 3 years	33 (33.0)
More than 3 years	67 (67.0)
Level of computer expertise	
Novice	0 (0.0)
Moderate	37 (37.0)
Above moderate	48 (48.0)
Expert	15 (15.0)

[a]KBC: Knowledge-Based Charting.

Nurse Perception of the Usability of the Knowledge-Based Charting System

The internal consistency reliability of the questionnaire was acceptable (Cronbach alpha=.82). Nurses' responses to the rated survey items reflecting their perceptions of the usability of the KBC system were coded as *Agree* for agree or strongly agree responses and *Disagree* for disagree or strongly disagree responses. Items with a neutral response remained *Neutral* (see Multimedia Appendix 1).

The majority of the nurses agreed that there is a need for the system to suggest most critical interventions, alert nurses for safety considerations and when inappropriate CPGs were selected, and to provide a summary of changes in the patient care plan (Items 1, 2, 4, and 5; 80/100, 80.0% to 90/100, 90.0%).

Although the system includes CPGs for the majority of the medical conditions (Item 6; 74/100, 74.0% agreement), it is missing important CPGs for medical conditions often seen in ICUs (Item 12; 63/100, 63.0% agreement). The majority of the nurses (63/100, 63.0% to 72/100, 72.0%) believed the system helps them with medical conditions that they were not familiar with (Item 7), promotes patient engagement (Item 13), individualizes patient care (Item 14), improves the quality of nursing documentation (Item 15), and provides comprehensive nursing care (Item 16). On the contrary, only one half of the nurses agreed that they see the value of nursing documentation

on patient outcomes using the system (Item 24; 54/100, 54.0%) and that the system has positive effects on patient outcomes (Item 29; 49/100, 49.0%).

The majority of the nurses agreed to the consistency of terminologies used to display CPGs and CPGs' components (Item 11; 64/100, 64.0% and Item 8; 70/100, 70.0%) and more than half agreed to the ease of use of some features of the system (Items 3, 10, 19, 25, and 28; 52/100, 52.0% to 84/100, 84.0%). Yet, only 37.0% (37/100) to 48.0% (48/100) of the nurses believed it is easy to locate CPGs, the documentation of the multidisciplinary team, and the nursing documentation by other disciplines (Items 30, 31, 32, and 33). In addition, although 59.0% (59/100) to 69.0% (69/100) of the nurses considered themselves proficient system users (Item 9) and reported availability of help resources for system use (Item 17), only 58.0% (58/100) reported receiving adequate training on system use (Item 20), and 56.0% (56/100) believed they would benefit from refresher training classes (Item 22).

According to the nurses, the KBC system did not improve documentation efficiency (Item 35; 45/100, 45.0%) and only one-fifth of the nurses believed that the quality of their work is based on the KBC system (Item 37; 20/100, 20.0%). The majority of the nurses (59/100, 59.0%) used workarounds when interacting with the system (Item 18). The overall nurse satisfaction with the system was just above average (Item 26; 54/100, 54.0%).

Open-Ended Questions

Missing Clinical Practice Guidelines

A total of 76 nurses (NeuroICU [17/20], STICU [15/28], MICU [23/26], and TCICU [21/26]) listed missing CPGs that nurses would have liked the system to include. Nurses from the NeuroICU suggested 15 CPGs (eg, mechanical ventilation, neurological diseases, multiple sclerosis, and embolic stroke). STICU nurses suggested 11 CPGs (eg, snakebites, hemodynamics, more trauma-related CPGs, postoperative, and gastrointestinal), whereas MICU nurses suggested 30 (eg, gastrointestinal bleeding, acute liver/renal failure, pulmonary embolism, and respiratory/congestive heart failure). Nurses from TCICU listed the following CPGs as missing: liver and lung transplant, trauma, coronary artery bypass grafting, and toxic ingestion of a specific drug. Gastrointestinal bleeding, flaps, altered mental status, and toxic ingestion of a specific drug were reported by nurses from 2 or more ICUs.

Advantages of the System

A total of 88 nurses (NeuroICU [15/20], STICU [26/28], MICU [23/26], and TCICU [24/26]) listed advantages of the KBC system. Major themes with examples are presented in Multimedia Appendix 2. The 2 most common themes were related to the system (1) serving as a reminder to provide complete care and (2) helping nurses organize patient care and track progress toward achieving individualized patient outcomes. The least commonly reported themes were related to ease of system use and system role in promoting accountability and EBP and educating nurses on new medical conditions, specifically the new hires.

Negative Aspects of the Knowledge-Based Charting System

A total of 90 nurses (NeuroICU [18/20], STICU [25/28], MICU [23/26], and TCICU [24/26]) provided details on difficulties and negative aspects of using the KBC. Common themes with examples are presented in Multimedia Appendix 3. Duplicate charting and time consuming were the most commonly cited negative aspects of the system. A total of 20 nurses related this to repetitive interventions as a result of lack of communication across CPGs, especially when a patient has multiple CPGs, and lack of cross-communication among different flowsheets; this required the nurses to spend a long time documenting care and negatively affected the time spent with patients.

Difficulty finding appropriate or specific CPGs was another negative aspect contributing to a long time of system use. Nurses suggested listing CPGs by body systems (eg, "if it was listed by systems it would be easier to find"), the use of search features or a search engine instead of viewing a long list of CPGs, and the need for the system to automatically suggest and display related CPGs based on the medical diagnosis. In addition, some of the CPGs are too broad and others are missing from the system.

A total of 25 nurses reported that the system has no value to patient care or nursing and that they select CPGs and complete the documentation for legal purposes only. A careful examination of the data showed that all these nurses have more than 3 years of experience in system use. The complexity of the system also resulted in selecting CPGs at the end of the shift for documentation purposes only instead of using CPGs at the beginning of the shift to guide care. The least common themes were related to system lack-of-safety features and lack of training on system use, specifically for the new hires.

Relationship Between Variables

No significant correlations were found between years of experience in KBC system use, ICU, age, years in ICU, and satisfaction with the system (P=.10 to P=.25).

Discussion

Principal Findings

To the best of our knowledge, this is the first study to assess nurses' perceptions of the usability of a care plan and documentation system that is based on hundreds of CPGs in ICUs. Nurses' perceptions were favorable on 12 out of 37 features of the system, with more than 60.0% agreement. These were related to ease of use of some features (eg, add and discontinue CPGs) and system usefulness to nursing and patient care (eg, educates nurses on medical conditions and engages the patient in care). On the other hand, nurses reported moderate perceptions with 50.0% to 59.0% agreement on 10 features of the system (eg, training on system use, ease of use and navigation, relevancy of information to nursing care, system support to nursing workflow and information need, and perceived value of nursing documentation on patient outcomes). Negative perceptions were reported on 9 features of the system (20.0% to 49.0% agreement) related to system effect on patient outcomes, difficulty in locating CPGs, lack of system support

to interdisciplinary communication, inefficient documentation, and underuse of behavioral CPGs by nurses. In addition, the majority of the nurses agreed on 4 missing safety features of alerts and reminders within the system and the use of workarounds. Overall satisfaction with the system was just above average.

Our findings were consistent with common areas identified by usability studies of nursing documentation systems related to the long time for documentation and task completion, lack of data relevancy, and nurse perception of lack of system effect on quality of care [24,31,32,37,38]. Yet, our study was specific to the usability of a CPG-based care planning solution within the nursing documentation system and found a lack of system safety features as a major concern for nurses. The need for the KBC system to suggest critical interventions and alert nurses on safety considerations and inappropriate selection of CPGs was perceived as essential by almost all nurses.

Consistent with the findings from the rated survey items, common themes on negative aspects of the system in the narrative data were related to unnecessary repetitive documentation, difficulty finding appropriate CPGs, missing unit-specific information, irrelevancy of information, and the lack of perceived system value. These findings may explain the use of workarounds and inappropriate system use, such as using the system at the end of the shift for documentation purposes to cover nurses legally instead of using it to guide nursing care and the decision-making process. These forms of workarounds are examples of inappropriate use of EHR and are classified by Sittig and Singh [39,40] as EHR-related errors.

Although nurses recognized the system value on standardizing and individualizing care, 80.0% (80/100) did not believe that the quality of nursing care is based on system use. The difficulties nurses face in system use might mask the perceived effect of the system on improving patient outcomes and the value of nursing documentation on patient outcomes. The most commonly reported difficulty was repetitive documentation. Duplicate documentation is not only time consuming but also error-prone and, in our study, resulted from (1) lack of seamless data transmission and lack of communication across CPGs and flowsheets, (2) irrelevancy of CPGs to specific ICUs, which resulted in searching a long list to find an appropriate CPG and searching long lists of interventions and assessment, and (3) the need to go out of Sunrise to select CPGs. Another commonly cited downside of the system was lack of support to nursing information needs by missing important CPGs for some critical cases.

Although no significant correlations were found between years of experience and nurse satisfaction with the system, the value of the system to new nurses with less ICU experience and the lack of system value to expert nurses were supported by different comments from novice and expert nurses. This may support the difference in information need and the decision-making process between novice and expert ICU nurses. It may also suggest that expert ICU nurses appreciate systems that promote safety and efficient documentation, present only relevant information in a visible and easy-to-find manner, and allow nurses to have a sense of control in system use instead of searching long lists. Another possible explanation is the lack of appreciation among expert nurses that new evidence continues to change the way we provide care. One of the expert nurses commented, “You can perform without referring to KBC, if familiar with the interventions.”

Consistent with previous studies [37,38], our results supported the need for periodic training on system use. Almost 60% of the nurses reported they would benefit from refresher training sessions. Nurses’ inability to locate CPGs and the documentation of the multidisciplinary team reflects the difficulty in system use and supports the need for training. The reported difficulty in locating behavioral CPGs is a plausible explanation for behavioral CPG underuse. Another possible explanation is the complexity of medical conditions in ICUs that requires heavy reliance on medical-surgical CPGs for life-threatening conditions (eg, dysrhythmia). In the narrative data, one of the nurses commented on excessive documentation of 11 to 12 problems per patient. Managing and documenting the assessment, interventions, and patient education for that many problems is unrealistic in ICUs and suggests the need for training on system use. Nurses were educated to focus on 3 to 5 high-priority problems in patient care. On the contrary, nurses’ concerns about the legal aspects of documentation might explain the selection of multiple CPGs that would result in unmanageable care and excessive documentation. In addition, although the system is missing some CPGs for critical patient conditions often seen in ICUs, some of the CPGs reported by nurses as missing are actually available within the system, such as mechanical ventilation, neurological diseases, multiple sclerosis, and embolic stroke. This can be explained by the long list of CPGs and lack of automatic integration or suggestions of CPGs based on patient conditions and further supports the need for training on system use.

The use of a questionnaire in this study provided valuable input on system deficiencies and set the stage for future initiatives on observing user-system-task-environment interaction. This study provides valuable information for end users, leaders, researchers, stakeholders, and system vendors on strategies for system and workflow redesign improvement. The study identified usability issues that complicate nurses’ work, threaten appropriate system use, and initiate unsafe workarounds in complex ICU environments. In summary, usability issues identified by nurses in this study reflect system failure to achieve at least 10 of Zhang and Walji’s 14 usability principles [36] and suggest an urgent need for system redesign. For example, difficulties in finding CPGs negatively affect the *systemvisibility* principle. The moderate agreement to the statement “method and sequence of data entry match the workflow and thought processes of the nurse” and irrelevancy of data displayed by the system suggest a *mismatch between the system and nursing world*. Lack of safety features and workarounds are indicators of lack of *informative feedback*, inability to *prevent user errors*, and unavailability of *error message* principles. Nurses’ inability to discontinue one aspect of a CPG negates *flexibility and customizability* and *user control* principles. Inefficient documentation indicates system failure of the *help and documentation* principle. Lack of seamless data transition across

CPGs and flowsheets and excessive data entry increase *memory load* and invalidate the *minimalist design* principle.

Implications

Nursing documentation has safety, compliance, nursing and interdisciplinary communication, legal, accreditation, and financial implications for practitioners, administrators, researchers, and accreditation, safety, and reimbursement agencies. The Joint Commission requires the use of individualized plan of care for each patient to promote effective, continuous, and safe care. The use of EHR-integrated CPGs and CPG-based care planning IT solutions is essential to evidence-based and safe practice, individualized patient care, and complete and standardized documentation. However, inappropriate design, integration, and use of care planning systems such as the KBC would mask any relationships between CPG use and effective and complete documentation; CPG use and quality and safety of care; and complete documentation and safety and quality of care. To be effective, vendors and health care leaders should make certain that CPG-based care planning systems suggest critical interventions and alert nurses on safety considerations and inappropriate selection of CPGs; include a complete list of CPGs for ICU medical conditions; have a search engine for nurses to easily locate relevant unit-specific CPGs; and allow communication across CPGs to eliminate unnecessary repetitive documentation. IT and quality improvement departments and researchers are tasked to conduct periodic examination of nurses' perceptions and use of the system, workarounds, as well as periodic training on system use as critical factors for system success.

Limitations

The findings of this study should be interpreted in light of the following limitations. The study was implemented in ICUs where urgency of care, pressure to find relevant and supportive information, and efficiency of documentation are crucial. Nurse perception of the usability of the same system in other units with less critical care needs might be different. Although our data collection procedure was successful to achieve our target sample size, increasing the sample of ICU nurses and including non-ICU nurses may increase the generalizability of the study. The high response rate may also reflect nurse frustration with the system and the urgent need for system redesign. Finally, nursing care plan and documentation systems vary widely across health institutions in terms of technical complexity, customizability, amount, relevancy, visibility, organization, sources, credibility, and transition of information, safety features, and interoperability between nursing documentation systems and other modules in an EHR. This introduces a challenge for direct comparison across studies of different systems or even the same system with different implementation and EHR-integration frameworks. Nevertheless, the comparison can be made using usability principles.

Conclusions

CPG-based care planning systems provide nurses access to easy-to-understand recommendations from hundreds of CPGs without the complexity of statistical jargons. Nevertheless, nurses' perceptions of the usability of these systems are essential for appropriate and safe system use as well as safety and quality of care. Periodic training on system use is necessary. Training should not be limited to technical aspects of system use but should also highlight system value to nursing and patient care. Nursing care plan systems with CPGs in ICUs should be easy to navigate; promote safety; support efficient documentation; present relevant, unit-specific, and easy-to-find information; endorse interdisciplinary communication; and improve safety and quality of care.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Nurse perception of the usability of the knowledge-based charting system (N=100).

[PDF File (Adobe PDF File), 30KB - humanfactors_v6i1e11846_app1.pdf]

Multimedia Appendix 2

Thematic categories of advantages of knowledge-based charting system (N=88 nurses).

[PDF File (Adobe PDF File), 23KB - humanfactors_v6i1e11846_app2.pdf]

Multimedia Appendix 3

Thematic categories of negative aspects of knowledge-based charting system (N=90 nurses).

[PDF File (Adobe PDF File), 25KB - humanfactors_v6i1e11846_app3.pdf]

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Abbreviations

CPG: clinical practice guideline
EBP: evidence-based practice
EHR: electronic health record
ICU: intensive care unit
IT: information technology
KBC: Knowledge-Based Charting
MICU: medical intensive care unit
NeuroICU: neuro intensive care unit
STICU: surgical trauma intensive care unit
TCICU: transplant and cardiac intensive care unit

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Original Paper

Improving Provider Adoption With Adaptive Clinical Decision Support Surveillance: An Observational Study

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Abstract

Background: Successful clinical decision support (CDS) tools can help use evidence-based medicine to effectively improve patient outcomes. However, the impact of these tools has been limited by low provider adoption due to overtriggering, leading to alert fatigue. We developed a tracking mechanism for monitoring trigger (percent of total visits for which the tool triggers) and adoption (percent of completed tools) rates of a complex CDS tool based on the Wells criteria for pulmonary embolism (PE).

Objective: We aimed to monitor and evaluate the adoption and trigger rates of the tool and assess whether ongoing tool modifications would improve adoption rates.

Methods: As part of a larger clinical trial, a CDS tool was developed using the Wells criteria to calculate pretest probability for PE at 2 tertiary centers' emergency departments (EDs). The tool had multiple triggers: any order for D-dimer, computed tomography (CT) of the chest with intravenous contrast, CT pulmonary angiography (CTPA), ventilation-perfusion scan, or lower extremity Doppler ultrasound. A tracking dashboard was developed using Tableau to monitor real-time trigger and adoption rates. Based on initial low provider adoption rates of the tool, we conducted small focus groups with key ED providers to elicit barriers to tool use. We identified overtriggering of the tool for non-PE-related evaluations and inability to order CT testing for intermediate-risk patients. Thus, the tool was modified to allow CT testing for the intermediate-risk group and not to trigger for CT chest with intravenous contrast orders. A dialogue box, "Are you considering PE for this patient?" was added before the tool triggered to account for CTPAs ordered for aortic dissection evaluation.

Results: In the ED of tertiary center 1, 95,295 patients visited during the academic year. The tool triggered for an average of 509 patients per month (average trigger rate 2036/30,234, 6.73%) before the modifications, reducing to 423 patients per month (average trigger rate 1629/31,361, 5.22%). In the ED of tertiary center 2, 88,956 patients visited during the academic year, with the tool triggering for about 473 patients per month (average trigger rate 1892/29,706, 6.37%) before the modifications and for about 400 per month (average trigger rate 1534/30,006, 5.12%) afterward. The modifications resulted in a significant 4.5- and 3-fold increase in provider adoption rates in tertiary centers 1 and 2, respectively. The modifications increased the average monthly adoption rate from 23.20/360 (6.5%) tools to 81.60/280.20 (29.3%) tools and 46.60/318.80 (14.7%) tools to 111.20/263.40 (42.6%) tools in centers 1 and 2, respectively.

Conclusions: Close postimplementation monitoring of CDS tools may help improve provider adoption. Adaptive modifications based on user feedback may increase targeted CDS with lower trigger rates, reducing alert fatigue and increasing provider adoption. Iterative improvements and a postimplementation monitoring dashboard can significantly improve adoption rates.

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KEYWORDS

pulmonary embolism; clinical decision support; evidence-based medicine

Introduction

As adoption of electronic health records (EHRs) has become increasingly widespread, the potential for electronic clinical decision support (CDS) to improve quality of care has been increasingly recognized [1,2]. CDS uses patient-specific information to make assessments and recommendations to the provider at the point of care [3]. Clinical prediction rules (CPRs) are a form of CDS that function as calculators, using elements of a patient's history, physical examination, and test results to predict the likelihood of a diagnosis, prognosis, or response to treatment [4]. Using well-validated, evidence-based CPRs, CDS tools have reduced antibiotic prescriptions [5], improved lipid management [6], and reduced overtesting [7,8]. However, the impact of these tools has been limited by poor provider adoption, with rates between 10% and 20% [9].

Nonadherence is one of the biggest challenges to the implementation of a successful CDS [10]. Depending on the type of CDS tool, trigger or alert fatigue is an issue that may invariably lead to provider overrides and dismissals. As reported in a study, a provider may receive, on average, 56 alerts per day and spend 49 minutes per day processing them [11]. As an example, alert overrides may occur for 49%-96% of drug safety alerts [12]. User-centered design of CDS with "smart," targeted triggering to maximize alert appropriateness may improve provider adoption rates [3].

One of the most well-known [13] and well-validated [14] CPRs is the Wells criteria for assessing pulmonary embolism (PE) risk. The need for this CDS is important because emergency departments (EDs) across United States have drastically increased computed tomography pulmonary angiography (CTPA) use for PE evaluation [15,16]. Evidence to justify this increase in utilization is lacking [17], and it places the patient at unnecessary risk to radiation, contrast-induced nephropathy, and increased health care costs [18]. It has been reported that the CTPA yield, a measurement of efficiency [19], ranges between only 7%-10% in the United States [15], suggesting overutilization of this test. The Wells CPR has the potential to rule out 70%-80% of patients without further testing [13,14] and reduce costs of unnecessary testing. By integrating the Wells CPR into the EHR of the ED, Drescher et al found an associated increase in CTPA yield from 9% to 12% for the diagnosis of PE [20]. Despite this improvement in CTPA yield, Drescher et al reported major resistance from the ED physicians, leading to the eventual removal of the tool [20,21]. The findings emphasize the importance of implementing a PE CDS into the providers' workflow in a way to maximize usability and acceptance.

Our research team developed an electronic Wells CDS tool based on our previous experience in creating CDS tools at the point of care [3]. The first phase of our project included formative assessment and focus groups to determine providers' level of interest [22], followed by iterative rounds of usability testing for input on design and content of the tool [23]. Using a new usability process called "sensitivity and specificity trigger analysis," we found the most sensitive way to trigger the CDS tool with minimal sacrifice to the specificity [24]. This process allowed us to limit inaccurate triggering of the CDS tool and reduce trigger fatigue.

A key element in the postimplementation period is the continuous monitoring and sustainability of the tool among clinical providers [3,24]. It has been noted that evaluations of postimplementation alerts' appropriateness can be labor-intensive and costly [25]. Nevertheless, investigators are beginning to develop tools to efficiently evaluate alerts [26]. With the launch of our CDS tool based on the Wells criteria for PE, we developed a system to track the trigger rate (defined as the number of times the CDS tool is triggered divided by the number of total visits). Based on analyses of the trigger rates over time and modifications to the CDS, we hypothesized that iterative changes to the Wells CDS can lead to an increase in the adoption of the tool.

Methods

Our research team consisted of expert evidence-based medicine researchers, implementation scientists, health informaticists, and internal medicine and emergency medicine physicians. We worked with Allscripts' EHR and Sunrise Emergency Care (Allscripts Healthcare, Llc) to develop and integrate the Wells CDS tool into the EDs of 2 tertiary care centers' within our health care organization. All study procedures were approved by the Institutional Review Board and the Emergency Medicine Research Committee within Northwell Health.

The CDS tool developed includes a calculator, with risk factors from the Wells PE clinical rule, and a dialogue box to outline recommendations, with an accompanying order set that illuminates orders according to the risk stratification (Figure 1). After thorough usability testing of the tool in the EHR playground environment within our Usability Lab [22-24], we launched the tool within the emergency rooms at 2 large academic tertiary centers in a staggered rollout. The initial design aspect of the usability testing was analyzing the sensitivity and specificity of triggers that would elicit the Wells CDS tool to trigger [24]. Critical characteristics of the tool development that employ user-centered design include qualitative research (interviews) to learn about users' context and workflow, usability surveys, system usage data, and "think aloud" interviews outlined by the study team in the usability testing and formative assessment articles [22,23].

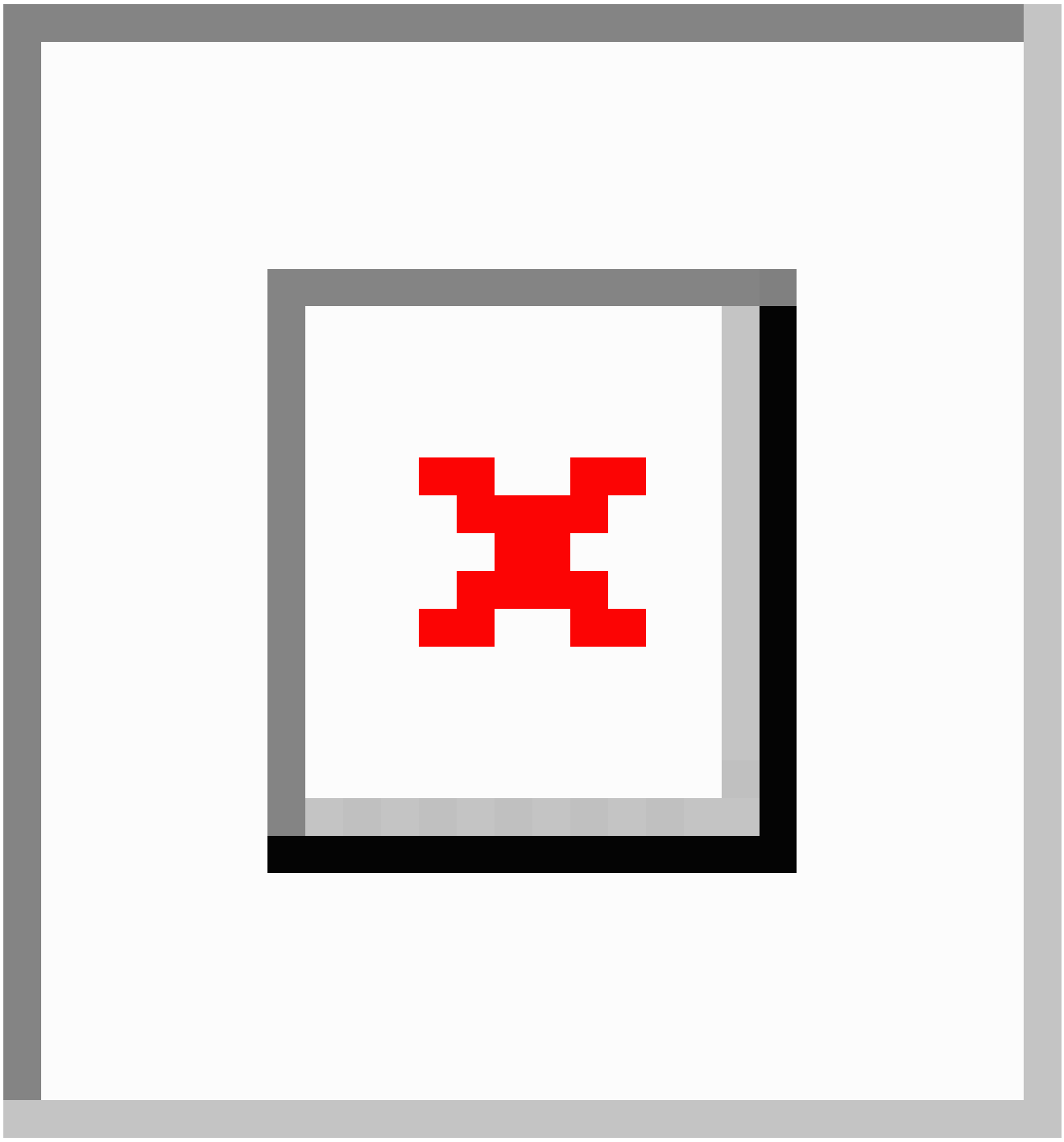
When integrated into the order entry workflow, the Wells CDS tool would be triggered when a provider attempted to order any test that is used to evaluate a suspected PE. Initially, the triggers were D-dimer, computed tomography (CT) chest, CT angiography, ventilation-perfusion scan, and lower extremity Doppler ultrasound (Textbox 1). Upon triggering, the provider filled out the Wells CDS tool as it appears in Figure 1. The completed tool calculated the patient's risk for PE and stratified the patient into low, intermediate, or high categories, each with

a bundled order set that the provider could choose for the next step [23].

Clinicians attempting to order CTPA in a low-risk patient were able to order by dismissing the tool, after which all orders become ungrayed and visible. If a patient had a positive D-dimer, the clinician would move forward with ordering the CTPA and would not be forced to order the D-dimer despite the low risk. If a patient was intermediate and high risk, both D-dimer and CTPA were available for the clinician to order. It is under the clinician's discretion to order the preferred test for these two groups as suggested through current literature [27]. Exclusion criteria for the tool triggering included individuals aged <18 years, as the CDS was firing at 2 tertiary adult hospitals.

A trigger rate tracking tool was developed using Tableau (Tableau Software) to monitor adoption and trigger rates of the Wells CDS tool implementation. This tool gave a monthly status report of each of the 2 tertiary hospitals' EDs' usage of the tool by providing the trigger rate by taking the number of times the Wells CDS tool was triggered over the total number of ED visits during the same period. The tracking tool also monitored the number of times the triggered CDS tool was completed, with the provider using the tool to place orders for PE evaluation. This gives us the completion rate of the Wells CDS tool when divided by the total number of triggers opened for that period. Figures 2 and 3 demonstrate the logic for arriving at trigger rates and completion rates for each tertiary center.

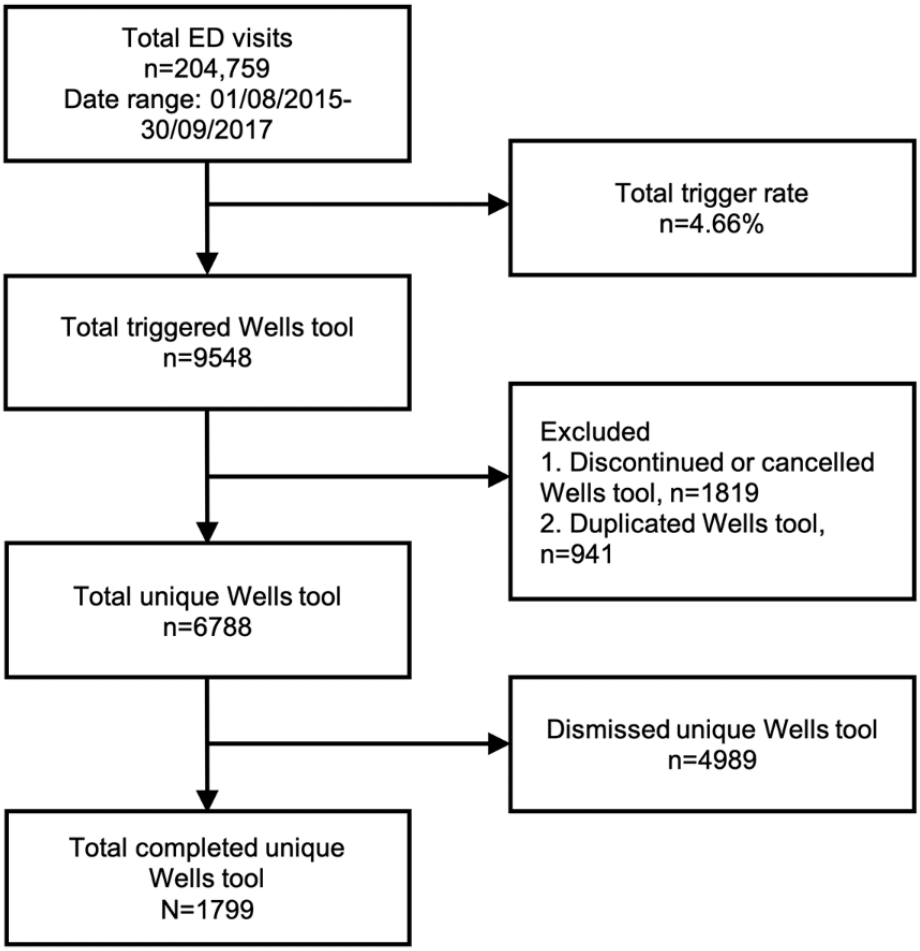
Figure 1. Wells criteria for pulmonary embolism, recommendations, and order set. Source: Allscripts Healthcare Solutions.



Textbox 1. Wells clinical decision support tool trigger points at order entry.

Computed tomography (CT) angiography chest with contrast
CT chest with contrast
D-dimer
Nuclear medicine pulmonary ventilation-perfusion scan
Ventilation-perfusion scan
Lower extremity Doppler ultrasound

Figure 2. Summary report for the emergency department (ED) of tertiary center 1.



After deployment of the Wells CDS tool at the 2 tertiary centers, we conducted focus groups with qualitative feedback with ED providers. We synthesized these feedbacks and developed modifications to the CDS. In December 2015, we implemented 3 iterative changes to the Wells CDS tool. First, our Sunrise CDS team removed CT chest as a trigger for the CDS tool. Then, the team updated the PE order availability algorithm, allowing a low risk (Wells score <2) to open up a lab order called "D-Dimer Assay, Quantitative" and allowing the intermediate risk (Wells score 2-6) to open up the order for "Imaging Studies." Last, a dialogue box was added to appear before the actual order set opened, and a Dynamic Label functionality was added for the "Recommendations" field in the order set (Figure 4). This functionality allowed the actual score (result of documentation) to be referenced in the recommendations field (highlighted) instead of a generic message with static numbers. As outlined in Figure 4, the tool logic was triggered when a clinician entered a diagnostic test for PE that prompted the Wells criteria calculator, recommendations, and accompanying order sets.

Figure 3. Summary report for the emergency department (ED) of academic tertiary center 2.

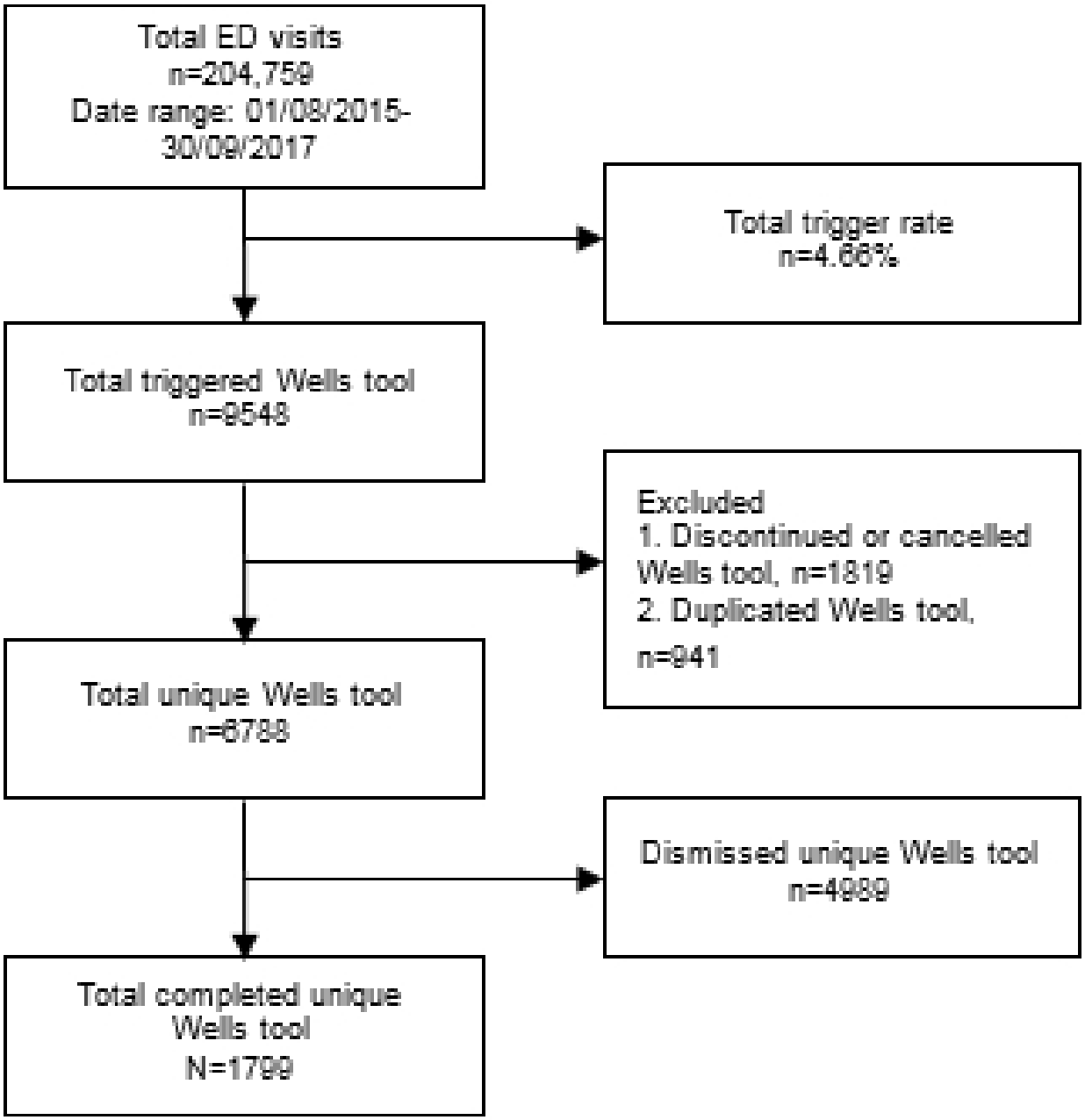
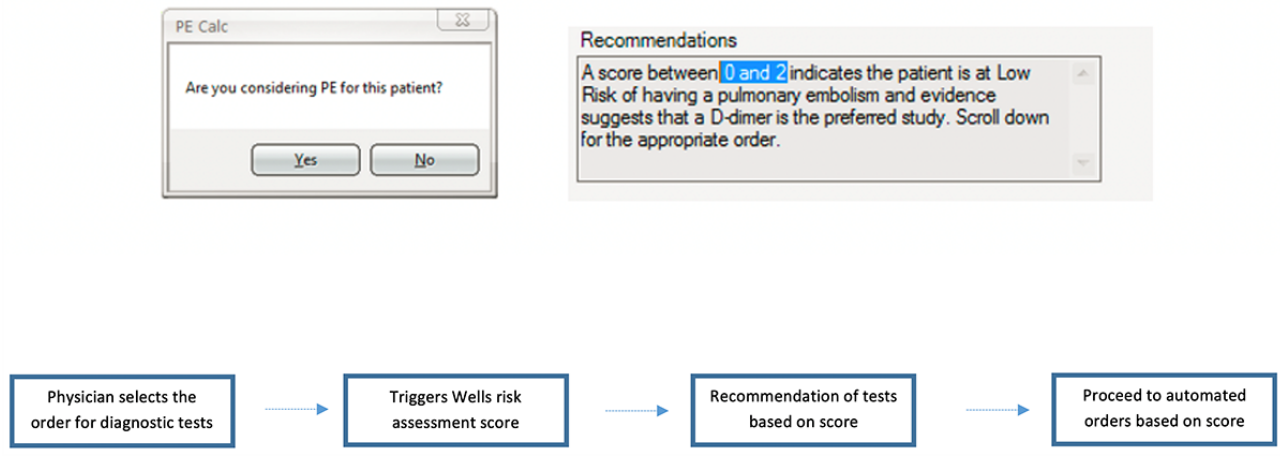


Figure 4. Dialogue box, dynamic label for recommendations, and tool logic. Source: Allscripts Healthcare Solutions.



Results

From the time the Wells CDS tool was deployed in the tertiary academic centers (demographic characteristics in Table 1) to the implementation of the CDS modifications, the trigger rates were relatively high for both tertiary centers.

As seen in Figure 5, the average trigger rates were 6.73% (2036/30,234 visits; 95% CI 6.33%-7.13%) and 6.37% (1892/29,706 visits; 95% CI 6.06%-6.70%) at tertiary centers 1 and 2, respectively. The average completion (adoption) rates of the tool were relatively low 6.5% (23.20/360; 95% CI 5.08%-7.94%) and 14.7% (46.60/318.80; 95% CI 10.69%-18.77%) for tertiary center 1 and 2, respectively.

In December 2015, modifications to the CDS tool were implemented to optimize the triggering event. The 5-month period after implementation of changes is termed the "postmodification period" here to contrast with the "premodification period." At tertiary center 1, the average trigger rate decreased to 5.20% (1629/31,361 visits; 95% CI 4.37%-6.07%). Adoption rates increased to 29.3% (81.60/280.20; 95% CI 22.20%-36.46%), a staggering 4.5-fold increase. Similarly, at tertiary center 2, the average trigger rate dropped to 5.11% (1534/30,006 visits; 95% CI 4.51%-5.73%). The adoption rates increased to 42.6% (111.20/263.40; 95% CI 33.56%-51.72%), an almost 3-fold increase.

The significant increase in adoption rate in 2015 is evident in Figure 6, after the modifications to the Wells CDS tool were implemented. This graph shows the sustainability of the adoption rate upsurge well past the 5-month "postmodification period" we examined above. At the same time, the graph shows a decline in trigger rates after the initial implementation of the CDS tool. In the figure, arrows mark the time of modifications. Red arrow indicates removing CT chest as a trigger, green arrow indicates allowing CTPA for an intermediate score, and blue arrow indicates adding the dialogue box for "Are you considering PE for this patient?" and the dynamic label.

Table 1. Demographics of populations in tertiary academic centers.

Race or ethnicity	Patients, n (%)	
	Tertiary center 1 (n=981,701)	Tertiary center 2 (n=498,256)
White	276,181 (28)	287,391 (58)
Hispanic	234,050 (24)	68,864 (14)
African American	153,044 (16)	19,587 (4)
Asian	253,245 (26)	113,444 (23)
Other or multirace	60,085 (6)	8530 (1)

Figure 5. Average trigger and completion rates at tertiary centers 1 and 2 pre- and postmodifications.

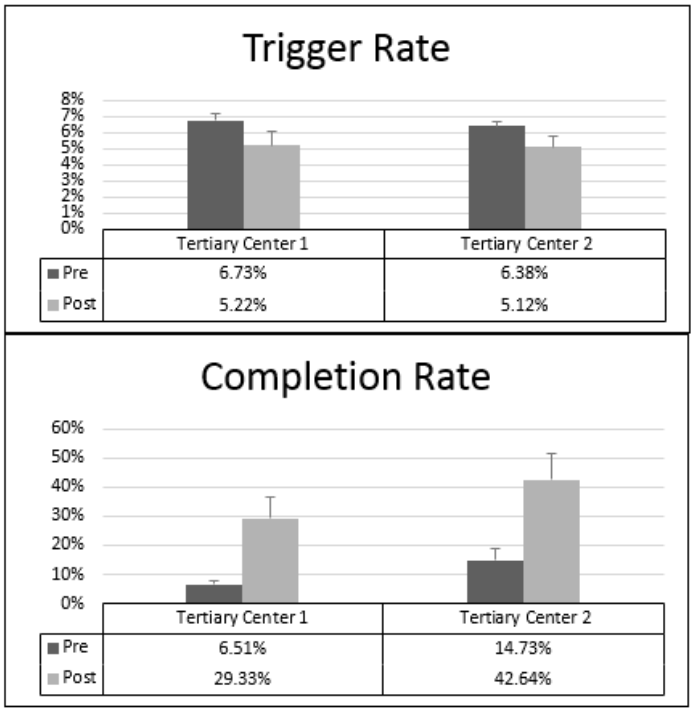
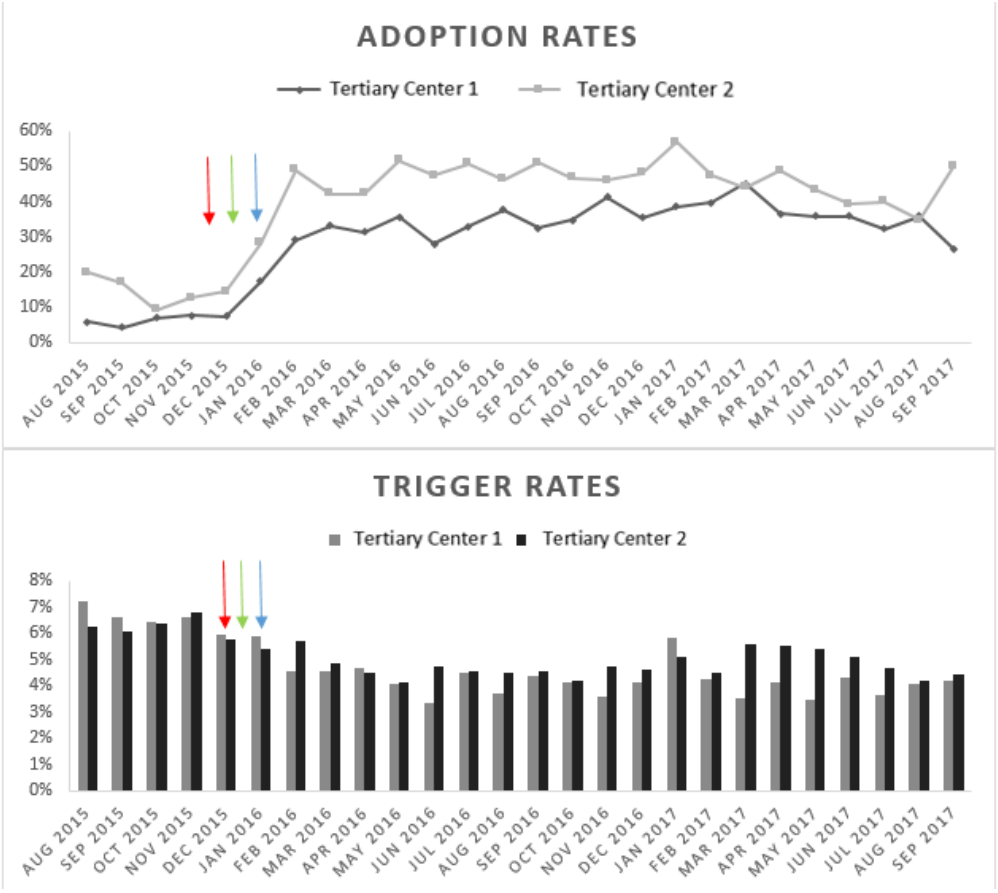


Figure 6. Wells clinical decision support tool adoption and trigger rates at tertiary centers 1 and 2.



Discussion

Principal Findings

The integration of CDS into an EHR to guide management plans has been well documented to improve patient care [5-7]. Use of the Wells criteria for PE increases the yield of CTPA for suspected PE [28]. Unfortunately, as evidenced by Drescher et al's study, the CDS was poorly accepted by emergency physicians and was eventually removed despite showing positive results [20,21]. It is, thus, crucial to devise computerized tools that are optimally integrated into clinician workflow without causing alert fatigue [24] because usability may be as important as accuracy and effectiveness in implementing CDS [23]. We speculate that the high adoption rates of 29.3% (81.60/280.20) to 42.6% (111.20/263.40) observed in our study, as opposed to an average of 10%-20% adoption rates from previous CDS research [9], were a result of the comprehensive user-centered development process including workflow assessment of the ED, focus groups, usability testing, and collaboration with a multidisciplinary team [22-24].

We developed an electronic Wells CDS tool based on user-centered design principles from our extensive experience. As our past research study has shown, usability testing prior to integration of the tool can lead to high adoption rates [3]. Thus, we implemented a two-phase usability testing approach with emergency physicians prior to the integration of the Wells CPR into the EHR [23]. Despite rounds of usability testing, in a near-live environment, where multiple triggers were created, the use of CT chest with contrast as a trigger was an oversight and was not picked up. The near-live environment is able to mimic the live environment to a certain degree of limitation, which further reiterates the importance of postimplementation monitoring and evaluation of CDS use.

Furthermore, the sensitivity and specificity trigger analysis was developed to identify optimal trigger locations to avoid underutilization and overtriggering [24]. From our past studies, we have also learned that adoption of CDS tools can be dependent on individual user characteristics such as age, training level, and experiences with health technology [29]. It was found that while attendings had the most experience with CDS tools, they were least likely to use them compared with the residents [29]. A dynamic and adaptive design may have a large impact on the adoption of CDS tools [30]. To monitor and prepare for an adaptive electronic CDS with iterative changes, we designed a new tracking method for trigger rate.

A key concept behind developing the tracking mechanism and monitoring adoption rates is maintenance, which is one of the essential pieces of the RE-AIM theoretical framework. The framework is utilized to understand translational and system-change efforts in health care [31]; the different dimensions of the theory include research, effectiveness or efficacy, adoption, implementation, and maintenance. The theory has been used in several studies to successfully provide evidence that help informatics interventions overcome their frequent deficiencies in external validity [32-34]. Following implementation of the Wells CDS, we obtained feedback from the end users in accordance with the theoretical framework to

further assess adoption and implementation. A key aspect of the framework is maintenance, and as the study team continued to monitor the uptake of the Well's CDS tool and review current literature, the appropriate addition to include imaging as an option for intermediate-risk patients was implemented.

The postimplementation tracking method trends the trigger rate and completion rate of the Wells CDS tool at our 2 tertiary hospitals. The combination of these rates gives us the sense of the CDS acceptability and adoption on a monthly basis. We have demonstrated that postimplementation tracking and iterative changes to a deployed CDS can result in a 4.5-fold increase in adoption rate. Similar mechanisms have been implemented to track the effectiveness of CDS; Chaffee et al devised monthly reports on alert occurrence and override rates organized into a dashboard view [35]. Using postimplementation tracking methods such as this allows for the development of novel metrics for predicting inappropriate alerts and responses [25]. A "smart" alert system can be used to track a clinician's response to a specific alert and identify inappropriate alerts [25].

As far as we know, this is the first reported use of a postimplementation tracking mechanism to monitor Wells CDS tool adoption rate. Prior studies have recognized the potential and effectiveness of CDS if properly implemented and utilized. While usability testing and a user-centered design process have helped improve initial provider uptake, longitudinal studies have shown a decrease in user participation as time goes on [36]. The development of a dynamic and adaptive CDS may help improve and sustain the adoption rate. This postimplementation CDS tracking method may serve as a springboard for the study and design of a "smart" CDS down the line.

Limitations

The user preferences may vary depending on the institution, and willingness to complete the tool will depend on individual workflows and cultural norms. Providers participating in the study were mostly residents and attending physicians. We would like to incorporate triage nurses in the next assessment with an upstream triage alert for the CDS.

Additional results of the ongoing study are forthcoming and will discuss ordering behavior, adoption by the provider, and overall effectiveness of the CDS tool in the evaluation of PE, which have not been outlined in the Discussion section.

The study was limited due to a single-institution setting, which may limit generalizability. However, the study included 2 academic tertiary centers within a large health system, with vastly different demographics to alleviate this constraint.

Conclusions

Implementation of electronic CDS has shown to improve patient outcomes. However, overtriggering or alerting of the CDS may lead to provider nonadherence and poor adoption of the tool. Postimplementation evaluation of the CDS trigger rate and adaptive modifications of the triggers may lead to more targeted triggers and improvements in the CDS adoption rate. This study provides an example of how iterative changes and postimplementation tracking mechanism of the CDS result in a significantly improved adoption rate.

Conflicts of Interest

None declared.

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Abbreviations

CDS: clinical decision support
CPR: clinical prediction rule
CT: computed tomography
CTPA: computed tomography pulmonary angiography
ED: emergency department
EHR: electronic health record
PE: pulmonary embolism

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Review

The Usability of Electronic Medical Record Systems Implemented in Sub-Saharan Africa: A Literature Review of the Evidence

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Abstract

Background: Electronic medical record (EMR) systems hold the exciting promise of accurate, real-time access to patient health care data and great potential to improve the quality of patient care through decision support to clinicians. This review evaluated the usability of EMR systems implemented in sub-Saharan Africa based on a usability evaluation criterion developed by the Healthcare Information and Management Systems Society (HIMSS).

Objective: This review aimed to evaluate EMR system implementations in sub-Saharan Africa against a well-defined evaluation methodology and assess their usability based on a defined set of metrics. In addition, the review aimed to identify the extent to which usability has been an enabling or hindering factor in the implementation of EMR systems in sub-Saharan Africa.

Methods: Five key metrics for evaluating EMR system usability were developed based on the methodology proposed by HIMSS. These were efficiency, effectiveness, ease of learning, cognitive load, and user satisfaction. A 5-point rating system was developed for the review. EMR systems in 19 reviewed publications were scored based on this rating system. It awarded 5 points per metric to any EMR system that was identified as excellent, 4 points for good, 3 points for fair, 2 points for poor, and 1 point for bad. In addition, each of the 5 key metrics carried a maximum weighted score of 20. The percentage scores for each metric were then computed from the weighted scores from which the final overall usability score was derived.

Results: In possibly contributing to the usability of implemented EMR systems, ease of learning obtained the highest percentage score of 71% (SD 1.09) followed by cognitive load in second place with a score of 68% (SD 1.62). Effectiveness followed closely in third place at 67% (SD 1.47) and efficiency was in fourth place at 64% (SD 1.04). User satisfaction came in last at 63% (SD 1.70). The overall usability score for all systems was calculated to be 66%.

Conclusions: The usability of EMR systems implemented in sub-Saharan Africa has been good with ease of learning possibly being the biggest positive contributor to this rating. Cognitive load and effectiveness have also possibly positively influenced the usability of EMR systems, whereas efficiency and user satisfaction have perhaps contributed least to positively influencing EMR system usability.

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KEYWORDS

review; computer systems; delivery of health care; sub-Saharan Africa

Introduction

Background

The free dictionary defines an electronic medical record (EMR) as a repository for active notations about a patient's health; it is a computerized database that typically includes demographic, medical, laboratory, radiographic, drug, and other information about a patient [1]. EMR systems have evolved from pure record keeping to integrated enterprise-wide systems that hold the promise of accurate, real-time access to patient health care data while providing information necessary to improve patient care and lower costs [2]. Many institutions are developing integrated clinical workstations, which provide a single point of entry for access to patient-related, administrative, and research information. At the heart of the evolving clinical workstation lies the medical record in a new incarnation: electronic, accessible, confidential, secure, acceptable to clinicians and patients, and integrated with other nonpatient specific information [3].

EMR systems have also been shown to improve the quality of disease management, prevent disease-related comorbidities in hospitals [4], and to substantially reduce the risk of medication errors and adverse drug events [5]. They can significantly improve clinical documentation and medication refill turnaround time [6] and are perceived by physicians to have a positive impact on the quality of patient care [7]. The entire health care system can benefit immensely from the use of EMR systems with tangible benefits in cost savings and patient safety [8], making them especially relevant for low resource settings.

In Africa, electronic health care information systems have been driven mainly by the need to report aggregate statistics for government or funding agencies [9]. The use of computerized patient management systems is grossly limited in Africa where paper-based systems are still predominantly used in health care delivery. Some initiatives have been taken to deploy EMR systems though their focus has been heavily on HIV/AIDS care [10] and other infectious disease programs.

The Healthcare Information and Management Systems Society (HIMSS) defines a set of principles and methods for testing and evaluating EMR usability. It defines usability as the effectiveness, efficiency, and satisfaction with which specific users can achieve a specific set of tasks in a particular environment [11]. They submit that usability is possibly one of the most important factors hindering widespread adoption of EMRs and often has a strong direct relationship with clinical productivity, error rate, user fatigue, and user satisfaction. This literature review aimed at evaluating the usability of EMR systems implemented in sub-Saharan Africa using the usability evaluation criterion developed by HIMSS to identify the extent to which usability has enabled or hindered adoption of EMR systems in sub-Saharan Africa.

Objectives

The objectives of the literature review were the following:

1. To evaluate EMR system implementations in sub-Saharan Africa against a well-defined evaluation methodology and assess their usability based on a defined set of metrics
2. To identify the extent to which usability has been an enabling or hindering factor in the implementation of EMR systems in sub-Saharan Africa

Methods

Evaluation Metrics

This literature review assessed EMR systems implemented in a sub-Saharan African context, using the evaluation methods and metrics proposed by HIMSS. HIMSS defines principles and proposes methods for evaluating and rating EMR usability. Its principles for good usability of EMR systems include simplicity, which refers to lack of visual clutter, concise information display, inclusion of only functionality that is needed to effectively accomplish tasks; they include naturalness, which refers to how automatically familiar and easy-to-use the application feels to the user; they also include consistency, which refers to how much an applications structure, interactions, and behaviors match a user's experience with other software applications and how an application uses concepts, behavior, appearance and layout consistently throughout.

The principles also include minimizing cognitive overload by presenting all the information needed for the task at hand and displaying information organized by meaningful relationships: efficient interactions within the system, which refers to minimizing the number of steps it takes to complete tasks and providing shortcuts to experienced users and frequently used functions, incorporating forgiveness and feedback within the EMR system design, effective use of language in a form that is concise and unambiguous, effective information presentation in the appropriate density, and preservation of context by keeping screen changes and visual interruptions to a minimum.

From these principles, HIMSS proposes 5 key metrics for evaluating EMR system usability. These include efficiency, effectiveness, ease of learning, cognitive load, and user satisfaction. Efficiency as a test metric is defined as the speed at which a user can successfully accomplish the task at hand within the EMR system, whereas effectiveness is defined as the accuracy and completeness with which a user can achieve task goals within the EMR system. Ease of learning is defined as the time it takes a user to reach a specified level of proficiency in the use of the EMR system, whereas cognitive load is defined by how intuitively information and functionality are presented within the application, minimizing thought interruptions to users as they perform tasks within the software application. User satisfaction is defined as a person's subjective response to his or her interaction with the EMR system, and it can be evaluated through a Likert-scale rating system or system usability scale questionnaires.

Review Rating System

A 5-point rating system was developed for this review to rate instances of EMR systems implemented in sub-Saharan Africa based on the 5 key metrics mentioned above. The rating for this review weighted all 5 metrics equivalently in determining usability of EMR systems. Table 1 shows the applied rating per metric in the testing of EMR system usability.

Table 1. Key usability metrics used for the literature review and their maximum assigned weighted scores along with the 5-point rating system.

Key usability metric	Maximum weighted score	5-point individual usability rating for all metrics
Effectiveness	20	Excellent=5 points; Good=4 points; Fair=3 points; Poor=2 points; Bad=1 point
Efficiency	20	Excellent=5 points; Good=4 points; Fair=3 points; Poor=2 points; Bad=1 point
Ease of learning	20	Excellent=5 points; Good=4 points; Fair=3 points; Poor=2 points; Bad=1 point
User satisfaction	20	Excellent=5 points; Good=4 points; Fair=3 points; Poor=2 points; Bad=1 point
Cognitive load	20	Excellent=5 points; Good=4 points; Fair=3 points; Poor=2 points; Bad=1 point
Total	100	—[a]

[a]Not applicable.

For each of the 5-key metrics, a 5-point usability rating was applied to each individual metric and EMR systems rated based on how the authors of a publication about an EMR system described the performance of the system in their publication. For instance, if an EMR system was described as being excellent for any of the key usability metrics, then that EMR system was rated with 5 points for that metric. If it was described as good by the authors, then it was rated with 4 points, fair with 3 points, poor with 2 points, and bad with 1 point.

To illustrate, if an EMR system's effectiveness was described as being excellent by the authors, then a usability rating of 5 points was assigned to that system's publication for effectiveness. If the same system's ease of learning was defined as poor by the authors, then the same system was assigned a usability rating of 2 points for ease of learning. Therefore, the highest usability rating that was attainable for any key metric was 5, whereas the lowest was 1. The search keywords and phrases were scored against this 5-point rating system in a uniform manner across all 5 metrics. Table 2 shows the uniform rating applied to keywords in the review.

In addition, in the methodology developed for this review, each metric carried a maximum weighted score of 20 per reviewed system, that is, effectiveness 20, efficiency 20, ease of learning 20, user satisfaction 20, and cognitive load 20. The rating for each system in each key metric was then computed as a score of the weight of that metric, that is, if a system was rated as fair in effectiveness by the authors, it was assigned a usability rating of 3 for effectiveness equating to a weighted score of (3/5)x20=12 for effectiveness. The same rating and scoring system was assigned to EMR system publications across all 5 key usability metrics.

The total score for all reviewed systems in each metric was then computed by summing up the weighted scores of the systems scored for that metric. The number of systems scored per metric was noted and the maximum attainable total score per metric was then calculated by multiplying the maximum weighted score of that metric by the number of systems scored in that metric. The percentage score for each metric was then calculated by dividing the total weighted score of that metric by the maximum attainable total score of the same metric and multiplying the result by 100%.

Table 2. Uniform rating of keywords against the 5-point rating system.

Scoring of search keywords	Effectiveness	Efficiency	Ease of learning	User satisfaction	Cognitive load
Excellent=5 points	Enhanced patient care and management	Totally eliminated delays	Quick user proficiency	Preferred system, viewed system as essential	Inclusion of standard treatment guidelines
Good=4 points	Significant improvement and system indispensable	Reduced patient or provider burden	User friendly interfaces, easy to comprehend, similarity with paper forms	Happy with system, user enthusiasm, rely on system, many perceived benefits from system use	Easily discerned functionality, well organized information, logical and systematic documentation
Fair=3 points	Effective, met objectives, improved data quality or records availability, decision support	Efficient, reduced time, streamlined procedures, and improved workflow	Easy to learn, simple, easy to use, and language customization	User satisfaction, acceptability, some benefits from use, limited adoption challenges	Intuitive, easy access to system information, and availability of reports
Poor=2 points	Functionality limitations and low usage	Increased time or burden	Complicated interfaces	User dissatisfaction and adoption challenges	Cluttered information and disorganized information
Bad=1 point	Did not meet objectives, ineffective, led to errors	Complicated workflow	Extensive effort to gain user proficiency	Hated system, perceived no benefit from use of system	Complicated access to functionality

Table 3. Grading ranges for overall electronic medical record system usability.

Percentage score range	Overall grading
80-100	Excellent
60-79	Good
40-59	Fair
20-39	Poor
0-19	Bad

For example, if the total score for all systems reviewed for effectiveness was calculated to be x and the number of systems scored for effectiveness was y, the maximum attainable total score for effectiveness was calculated as (yx20). The percentage score for effectiveness was then calculated as (x/[yx20])x100%. The same was applied across all 5 metrics to get the percentage scores for each metric. A 95% CI was applied to the percentage score of each metric.

The overall usability percentage score for EMR systems implemented in sub-Saharan Africa was then calculated as the sum of the total weighted scores of all 5 metrics divided by the sum of the maximum attainable total scores of all 5 metrics and the result expressed as a percentage. Finally, a predefined grading system of 5 ranges was applied to the overall percentage score to determine the overall usability performance of the reviewed EMR systems. The final overall usability of implemented EMR systems was graded based on Table 3.

Search Criteria

The literature for this review was obtained from searches in PubMed, Google Scholar, and the directory of open access journals in which 300 articles and literature published between the years 2000 and 2016 were reviewed. Of these, 19 articles were identified to meet the requirements for the literature review and were selected for review. The search terms used for the literature review included the following: implementation of EMR systems in sub-Saharan Africa, evaluation of EMR systems in Africa, computerized patient management systems in Africa, computerized hospital information system in Africa, health information systems in sub-Saharan Africa, testing or implementing electronic health record systems in Africa, and computerized clinic patient system in Africa. Country names from sub-Saharan Africa were also included in the search terms and appended to the ends of the search terms, replacing the words Africa or sub-Saharan Africa for some searches. Google translate was used to translate some French and Portuguese documents. Figure 1 shows a preferred reporting style flow diagram for systematic reviews and meta-analyses, showing the number of articles identified for the review, screened for eligibility, and finally included in the review.

A mixed-methods research approach was adopted for the literature review and involved both qualitative and quantitative research methods. The qualitative aspect focused on identification and extraction of keywords, phrases, and themes related to the 5 key usability metrics from articles included in the final review. The quantitative aspect focused on rating and scoring the systems in these articles using the 5-point rating and weighted scoring systems. Quantitative analysis was subsequently performed on the scores for each system in relation to the research objectives to identify the extent to which usability has been an enabling or hindering factor in the implementation of EMR systems in sub-Saharan Africa. Table 4 lists the 19 publications identified to meet the requirements of the literature review. Multimedia Appendix 1 shows the matching keywords identified in each publication for the 5 metrics. Tables 5 and 6 show the rating and scoring of each of the 19 systems in the 5-key metrics.

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flow diagram for identification, screening, and final inclusion of articles in the literature review. EMR: electronic medical record.

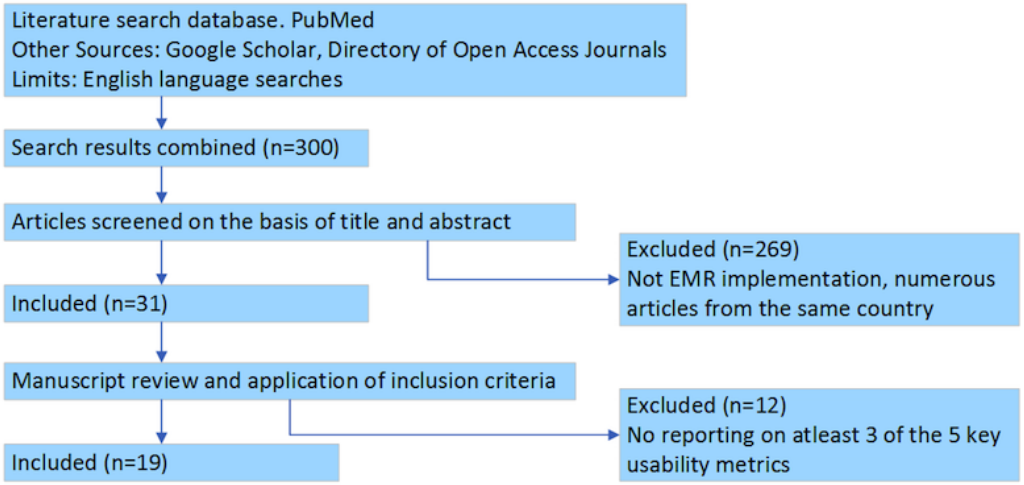


Table 4. List of publications identified to meet the requirements for the literature review.

Number	Publication	Software	Country	Focus
1	A global approach to the management of EMR (Electronic Medical Records) of patients with HIV/AIDS in Sub-Saharan Africa: the experience of DREAM Software [12]	DREAMS	Mozambique; Malawi: Tanzania; Kenya; Guinea; Republic; Guinea Bissau; Cameroon; Congo; Democratic Republic of Congo; Angola; Nigeria	HIV/AIDS
2	An electronic health record for infertility clinics [13]	EHRIC	South Africa	Reproductive health
3	An Electronic Patient Referral Application: A Case Study from Zambia [14]	ZEPRS	Zambia	Perinatal care
4	Combining Vital Events Registration, Verbal Autopsy and Electronic Medical Records in Rural Ghana for Improved Health Services Delivery [15]	MGV-Net VRVA	Ghana	Birth registration
5	Comprehensive Evaluation of Electronic Medical Record System Use and User Satisfaction at Five Low-Resource Setting Hospitals in Ethiopia [16]	SmartCare	Ethiopia	HIV/AIDS, Tuberculosis, and Pediatric Care
6	Designing and implementing an electronic health record system in primary care practice in sub-Saharan Africa: a case study from Cameroon [17]	MEDCAB	Cameroon	Primary health care
7	Electronic Patient Management System ePMS-Zimbabwe Collecting and Managing Data at the Patient Level for Better Treatment and Care [18]	ePMS	Zimbabwe	HIV/AIDS and Tuberculosis
8	Evaluation of Hospital Information System in the Northern Province in South Africa [19]	HIS	South Africa	General care
9	Experience Implementing Electronic Health Records in Three East African Countries [20]	OpenMRS	Kenya; Uganda; Tanzania	HIV/AIDS
10	Impact of an electronic clinical decision support system on workflow in antenatal care: the QUALMAT eCDSS in rural health care facilities in Ghana and Tanzania [21]	QUALMAT eCDSS	Ghana; Tanzania	Antenatal care
11	Implementation of a Cloud-Based Electronic Medical Record to Reduce Gaps in the HIV Treatment Continuum in Rural Kenya [22]	Uamuzi Bora	Kenya	HIV/AIDS
12	Implementation of Provider-Based Electronic Medical Records and Improvement of the Quality of Data in a Large HIV Program in Sub-Saharan Africa [23]	IDI ICEA	Uganda	HIV/AIDS
13	Implementing OpenMRS for patient monitoring in an HIV/AIDS care and treatment program in rural Mozambique [24]	OpenMRS	Mozambique	HIV/AIDS
14	Improvement of Service Capabilities Following the Establishment of an Electronic Database to Evaluate AIDS in Central Africa [25]	IeDEA DMS	Burundi; Cameroon; Democratic Republic of Congo	HIV/AIDS
15	Integration of ICT In Health Service Management in Heal Africa Hospital in DRCongo [26]	HEAL HMS	Democratic Republic of Congo	Primary health care and general care
16	OpenMRS Ebola Case Study [27]	OpenMRS	Sierra Leone	Ebola
17	Scale-up of networked HIV treatment in Nigeria: Creation of an integrated electronic medical records system [28]	FileMaker Pro EMRS	Nigeria	HIV/AIDS
18	Using Electronic Medical Records for HIV Care in Rural Rwanda [29]	OpenMRS	Rwanda	HIV/AIDS
19	Using Touchscreen Electronic Medical Record Systems to Support and Monitor National Scale-Up of Antiretroviral Therapy in Malawi [30]	POC EMR	Malawi	HIV/AIDS

Table 5. Rating of keywords for the 19 systems on the 5 key metrics.

Publication	Effectiveness		Efficiency		Ease of learning		User satisfaction		Cognitive load	
	Rating[a]	Maximum Weighted Score=20 points	Rating[a]	Maximum Weighted Score=20 points	Rating[a]	Maximum Weighted Score=20 points	Rating[a]	Maximum Weighted Score=20 points	Rating[a]	Maximum Weighted Score=20 points
Nucita, 2009 [12]	4	16	3	12	3	12	4	16	__[b]	—
Coetsee, 2014 [13]	3	12	3	12	—	—	3	12	—	—
Darcy et al, 2010 [14]	3	12	3	12	3	12	4	16	3	12
Ohemeng-Dapaaha et al, 2010 [15]	3	12	3	12	—	—	2	8	—	—
Tilahun and Fleur, 2015 [16]	2	8	2	8	3	12	2	8	4	16
Kmadjeu at al, 2005 [17]	3	12	3	12	3	12	3	12	4	16
United Nations Development Programme, 2014 [18]	3	12	4	16	—	—	4	12	3	12
Mbananga et al, 2002 [19]	3	12	3	12	—	—	2	8	—	—
Tierney et al, 2010 [20]	3	12	3	12	—	—	4	16	—	—
Mensah et al, 2015 [21]	3	12	3	12	—	—	—	—	3	12
Haskew et al, 2015 [22]	5	20	—	—	4	16	—	—	3	12
Castelnuovo et al, 2012 [23]	5	20	3	12	4	16	3	12	3	12
Manders et al, 2010 [24]	3	12	3	12	4	16	3	12	—	—
Newman et al, 2011 [25]	3	12	4	16	4	16	3	12	3	12
Guylain et al, 2015 [26]	3	12	—	—	4	16	—	—	2	8
Open MRS, 2015 [27]	3	12	4	16	3	12	3	12	5	20
Chaplin et al, 2015 [28]	5	20	3	12	4	16	4	16	4	16
Amoroso et al, 2010 [29]	4	16	4	16	4	16	2	8	3	12
Douglas et al, 2010 [30]	3	12	—	—	3	12	5	20	4	16

[a]Rating: Excellent=5, Good=4, Fair=3, Poor=2, Bad=1.

[b]Not applicable.

Table 6. Overall scoring of the 19 systems on the 5 key metrics.

Scores[a]	Effectiveness (19 systems scored)	Efficiency (16 systems scored)	Ease of learning (13 systems scored)	User satisfaction (16 systems scored)	Cognitive load (13 systems scored)
Total weighted score	256	204	184	200	176
Maximum attainable total score (max. weight x no. scored)	380	320	260	320	260
Percentage score (total/max x 100)	67%	64%	71%	63%	68%

[a]Overall usability percentage score=(sum of total weighted scores/sum of max attainable scores)x100%=66%.

Results

Effectiveness

All 19 publications reviewed were rated for effectiveness. Effectiveness was translated to systems being able to enhance patient care and management, provide significant improvement or be indispensable, be effective, meet implementation objectives, improve data quality, improve records availability, or being able to provide decision support to users. From the 19 systems, 3 systems (16%) obtained a rating of excellent for effectiveness, 2 systems (11%) obtained a rating of good for effectiveness, whereas 13 systems (68%) obtained a rating of fair for effectiveness. 1 system (5%) obtained a rating of poor for effectiveness and no system obtained a rating of bad for effectiveness. A majority of the systems reviewed were therefore found to be good in effectively achieving their implementation objectives. The percentage score for effectiveness of all 19 systems was found to be *67%* (SD 1.47; 95% CI).

Efficiency

In the literature review, efficiency was associated with eliminating delays, reducing patient or provider burden, reducing time, and streamlining procedures or improving workflows. Efficiency was rated for 16 out of the 19 systems reviewed. No system obtained a rating of excellent for efficiency out of all 16 systems. From the 16 systems, 4 systems (25%) obtained a rating of good for efficiency. The majority of the systems, 11 out of 16 (69%), obtained a rating of fair for efficiency. Furthermore, 1 system (6%) obtained a rating of poor for efficiency and no system was found to be bad in efficiency. The percentage score for efficiency of the 16 systems scored was found to be *64%* (SD 1.04).

Ease of Learning

Ease of learning was associated with quick user proficiency, user-friendly interfaces, easy system comprehension, similarity with paper forms, system ease of learning and use, as well as availability of language customization capabilities in the reviewed EMR systems. A total of 13 out of the 19 systems reviewed were rated for ease of learning. Out of the 13, no system obtained a rating of excellent for ease of learning. The majority of the systems, 7 out of 13 (54%), obtained a rating of good for ease of learning, whereas the rest of the systems, 6 out of 13 (46%), obtained a rating of fair for ease of learning. Ease of learning obtained the highest percentage score of all the 5 key usability metrics with a score of *71%* (SD 1.09).

User Satisfaction

A total of 16 out of 19 systems reviewed were rated for user satisfaction. User satisfaction was associated with mention that users preferred the system or viewed the system as essential, were happy with or enthusiastic about the system, relied on the system, perceived many benefits from use of the system; there was also little mention of EMR system adoption challenges. Out of the 16, 1 system (6%) obtained a rating of excellent for user satisfaction. A substantial number of systems, 5 out of 16 (31%), obtained a rating of good for user satisfaction. The majority of the systems, 6 out of 16 (38%), obtained a rating of fair for user satisfaction. A total of 4 systems (25%) obtained a rating of poor for user satisfaction and no system obtained a rating of bad for user satisfaction. The percentage score for user satisfaction was the lowest of all the 5 metrics with a score of *63%* (SD 1.70).

Cognitive Load

A total of 13 out of the 19 systems were rated for cognitive load. Cognitive load was associated with inclusion of standard treatment guidelines, easy discernment of system functionality, well-organized information within the system, logical and systematic documentation within the system, intuitive design of the EMR system, easy access to system information as well as availability of reports within the EMR system. Of the 13 systems, 1 system (8%) obtained a rating of excellent for cognitive load, whereas 4 systems (31%) were rated as having good cognitive load. The majority of the systems, 7 out of 13 (54%), obtained a rating of fair for cognitive load. Furthermore, 1 system (8%) was rated as having poor cognitive load and no system was found to have bad cognitive load. Cognitive load was found to have a percentage score of *68%* (SD 1.62) for the systems reviewed.

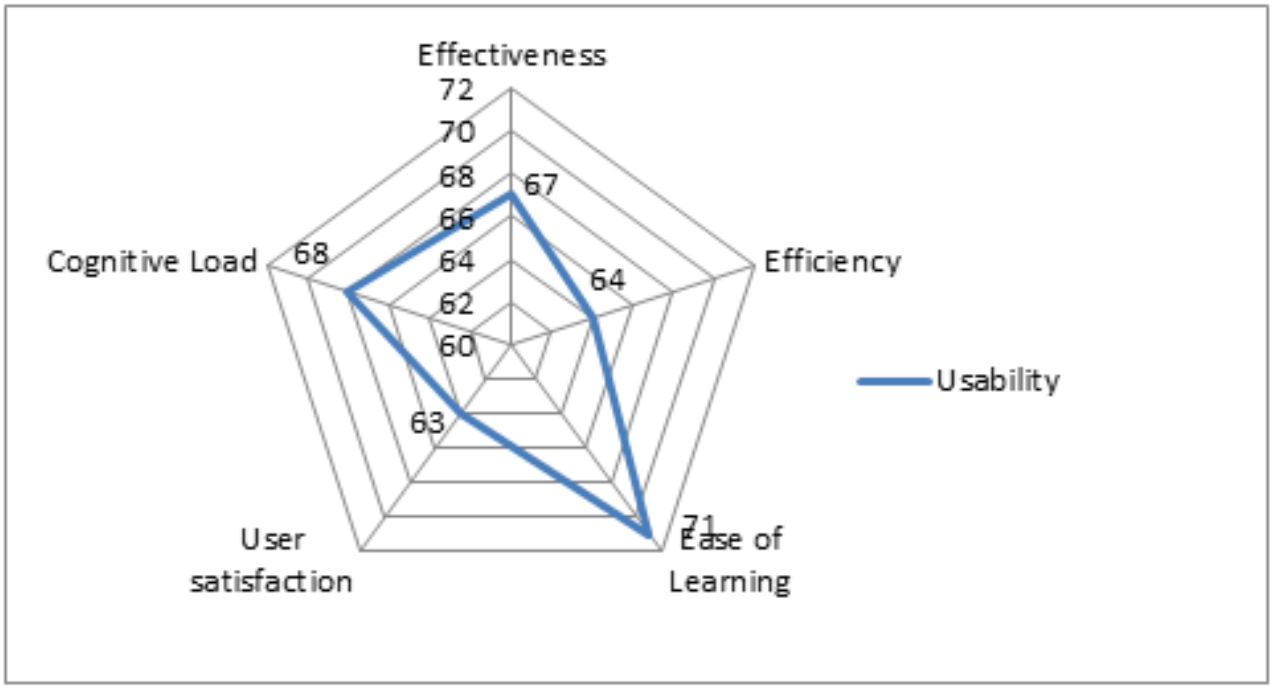
Total Scores Per Metric

The total percentage scores per metric were calculated as indicated in the results section above for each metric and plotted on a radar graph in Figure 2 to visualize their effect on EMR system usability.

Overall Electronic Medical Record Usability Score

The overall usability score for EMR systems implemented in sub-Saharan Africa was calculated as the sum of the total weighted scores of all 5 metrics divided by the sum of the maximum attainable total scores of all 5 metrics and the result expressed as a percentage. It was found to be *66%*.

Figure 2. Radar graph showing usability of electronic medical record (EMR) systems implemented in sub-Saharan Africa. Ease of Learning has possibly positively influenced usability most.



Discussion

Principal Findings

The usability of EMR systems implemented in sub-Saharan Africa has been good with an overall score of 66% across 5 key usability metrics. Ease of learning has possibly had the most positive influence on this rating and was defined for this review as the time it takes a user to reach a specified level of proficiency in the use of an EMR system. It probably has allowed users speedy and easy acquaintance with implemented systems, thereby enhancing their usability.

A relationship was observed between the scores for ease of learning and effectiveness in which a number of systems reviewed simultaneously obtained high scores in both metrics, suggesting that EMR systems might be more effective when they are easy to learn. A slight relationship was also observed between ease of learning and efficiency in which a few of the reviewed systems simultaneously obtained high scores in both metrics.

From the results, cognitive load has possibly contributed the second most to the usability of EMR systems with a percentage score of 68% (SD 1.62) for systems reviewed across the 5 key usability metrics. Cognitive load for this review was defined by how intuitively information and functionality are presented within the EMR system and appeared to have a slight relationship with user satisfaction.

Following closely in third place with a percentage score of 67% (SD 1.47) has been effectiveness in potentially positively contributing to EMR system usability in sub-Saharan Africa. Effectiveness was defined as the accuracy and completeness with which a user can achieve task goals within an EMR system, and it was found to have a relationship with ease of learning as described above and a slight relationship with user satisfaction.

Efficiency has probably contributed the second least to positively influencing the usability of EMR systems implemented in sub-Saharan Africa. Efficiency, defined as the speed at which a user can successfully accomplish the task at hand within the EMR system, obtained a percentage score of 64% (SD 1.04). A slight relationship was observed between efficiency and ease of learning as mentioned above, suggesting that efficiency benefits might be accrued from EMR systems that are easy to learn.

Finally, user satisfaction has probably contributed the least to positively influencing the usability of EMR systems implemented in sub-Saharan Africa. User satisfaction, which was defined as a person's subjective response to his or her interaction with the EMR system, obtained a percentage score of 63% (SD 1.70). A slight relationship was observed between user satisfaction and effectiveness and user satisfaction and cognitive load as mentioned above, which might imply that where cognitive load is well-incorporated into the EMR system design, the systems are more likely to be effective and users are more likely to accept them.

Conclusions

This literature review of the usability of EMR systems in sub-Saharan Africa used an evaluation methodology and usability metrics proposed by HIMSS to evaluate the implemented systems through a mixed-methods approach. The review identified that ease of learning has possibly had the most positive influence on the usability of EMR systems implemented in sub-Saharan Africa. Cognitive load and effectiveness have followed closely as second and third potential positive contributors to EMR system usability. Efficiency has possibly contributed the second least and user satisfaction probably contributed the least to EMR system usability.

Overall, usability appears to have been an enabling factor in the implementation of EMR systems in sub-Saharan Africa as it was found to be good in this review, and the approaches to incorporate usability into EMR implementations ought to prioritize ease of learning of the systems as this has been identified to potentially influence usability most. This supposition that ease of learning with 71% is the largest impact is true within the 95% CI because cognitive load at 68%+1.62=69.62 is below 71%−1.09=69.91 and therefore clearly distinct. Easy-to-learn EMR systems are possibly more effective as a relationship between ease of learning and effectiveness was identified in this literature review. Special attention also ought to be paid to user satisfaction while implementing EMR systems as this might not have been given adequate attention among the reviewed systems and therefore possibly contributed the least to the usability of EMR systems implemented in sub-Saharan Africa.

Limitations of the Review

Methodology Limitations

This literature review of the usability of EMR systems implemented in sub-Saharan Africa was performed solely by the author and only evaluated EMR systems from publications and documentation about them. No physical evaluation or interaction with the actual systems was carried out as part of this literature review. Therefore, the review had limitations of not evaluating the EMR systems in their production clinical settings. The review also did not interview users of the systems to solicit their opinions on the usability of the systems. Moreover, only EMR system implementations where publications mentioned at least 3 of the 5 key usability metrics developed for this review were included in the final review.

Other Limitations

The review also equated EMR systems to patient management systems, clinical and hospital information systems, decision support systems, and electronic health record systems, and it did not take into consideration other confounding factors that might have influenced the usability of the reviewed systems such as hardware and related infrastructure, support and technical expertise availability, user engagement, funding, and so on. Therefore, the review only reviewed implemented EMR systems in their *already used and published about* state with a focus on their usability along the 5 key metrics with all other factors assumed constant.

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Conflicts of Interest

None declared.

Multimedia Appendix 1

Matching keywords identified in publications for the usability metrics.

[PDF File (Adobe PDF File), 315KB - humanfactors_v6i1e9317_app1.pdf]

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Abbreviations

EMR: electronic medical record
HIMSS: Healthcare Information and Management Systems Society

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Original Paper

Computerized Clinical Decision Support System for Emergency Department–Initiated Buprenorphine for Opioid Use Disorder: User-Centered Design

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Abstract

Background: Emergency departments (EDs) frequently care for individuals with opioid use disorder (OUD). Buprenorphine (BUP) is an effective treatment option for patients with OUD that can safely be initiated in the ED. At present, BUP is rarely initiated as a part of routine ED care. Clinical decision support (CDS) could accelerate adoption of ED-initiated BUP into routine emergency care.

Objective: This study aimed to design and formatively evaluate a user-centered decision support tool for ED initiation of BUP for patients with OUD.

Methods: User-centered design with iterative prototype development was used. Initial observations and interviews identified workflows and information needs. The design team and key stakeholders reviewed prototype designs to ensure accuracy. A total of 5 prototypes were evaluated and iteratively refined based on input from 26 attending and resident physicians.

Results: Early feedback identified concerns with the initial CDS design: an alert with several screens. The timing of the alert led to quick dismissal without using the tool. User feedback on subsequent iterations informed the development of a flexible tool to support clinicians with varied levels of experience with the intervention by providing both one-click options for direct activation of care pathways and user-activated support for critical decision points. The final design resolved challenging navigation issues through targeted placement, color, and design of the decision support modules and care pathways. In final testing, users expressed that the tool could be easily learned without training and was reasonable for use during routine emergency care.

Conclusions: A user-centered design process helped designers to better understand users' needs for a Web-based clinical decision tool to support ED initiation of BUP for OUD. The process identified varying needs across user experience and familiarity with the protocol, leading to a flexible design supporting both direct care pathways and user-initiated decision support.

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KEYWORDS

user-centered design; decision support systems, clinical; opioid-related disorders; opiate substitution treatment; health information technology

Introduction

Background

Opioid use disorder (OUD) is an escalating public health crisis that has impacted all regions of the United States and represents a substantial portion of emergency department (ED) visits each year. An estimated 2.1 million people in the United States have OUD [1] and 275 million people have OUD worldwide [2]. More than 33,000 opioid-related deaths occur annually in the United States and 118,000 opioid-related deaths occur annually worldwide [3]. From 2016 to 2017, EDs experienced a 30% increase in visits for opioid overdose [4]. As the primary source of care for many people with OUD, the ED offers an important opportunity to engage patients receiving care for acute and comorbid conditions related to opioid use.

Buprenorphine (BUP), a partial opioid agonist often combined with an opioid antagonist, is a proven effective treatment for OUD that decreases mortality, withdrawal symptoms, craving, and opioid use [5-7]. Initiating BUP in the ED doubles the rate of addiction treatment engagement in ED patients with OUD [8]. However, ED-initiated BUP has not yet been adopted in most hospitals [9,10]. This delay in adoption of evidence-based practice is not unique—on average, it takes 17 years from discovery to the adoption of evidence-based practices into routine care [11,12].

Clinical decision support (CDS), computerized systems that offer patient-specific assessments or recommendations to clinicians, represents one approach to facilitating and accelerating the implementation process [13,14]. A 2011 review of randomized controlled trials investigating CDS guidance for drug therapy showed that CDS improved care in 64% (37/59) of studies [15]. In a broad review of CDS designed to address a range of care processes, meta-analysis favored the use of CDS for supporting clinician treatment orders (odds ratio 1.57, 95% CI 1.35-1.82). Large studies have shown CDS implementation in the ED to have supported the adoption of evidence-based practices for computed tomography imaging use [16,17].

However, CDS faces its own challenges, including unintended consequences such as alert fatigue and increased cognitive load [18-22]. CDS design principles support careful consideration of the sociotechnical environment and delivery of the right information, to the right person, in the right format, and at the right time in clinical workflow to optimize medical decision making [23-26].

Across the fields of technology and human-computer interaction, building usable systems has been found to be essential to improve efficiency and reduce errors [27]. International Organization for Standardization standards for user-centered design outline the process by which technological design can incorporate context and organizational requirements to produce and evaluate solutions [28]. The engagement of end users (the people who will be using the technology) throughout the process is critical to anticipate and avoid pitfalls of new information technology such as increased cognitive load and lack of user engagement [26]. Specifically, pragmatic approaches to usability evaluation are necessary to rapidly design, iterate, and test health care information systems [29].

Objectives

Our objective was to develop a pragmatic, user-centered CDS for ED-initiated BUP and referral to treatment for patients with OUD. The user-centered design process for the development of this tool is described here. We developed this CDS specifically for the purposes of a planned multisystem pragmatic trial to study the effectiveness of user-centered CDS on adoption rates of ED-initiated BUP [30].

Methods

Clinical Context and Population

From March to July 2018, we utilized a multiphase, user-centered design methodology for the formative design, development, and evaluation of the EMergency department-initiated Buprenorphine for opioid usE Disorder (EMBED) CDS intervention. Primary phases in this method included (1) needs assessment, (2) initial prototype design, (3) iterative design feedback, and (4) final prototype testing. Formative feedback sessions were approved by our institution's institutional review board; given the minimal risk of the study and a protocol that did not involve the collection of participants' private information, all participants gave verbal consent for participation.

Eligible participants included ED clinicians and key stakeholders (including administrative and information technology leaders and ED addiction counselors) from an urban academic level I trauma center with 103,000 patient visits per year. Recruitment for user feedback sessions focused specifically on attending physicians and residents in the second, third, or fourth year of postgraduate medical training. During a 4-month period from March to June 2018, a total of 26 unique participants offered feedback during iterative design, including 14 through informal sessions and 12 through formal user feedback sessions. In addition, 6 participants offered feedback on multiple versions of the design. Informal sessions were conducted in the ED or private administrative offices and lasted 10 to 30 min. Formal sessions were conducted in the Yale Center for Medical Simulation and were approximately 45 min in length. Formal user design sessions were conducted in parallel with both attending and resident physicians by a human factors researcher (JR).

Pragmatic Approach

Given our goal to rapidly increase adoption rates of ED-initiated BUP for a subsequent pragmatic trial, we elected to take a pragmatic approach to formative usability evaluation, as described by Mann et al [29]. This approach included rapid iterative design and testing cycles to provide user feedback and input on prototype design iterations. All sessions of user testing included direct observation, think aloud, and observational note-taking. In addition, notes were reviewed with each participant at the end of each session to ensure completeness. Pragmatic data analysis was performed by the design team during weekly meetings to debrief and summarize findings and to determine the design, functionality, and interface changes to

make based on these findings. Termination was based on consensus, cost, and time constraints, as opposed to thematic saturation [29]. To minimize the assessment burden, we did not capture demographic data such as age, gender, race, or ethnicity (other than professional role) for the participants in the study [31].

Phase 1: Needs Assessment

The initial phase of design consisted of a focused discussion with key content and context experts as well as 3 ethnographic observation sessions of 2 to 5 hours in length. In the first 2 observations, the lead designer (MM) shadowed attending physicians in the ED. The third observation period focused on the processes of registration and the administration of patient flow through the waiting room and ED. Five 1-hour, individual interviews were then conducted with an ED drug and alcohol program counselor, a drug and alcohol treatment coordinator, an attending physician, and a resident. Interviews captured additional detail on workflow, roles, and user information needs.

Phase 2: Initial Prototype Design

After identifying potential users and their information needs, an initial low-fidelity prototype was designed. This prototype focused on key components necessary for implementing the ED-initiated BUP protocol, including modules to evaluate patients for OUD based on the Diagnostic and Statistical Manual of Mental Disorders, 5th Edition (DSM-5) criteria [32] and for opioid withdrawal severity using the Clinical Opioid Withdrawal Scale (COWS); the protocol for initiating BUP in the ED; and the steps necessary for referring patients for continued medication for OUD [33,34]. The initial prototype design was then reviewed by the design team as well as a subject matter expert on ED management of substance use disorder (GD) and a targeted sample of attending physicians and administrative leaders from the department. The goal of the initial prototype design phase was to establish the components necessary for the decision support tool and workflow. Questions identified during the initial review were addressed at this stage of design before moving forward to iterative design feedback sessions.

Phase 3: Iterative Design Feedback and Prototype Revision

With the initial static design complete, an interactive prototype was built in InVision (InVision, New York, NY). This prototype provided users with an interactive navigation and functionality experience. Feedback was gathered both through informal review and through formal user design sessions. Informal review included the distribution of electronic or print versions of all screens in the design to both attending and resident physicians. After verbal consent was obtained, each participant was oriented to the session format and read a case (Multimedia Appendix 1) of a patient presenting to the ED for treatment following an opioid overdose. Users were then given an electronic version of the CDS and asked to talk through how they would proceed. If participants did not initially mention the use of the tool, they were prompted to think about how and when they would expect to access the tool in this patient encounter. Participants were asked to think aloud describing how they expected to interact with the tool and were prompted for their initial reactions to it [35]. At the conclusion of each session, participants were asked to provide their overall impression of the tool's content and format as well as suggestions to make the tool easier to use and to increase the likelihood of incorporating it into their practice. All data were entered in a design log identifying the user need, recommendation, and changes resulting from those recommendations. Recommendations were reviewed by the design team weekly to determine how they should inform design revisions. After each iteration, additional feedback sessions were conducted to gather additional data and further refine design.

Phase 4: Final Prototype Testing

Final testing of the interactive InVision prototype consisted of formal user feedback sessions that proceeded until the design team reached a consensus that the prototype would exceed all users' needs 80% of the time based on the 80/20 rule [36]. These sessions followed the format of the formal iterative design feedback sessions (detailed above in Phase 3). Participants included both resident and attending physicians with a wide range of experience with the ED-initiated BUP. Sampling was deliberate to include both participants from earlier iteration sessions as well as new participants naïve to the user design.

Results

Phase 1 (Needs Assessments) and Phase 2 (Initial Prototype Design)

Overall, 4 key topics for design were identified in Phase 1 (Table 1). These initial areas of concentration included appropriate patient identification, defining potential users of the decision support tool, avoiding workflow disruptions, CDS steps, and supporting user understanding of the treatment process. Attending physicians were expected to be the target system users, yet early observations and feedback suggested parts of the decision process might be completed by other members of the care team, such as medical students, residents, or nurses. This broadened view of system users, with varying clinical roles and experience, became an ongoing design challenge driving decisions of how and when to present support.

Activation of CDS tools was an early feedback topic. The initial design was an Epic (Epic Systems, Verona, WI) best practice alert (BPA; Figure 1) triggering a pop-up window when a patient was identified as potentially having OUD. However, users disliked the pop-up alert format as it could easily be dismissed if triggered at the wrong time in the clinical workflow, potentially causing a missed opportunity to support the intervention.

A second area of concern for users (throughout all iterations) was avoiding workflow disruptions; they preferred that the tool take no longer than 2 to 5 min to use. Similarly, users highlighted the need for system flexibility to accommodate for the user's experience level by allowing for decision support as needed as well as a direct care pathway selection with less support for more experienced clinicians.

Table 1. Needs assessment at baseline and ethnographic observation results.

Needs/topics	How they were expressed
Appropriate patient identification	Is it possible to have nurses identify patients with OUD[a]?
	Need to properly explain COWS[b] to patients, who may understand it as "dope sick"
	Can discharge instructions for opioid abuse be a trigger to activate CDS[c]?
	There needs to be advanced search terms to trigger the CDS system—BPAs[d] should not be the common denominator for analysis
Avoiding workflow disruptions	Avoid BPAs. They are intrusive and are rarely acted upon
	Sometimes, physicians do leave electronic health record to access MDCalc or clinical resources websites
	Attending physicians usually do not have time for decision support. Better to tailor this toward residents and nurses
	Entire intervention should take 2-5 mins to increase adoption
Streamlining CDS steps	Integrate COWS into the H & P[e] template, with integrated decision support and order sets to determine the need for BUP[f]
	If a user is initiated for OUD diagnosis, then workflow should be streamlined and skip through the diagnostic criteria for OUD and go straight to treatment decision support
Understanding treatment process	Should patients be given a 4 mg or an 8 mg dosage?
	Need to have a short SBIRT[g] included in CDS to assess patient willingness to begin treatment
	This is not the responsibility of our department but rather the substance abuse program
	Patients are rarely in the right range of withdrawal to prescribe BUP. Need to have a system to allow them to return at an appropriate time to the ED[h]
	Some patients may have a preference for suboxone versus methadone
	Some providers may have completed the waiver process but may not yet be recognized for it
	Should we have patients return to the ED for follow-up post BUP administration, using the 72-hour rule?

[a]OUD: opioid use disorder.
[b]COWS: Clinical Opioid Withdrawal Scale.
[c]CDS: clinical decision support.
[d]BPA: best practice alert.
[e]H & P: history and physical.
[f]BUP: buprenorphine.
[g]SBIRT: Screening, Brief Intervention, and Referral to Treatment.
[h]ED: emergency department.

Figure 1. Initial prototype user interface mockup as Epic best practice alert.

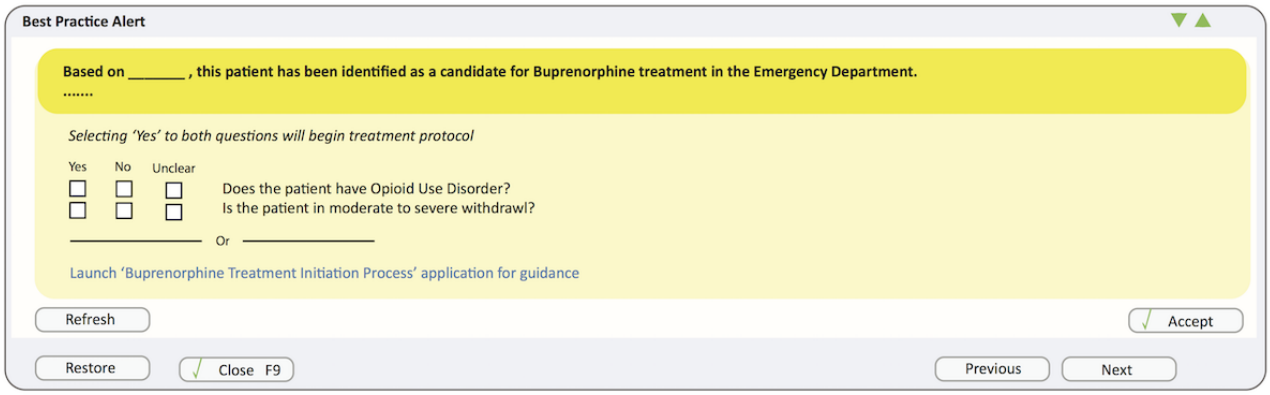
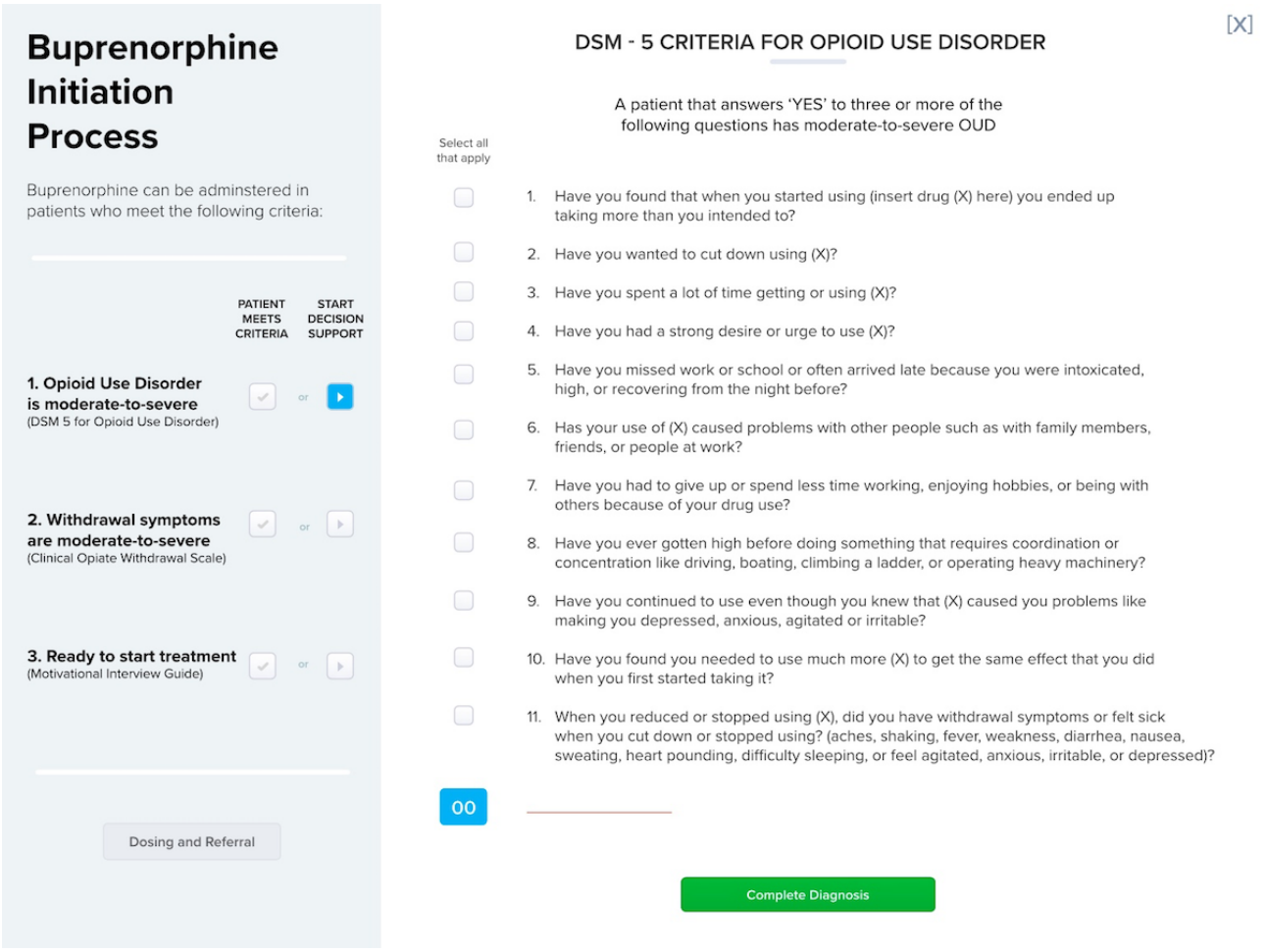


Figure 2. Second prototype user interface with optional decision support. DSM: Diagnostic and Statistical Manual for Mental Disorders; OUD: opioid use disorder.



These needs informed the development of the first prototype that incorporated existing paper forms into 1 process. This first iteration presented step-by-step guidance through 6 sequential screens (Figure 1 includes the first slide): introductory BPA, DSM checklist for diagnosing OUD, COWS withdrawal assessment, motivational interview prompts, treatment options, and a referral form. Each step was delegated to a single screen to emphasize the discrete steps in a streamlined workflow.

Phase 3 (Iterative Design)

We created 5 major prototypes based on ongoing feedback. Multimedia Appendix 2 documents feedback received from each version and how it was incorporated into the subsequent revision. Across all prototypes, feedback focused on 4 thematic needs: design changes, navigation, workflow integration, and treatment process.

Feedback on the initial prototype (described above) focused on streamlining the prototype. This feedback was used to inform the second prototype (Figure 2) with the goal of a user-initiated CDS (instead of a BPA trigger) that could be embedded within the electronic health record (EHR) and further streamline the information in the individual steps.

Users found that this second iteration still had too many steps and too much text. They expressed difficulty in locating the decision support elements. Specific suggestions included consolidating steps with more clarity in regard to navigating the treatment options by including a progress bar.

These suggestions led to a complete redesign of the CDS in prototype 3 (Figure 3). To improve clarity and consolidate steps, this version included all treatment options in a single table on 1 screen with a row for each treatment option. User feedback for this version focused on optimizing the design by changing fonts, reducing the amount of text, and labeling treatment options and the decision support tools appropriately.

This feedback informed the design of prototype 4 (Figure 4) in which treatment pathways were presented in columns (rather than rows) with 1-click treatment pathway selection at the bottom of each column. Buttons in the far left column provided access to modules for OUD diagnosis, withdrawal assessment, and motivation and assessment of patient readiness for treatment. Feedback for this version was mostly positive, with minor navigation concerns about where to start the tool and how to activate the decision support.

Figure 3. Third prototype user interface single-click care pathways. BUP: buprenorphine; COWS: Clinical Opioid Withdrawal Scale; DSM: Diagnostic and Statistical Manual of Mental Disorders; EHR: electronic health record; SL/PO: sublingual/by mouth.

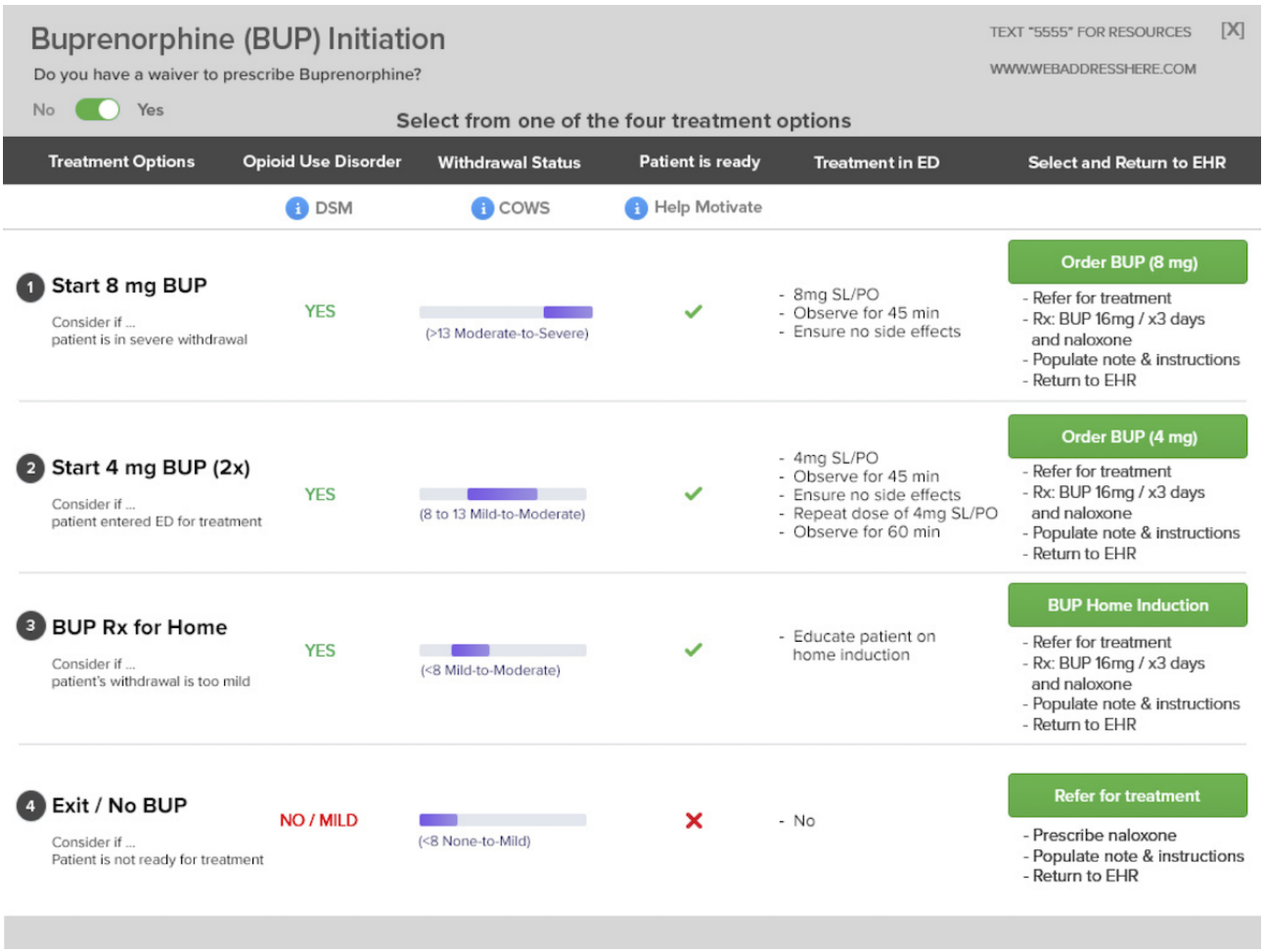
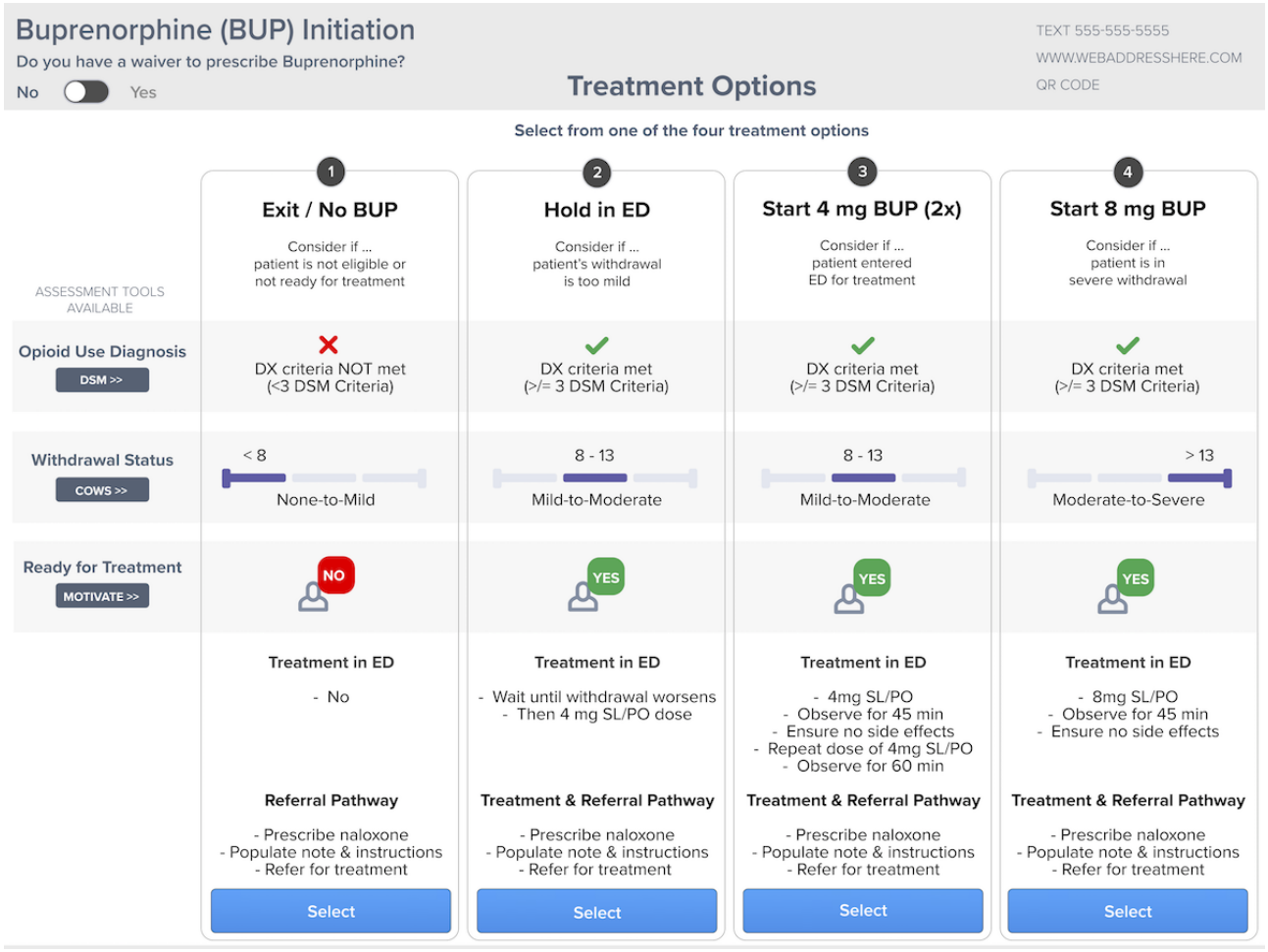


Figure 4. Fourth prototype user interface with care pathways to columns. BUP: buprenorphine; COWS: Clinical Opioid Withdrawal Scale; DSM: Diagnostic and Statistical Manual of Mental Disorders; SL/PO: sublingual/by mouth.



Phase 4 (Final Prototype Testing)

The final prototype design goal was an intuitive, simple layout offering flexibility for direct treatment or user-initiated decision support. In response to navigation concerns, nonessential text was removed, and decision support was presented with blue buttons in the far right column, following the horizontal path for the DSM, COWS, and motivational interview (Figure 5). Although feedback was generally positive for the simplified layout, users suggested that the direct care pathways needed clear delineation. These concerns were addressed in a final design change to outline each treatment column. During final testing, multiple users initially attempted to click in the middle of the main screen to select a care pathway, so care pathway activation buttons were changed to green to indicate the start of treatment. All participants at this stage thought that the system was easy to learn without training and reasonable for use in their routine emergency care practice. Figure 6 summarizes the needs assessment and general workflow of our intervention based on all phases of formative evaluation.

Figure 5. Final prototype user interface with decision support moved to the right column. BUP: buprenorphine; COWS: Clinical Opioid Withdrawal Scale; DSM: Diagnostic and Statistical Manual of Mental Disorder; OUD: opioid use disorder.

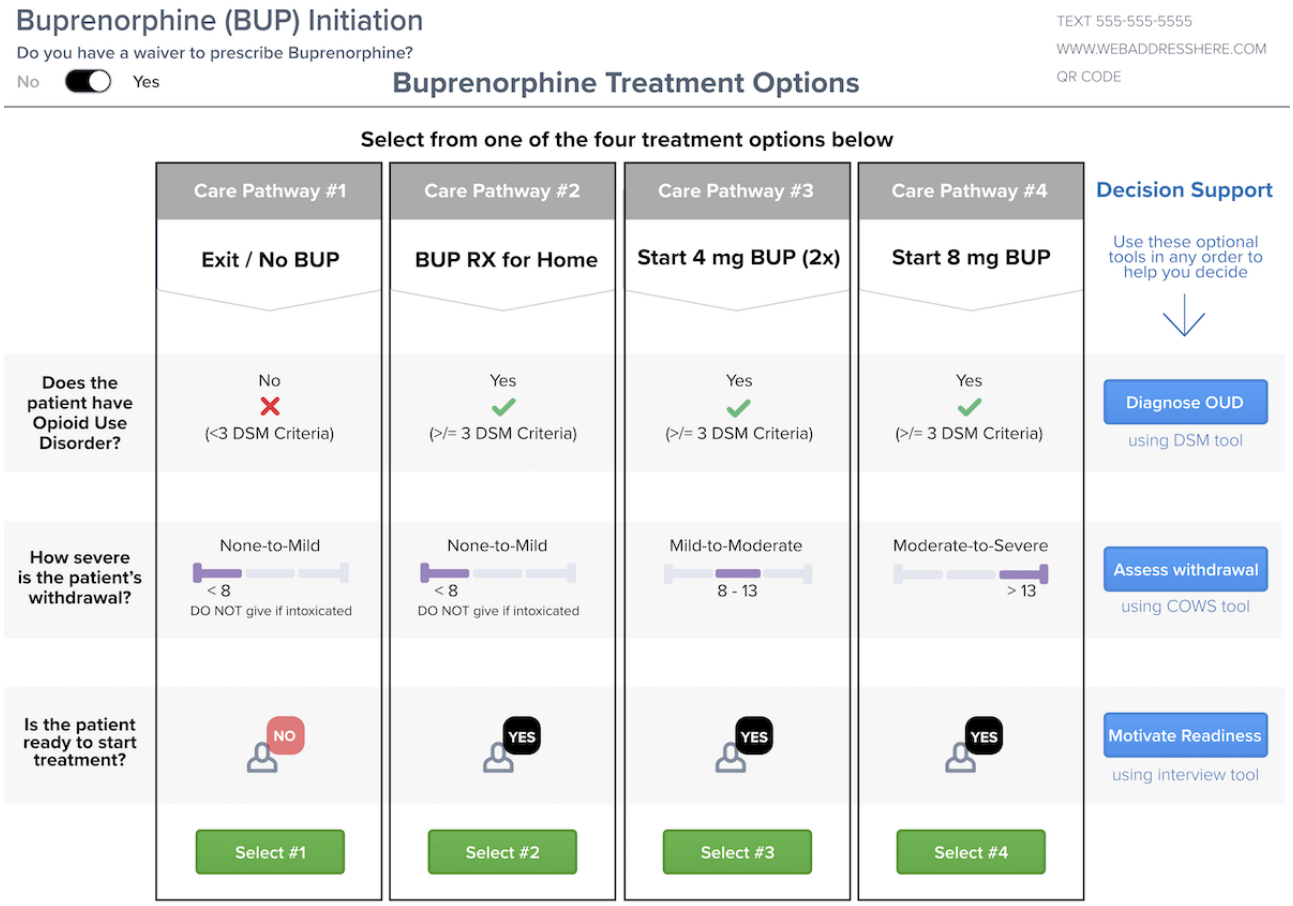
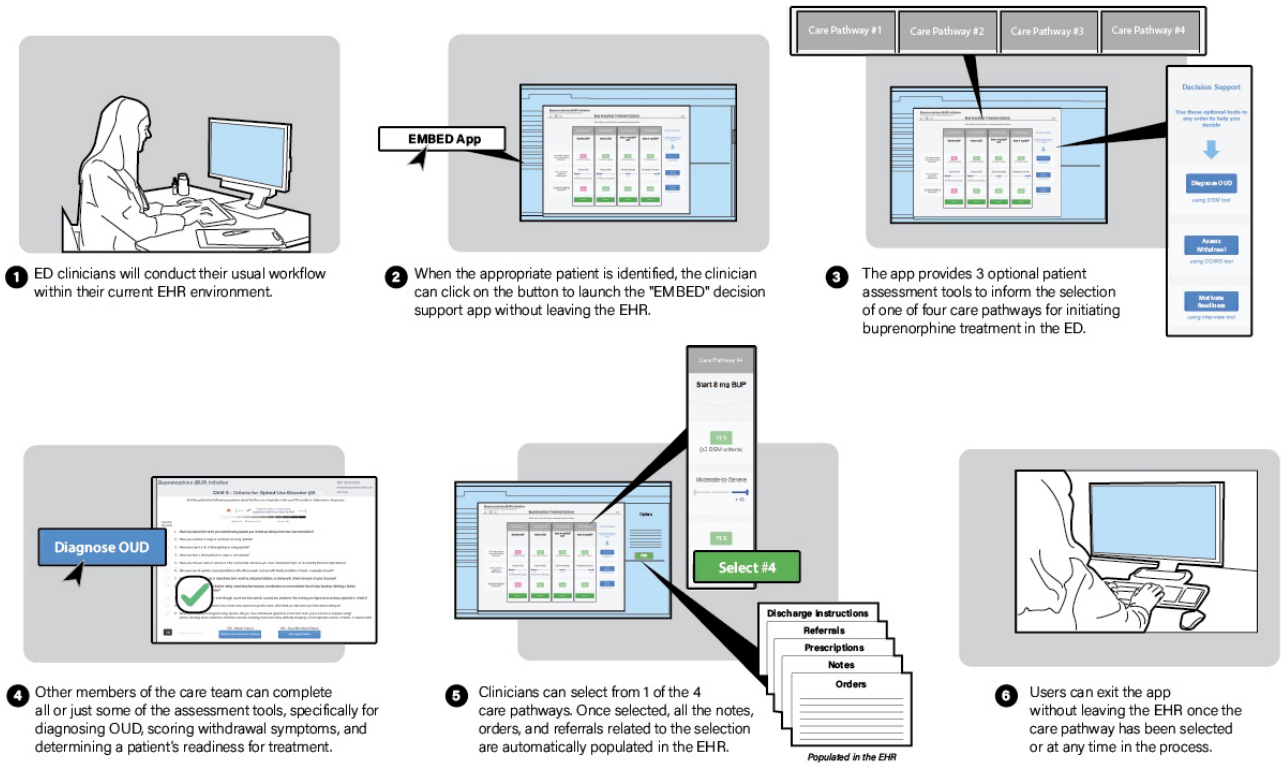


Figure 6. Final information technology workflow for user-centered clinical decision support intervention based on formative evaluation. ED: emergency department; EMBED: EMergency department-initiated Buprenorphine for opioid usE Disorder; EHR: electronic health record; OUD: opioid use disorder.



Discussion

Principal Findings

We describe the iterative user-centered design process to develop a CDS for ED-initiated BUP. Across 4 phases with 5 major revisions and continuous iteration, we identified user needs for a flexible tool to support members of the care team who could be either experienced users or those new to ED-initiated BUP. Interactive feedback sessions identified key themes throughout the refinement process, including issues of navigation, overall design recommendations, considerations for workflow integration, and questions regarding the treatment protocol. Throughout the design process, how and where to activate decision support represented a key challenge. Early prototype versions provided *step-by-step* guidance through existing forms and processes. Requests for a more efficient and flexible tool resulted in an easy-to-read layout with options for direct clinical care activation or user-activated decision support. The challenge of simultaneously providing both a direct care pathway and flexible decision support led to a design with multiple navigation options. Adoption of key design principles included minimizing unnecessary text, utilizing a standard form and colors for buttons, and layout of information in meaningful pathways. We selected a final design once all user-identified concerns had been addressed and user feedback indicated the tool was meeting their anticipated needs.

Strengths and Meaning of the Study

This study supports the use of user-centered design. Through both formal and informal feedback, we captured user needs and input that would not be captured in traditional CDS design processes that lack a needs assessment or formative evaluation. Expert review of content ensured accuracy, whereas feedback from users with varying levels of experience highlighted the need for flexible support. Comments from expert users emphasized the need for an option to directly launch the desired care pathway. Although a direct care pathway provides flexibility for expert clinicians, novice clinicians emphasized the need for more structured decision support and clarity in the diagnostic and treatment processes. Specifically, less experienced users welcomed the detailed criteria for OUD diagnosis and withdrawal assessment, instructions for conducting a motivational interview, and clarity regarding BUP dosing. This contrast in user needs presented a design challenge that highlights the importance of sampling participants across the range of user experience levels with the protocol supported by the CDS. A deliberate sampling of participants from earlier iteration sessions as well as new participants provided confirmatory feedback on how recommended changes were incorporated into the design. Finally, design relied on both user comments and existing standards for layout and use of specific design features such as color.

Limitations

As the CDS supports a treatment pathway, the underlying workflow driving development was identified as clinician workflow. As such, clinicians were the primary users studied. Less focus on other members of the care team could represent a limitation—in particular, if the user population is broadened in implementation at the site where the design process was conducted or at other sites using the tool in the future. A number of users suggested a role for other nonclinician staff in identifying OUD patients in the ED. In particular, multiple clinicians mentioned that the COWS could be completed by a nurse. Therefore, the tool is designed with resources that can be used by or distributed to other members of the care team (eg, nurse, medical student, and addiction counselor). In this way, a nonclinician could still complete the diagnostic or withdrawal assessment, and the clinician could incorporate this assessment into their final care pathway selection.

Given the urgency of the opioid epidemic, we made a conscious decision to take a pragmatic approach to the design and formative evaluation of our intervention. Developing the CDS through a pragmatic approach instead of a traditional academic approach allowed for the rapid inclusion of user feedback in a shorter time frame [29]. We recognize that limitations to this approach exist, including the potential for additional data that could be captured in a deeper, more rigorous data analysis typical of the academic approach. With a traditional academic approach, data saturation anticipates capturing 100% of user feedback themes, whereas this pragmatic approach to development relies on capturing 80% of critical issues [36]. However, we were willing to accept this trade-off to achieve the aim of the subsequent trial to accelerate getting this life-saving treatment into routine emergency care.

This work represents the initial phase of a larger project for the development, implementation, and testing of the effectiveness of the CDS developed here. Design and user feedback sessions were conducted at a single site, though implementation will include multiple sites and could potentially interface with other vendors' EHRs. Having a limited group of users engaged in design is practical and not unique to our work. However, we recognize that this introduces the potential for design features supporting local norms and processes that may not be generalizable. To mitigate this potential limitation, we sought feedback throughout the design process from external collaborators as well as guidance from a subject matter expert on ED management of substance use disorder.

Comparison With Prior Work

Given the devastating toll of the opioid epidemic, this user-centered CDS was developed to give clinicians the tools necessary to engage more people suffering from OUD in effective treatment at a time when they may be particularly open to it [8-10]. However, this intervention may be challenging to disseminate for several reasons: (1) it implements a multistep practice that is not familiar to clinicians; (2) ED clinicians are unlikely to see immediate effects of their efforts; (3) the targeted patient population is often perceived to be difficult to work with; and (4) the legal status of BUP for OUD is complicated, requiring a special waiver to prescribe for home use, but no waiver required if the treatment is administered onsite for no more than 72 hours [37,38].

Given these challenges to adoption, we perceived an opportunity to increase the likelihood of success by employing user-centered design to create the EMBED CDS intervention. Emerging literature supports this approach [39-42]. For example, Thursky

and Mahemoff have incorporated participatory design methods to create antibiotic CDS for physicians in intensive care units [39]. Kilsdonk et al have employed user-centered decision support to create a tool that improved the speed and accuracy of clinician's identification of appropriate screening procedures for childhood cancer survivors, relative to the use of a paper guideline [40]. Plaisance et al have used a process similar to our study to design a CDS for cardiopulmonary resuscitation in the intensive care unit [42]. We have also previously employed a user-centered design in developing CDS for patients with head injury in the ED [41].

Notably, these studies have shown that including user feedback in the design phase leads to greater effectiveness and efficiency and, ultimately, to a sense of physician ownership of the CDS, which increases its immediate uptake and continued use. They have also highlighted rapid-cycle prototyping with user engagement throughout a design process [42]. Similar to previous reports in this area, we found that different groups of users expressed different needs for the tool. We approached this challenge through a design approach that balanced the goals, priorities, and information processing needs of both novice and expert users. This resulted in a tool that could support multiple types of users and their preferred workflows. We demonstrate how a single tool can be designed with the flexibility to meet multiple users' work processes and information processing needs. Designing for the human requires an understanding of workflows, information needs, priorities, and preferences; user-centered design captures this through user engagement across the design and development life cycle [26-28].

Conclusions

This work describes the design and formative evaluation of a user-centered CDS for ED-initiated BUP. We add to the expanding literature on the design of user-centered CDS tools by describing the process and challenges of designing a flexible tool that supports both novice and expert clinicians in identifying appropriate patients and appropriate care pathways. Future work will include summative usability evaluation and pilot testing of the intervention to further optimize the tool for wide-scale implementation within existing ED workflows in a large pragmatic clinical trial across multiple health care systems. The aim of this subsequent pragmatic trial is to increase adoption of ED-initiated BUP for people suffering from OUD, thereby decreasing morbidity and mortality associated with opioid addiction. Users will also inform pilot implementation in a series of focus groups. Although early engagement of users supports the design process, we anticipate continued support of potential users will be equally important across the project life cycle.

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Authors' Contributions

ERM, JMR, MM, and GD conceived and designed the work. All authors substantially contributed to the acquisition, analysis, and interpretation of the study data. JMR and OMA drafted the initial manuscript. All authors edited and approved the final version submitted for publication. ERM takes responsibility for the study as a whole.

Conflicts of Interest

None declared.

Multimedia Appendix 1

User-centered design script.

[PDF File (Adobe PDF File), 179KB - humanfactors_v6i1e13121_app1.pdf]

Multimedia Appendix 2

Design iterations, feedback, and solutions.

[PDF File (Adobe PDF File), 168KB - humanfactors_v6i1e13121_app2.pdf]

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Abbreviations

BPA: best practice alert
BUP: buprenorphine
CDS: clinical decision support
COWS: Clinical Opioid Withdrawal Scale
DSM: Diagnostic and Statistical Manual of Mental Disorders
ED: emergency department
EMBED: EMergency department-initiated Buprenorphine for opioid usE Disorder
OUD: opioid use disorder

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Original Paper

Designing Online Interventions in Consideration of Young People's Concepts of Well-Being: Exploratory Qualitative Study

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Abstract

Background: A key challenge in developing online well-being interventions for young people is to ensure that they are based on theory and reflect adolescent concepts of well-being.

Objective: This exploratory qualitative study aimed to understand young people's concepts of well-being in Australia.

Methods: Data were collected via workshops at five sites across rural and metropolitan sites with 37 young people from 15 to 21 years of age, inclusive. Inductive, data-driven coding was then used to analyze transcripts and artifacts (ie, written or image data).

Results: Young adults' conceptions of well-being were diverse, personally contextualized, and shaped by ongoing individual experiences related to physical and mental health, along with ecological accounts acknowledging the role of family, community, and social factors. Key emerging themes were (1) positive emotions and enjoyable activities, (2) physical wellness, (3) relationships and social connectedness, (4) autonomy and control, (5) goals and purpose, (6) being engaged and challenged, and (7) self-esteem and confidence. Participants had no difficulty describing actions that led to positive well-being; however, they only considered their own well-being at times of stress.

Conclusions: In this study, young people appeared to think mostly about their well-being at times of stress. The challenge for online interventions is to encourage young people to monitor well-being prior to it becoming compromised. A more proactive focus that links the overall concept of well-being to everyday, concrete actions and activities young people engage in, and that encourages the creation of routine good habits, may lead to better outcomes from online well-being interventions.

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KEYWORDS

well-being; youth; online intervention; participatory design; technology

Introduction

Well-being has been shown to be associated with more adaptive responses to negative life events and protection against development of mental health and behavioral problems [1]. Consequently, promotion of well-being has been recognized as a health imperative in many countries worldwide [2-6]. Adolescence and young adulthood (ie, 12-24 years of age) are characterized by significant biological, cognitive, psychological, and social development [7] and influenced by socioeconomic

and ecological factors [8]. Mental disorders are a significant disease burden in this age group [9-11]. The prevalence of mental illness in adolescents 12-17 years of age in Australia is 14.4% [12]. It is also a period during which adoption of risky health behaviors, such as tobacco smoking and unsafe sex, most commonly occur [13].

Online well-being interventions have received some attention in the literature as a viable method for improving, at scale, the well-being of young adults [14-18] due to their relevance, accessibility, cost-efficiency, and promotion of anonymity and confidentiality [19-22]. However, in addition to the concepts of well-being varying by age [23], prior research suggests that young people's concepts of well-being depend on the individual's aims and values [24]. This is significant, as even professional youth workers can have distinctly different views of well-being compared with those of young people. For example, Bourke and Geldens [25] found that young people viewed the self and relationships as the most important elements to well-being, while youth workers were more focused on social contexts and emotions. Similar research in the field reveals that, overall, younger people tend to place more emphasis on self-knowledge, competence, and self-acceptance, while older people focus more on positively coping with change [26-28]. A more recent study in the United Kingdom that investigated general well-being perceptions of 13-year-olds found that, overwhelmingly, the concept of well-being was linked to the idea of physical health, with very few participants indicating mental health as also being important [29].

Individual conceptualization of well-being also varies according to societal and cultural contexts [8,23]. For example, Chapman [30] questioned how well-being might compete or align with a range of other educative and social goals and agendas, including the achievement of academic outcomes, equity, citizenship, economic prosperity, and social cohesion.

The contested understanding of the term, its substantial increase in use, and its various social meanings make the term *youth well-being* fit for rethinking [31]. Improvements in theorizing and operationalizing youth well-being are likely to occur through strengthening the understanding of the term's multiple dimensions, based on the views, perspectives, and contexts of young people's lives [23]. Such knowledge is likely to lead to the design of more relevant and impactful policies and interventions.

This exploratory qualitative study aimed to understand how young people in Australia conceptualize the term *well-being*.

Methods

Recruitment and Sampling

The collection of data for this study was conducted collaboratively by two groups of researchers: one group in Sydney, New South Wales, and the other in Adelaide, South Australia. For convenience, and due to the nature of the sites, one site in metropolitan New South Wales (metropolitan 1, M1) and four sites in rural or regional South Australia (rural 1-rural 4, R1-R4) were chosen (see Table 1). One workshop was conducted at each of these five sites.

Participants for the metropolitan workshop were recruited using a recruitment agency and included a mix of young people who were studying, working, and unemployed. One 5.5-hour workshop was conducted in November 2013. Participants were offered a small incentive of Aus $50 for their time. The workshop was facilitated by two staff members from the Sydney group.

An additional four workshops were conducted in rural South Australian schools. In order to obtain a dataset reflective of demographics of the selected rural South Australian schools, maximum variation sampling was applied [32]. To achieve this, both public (R2, R3) and private (R4) schools were approached, as well as a school site for disengaged youth (R1). Site R2 was also approached due to its outer regional location. Schools within the selected region were approached via professional contacts (ie, school counselors and year-level coordinators) and the project was advertised within each school site, either via an assembly presentation or during morning announcements. Students were encouraged by teachers to voluntarily participate in the workshop and, as an incentive, were provided with snacks and a certificate of participation. Workshops at the four school sites were run and facilitated between June and July 2014 by two researchers from the Adelaide group.

The Workshops

Due to logistical constraints, particularly at rural schools, the workshops drew on a range of different methods deemed suitable for the context and participants. All workshops explored how young people think about and experience well-being. In addition, methods were deliberately designed to be open and encourage participants to explore the question from a range of perspectives, including using metaphors for well-being. The rural workshops (R1-R4) were run in a *World Café* style [33]. This style of workshop was chosen due to the interactive nature of this design, which catered well to the age group and classroom setting of the participants, enabling them to respond via written or oral feedback to the group. The length of the sessions ranged from 20 to 30 minutes for each school site. The workshops conducted at schools were shorter due to time constraints associated with school timetables. The following questions were asked: "Well-being—what does it look like?" and "Well-being—what does it feel like?" Students were guided during the workshop to write down and discuss answers to the above questions in small groups.

The metropolitan workshop (M1) allowed for the creation of a shared definition of well-being, mapping well-being goals, and activities that could help to achieve these goals using the photovoice method [34]. Prior to attendance, participants completed a pretask where they took photographs that signified well-being to them and brought them to the workshop. Activities included a discussion and grouping of these photographs, writing down words associated with well-being and creating a shared definition, creating a well-being journey through mapping well-being goals, and exploring what they would need to reach these well-being goals.

Table 1. Workshop locations and participant demographics.

Workshop	Details
Metropolitan general young adults (M1)	12 participants (6 male, 6 female); 17-21 years of age; metropolitan New South Wales
Rural disengaged school (R1)	6 participants (5 male, 1 female); 15-22 years of age; inner regional South Australia
Rural public school (R2)	5 participants (5 male); 15-18 years of age; outer regional South Australia
Rural public school (R3)	5 participants (4 male, 1 female); 15-19 years of age; inner regional South Australia
Rural private school (R4)	9 participants (2 male, 7 female); 15-18 years of age; inner regional South Australia

Data Analysis

All five workshops were audiotaped and the recordings were professionally transcribed. Data from each workshop were collected and analyzed as a whole, with no distinction made between comments or terms expressed by male or female participants or participants of differing ages. Inductive, data-driven coding was then used to analyze the transcript and artifact (ie, written or photographed) data [35]. This *ground-up* approach was chosen so that all data would be coded specifically to identify key themes. The analytic process described by Braun and Clarke [35] was followed; this involved (1) reading and rereading of transcripts, (2) generation of initial codes by manually identifying keywords and phrases in the transcripts and artifacts, (3) searching for themes by grouping similar keywords and phrases and inputting these into an Excel spreadsheet, (4) reviewing themes, (5) defining and naming themes, and (6) producing a report. Steps 1-3 of this process were conducted separately by the two research groups—two authors per group—with the result that each transcript was double coded. Any disagreement between coders was resolved by consensus. The research groups then met in person to review and discuss all data (Step 4) in order to summarize and reach consensus on defining the broader, overarching themes and concepts (Step 5). If the theme emerged in at least four out of five of the workshops, it was classed as a *key theme* and was reported in the Results section.

Theoretical Framework

Despite using a data-driven, ground-up approach, exploration and analysis of the data were conducted in the context of Keyes' model of well-being. The researchers coded the key themes based on Keyes' broad categories of social, emotional, and psychological well-being [36].

Results

Themes Underpinning Young People's Conceptualization of Well-Being

Overview

Well-being was found to be a diverse concept and was conceptualized in many different ways; however, similar themes emerged between groups. The seven key themes that emerged were as follows: positive emotions and enjoyable activities, physical wellness, relationships and social connectedness, autonomy and control, goals and purpose, being engaged and challenged, and self-esteem and confidence. These themes are outlined below.

Positive Emotions and Enjoyable Activities

In conceptualizing well-being, participants in both groups repeatedly described feelings of happiness and enjoyment. When discussing *happiness*, they described activities related to positive emotions, including *smiles, laughing, seeing the humor in things, making jokes, having a good state of mind*, and *positive attitude*. They also described enjoyable activities that contributed to positive emotions, including *having fun, music, celebrating, doing the things you want to do, shopping, reading, parties, drinking, surfing*, and *gaming*. One participant from the R3 site commented, "If they have hobbies it means they know themselves."

Physical Wellness

In all five workshops, physical wellness was seen as an important aspect of well-being. Participants described the absence of illness (eg, "not going to the hospital"), as well as eating healthily and engaging in physical activity, as important aspects of well-being. Some of the words and activities they described included *health, fitness, healthy eating, fruits and vegetables, exercising, organics, vitamins, swimming, sport, running, sleeping, drinking water, massages*, and *destressing*. One participant from the M1 site commented, "What you do on the outside—your exercise, food—impacts on your mental health."

Social Connectedness and Altruism

Relationships and connections to others played a large role in young people's understanding of well-being. This occurred at an intrapersonal level (eg, friends and family), as well as at a group (ie, community) level (eg, a football team or club). Participants spoke about *realizing who actually matters, making new friends, unconditional love, loyalty, building relationships*, and *being part of your community*. Such friendships occurred both online and offline and participants did not distinguish between the two. One participant from an R2 site rural school spoke about how it can be easier to make friends and be confident online: "I'm a social butterfly online."

Participants also spoke about altruism and described how behaviors including *volunteering, respecting others, treating others well, responsibility for your friends, respecting others, kindness, looking after others, thinking of others*, and *caring* can contribute to well-being.

Autonomy and Control

Across all groups, participants discussed being independent and in control of their lives and their emotions. They said well-being includes *making decisions, protecting yourself (eg, taekwondo),*

being in control of yourself, being in control of your life, being in control of your own happiness and your actions, making good choices, and *rising above.* The following quotes illustrate these sentiments:

> *Not necessarily in control of their surroundings, but in control of themselves.* [R2 site participant]
>
> *I'd feel independent, like, I'm in control of my own happiness.* [R3 site participant]
>
> *You can't exactly always rely on other people to make you happy, you have to learn to make yourself happy.* [M1 site participant]

As part of having autonomy and control, participants discussed having their own money and working. Common themes were *balance between taking time for yourself and study and work, make good choices, "normal" behavior,* and *cleaning*. Money contributed to independence, which was important for well-being, as illustrated in the following quotes:

> *Saving [money] feels like you're moving forward.* [R4 site participant]
>
> *Money also goes into part of learning...we're learning to get money, like how to get money, get jobs, we're learning how to respect our money and not just use it all, I guess.* [M1 site participant]

Goals and Purpose

Participants discussed setting and achieving goals and feeling as though they were working toward something. Concepts included *perseverance, being motivated, having hobbies, setting goals, working toward something, planning,* and *hope for the future*.

Achieving and celebrating achievement was important, including *winning a grand final, something to show for your time and effort, recognizing your achievements,* and *receiving awards and prizes*.

Being resilient was also important, particularly in the metropolitan group, as illustrated in the following quote:

> *Well, if you're feeling down, to be able to get yourself up, get yourself motivated, comes a lot from rugby, really. If you get tackled you have to get yourself up.* [M1 site participant]

Being Engaged and Challenged

A key theme related to well-being was learning new things, trying new things, and challenging yourself in order to grow. Related behaviors included *learning, going to school, being willing to try stuff, keeping your mind occupied, travelling, exploring, seeing new things, discovery, living in the moment, taking risks, learning from your past mistakes, being outside your comfort zone,* and *competition*, as illustrated in the following quote:

> *...not just comfortable, but challenged by your surroundings, like you're improving yourself because of them.* [R2 site participant]

Taking risks was also important to well-being. One participant used the example of going outside your comfort zone to make new friends, as illustrated in the following quote:

> *Getting friends, you have to take a risk, to go up to them and say, "Hi, my name is blah, blah, blah, blah, blah..." To then hang out with them and all that takes risks, your whole life is about risks.* [M1 site participant]

Self-Esteem and Confidence

Participants felt that a person who possesses well-being has high self-esteem and confidence. Rural groups commented that someone with well-being possesses confident body language and *smiles*. Other behaviors in this theme included *believing in yourself, self-acceptance, being confident, being yourself, focusing on the positives of yourself, free of embarrassment, no judgment,* and *acting on your feelings*.

Examples of Actions and Things Associated With Maintaining Well-Being—What Makes Good Well-Being Possible?

Participants had no difficulty describing actions and things that lead to good well-being and what they perceived well-being to *feel* and *look* like. Actions that they used to achieve good well-being included physical, emotional, and social activities and are described in Table 2. These actions encompassed *connecting with friends and family, food they enjoyed, focusing on the positives, having employment,* and *leading a fulfilling life*.

Thinking About Well-Being was Reactive to Stress

Although the young people in the study were able to articulate a complex understanding of well-being when asked, they did not think about their well-being on a day-to-day basis, nor did they generally work to improve it. They did not think about well-being unless there was an issue that impacted negatively on them. Young people thought more about well-being when they were stressed. The following responses were given when a workshop moderator asked the trigger question, "Do you think about your well-being?"

> *Probably when something really bad happens, is probably when you are more likely to think about yourself.* [R4 site participant]
>
> *...and in challenging situations.* [R4 site participant]
>
> *I feel like in high pressure, as well in Year 12, when things are really full on, you think "Am I sleeping enough? Am I eating enough fruit? Like that kind of thing"...cause you don't want to just fall over in a heap.* [R4 site participant]

The following responses were given when a workshop moderator asked the trigger question, "What would prompt you to think about your well-being?"

> *Whenever I am down, I suppose.* [R2 site participant]
>
> *Let's face it, crap feelings are always stronger than nice feelings because, let's face it...you usually do remember crap days.* [R2 site participant]

Table 2. Things perceived to be needed for well-being, identified by young people in the workshops, and organized according to the key themes.

Theme	Examples of actions indicating or leading to well-being	Examples of things needed for well-being
Positive emotions and enjoyable activities	Feeling happy, smiling, laughing, making jokes, positive attitude, having fun, celebrating, shopping, reading, surfing, and gaming	Music, parties, karate, motorbikes, and a good state of mind
Physical wellness	Healthy eating, exercising, swimming, running, sleeping, drinking water, destressing, and relaxing	Health, fitness, sport, massages, organics, vitamins, and fruits and vegetables
Social connectedness and altruism	Talking, accepting others, getting together, loyalty, becoming part of teams or clubs, making new friends, being part of your community, fitting in, volunteering, respecting others, treating others well, responsibility for your friends, kindness, and caring	A support network, friends and family, and unconditional love
Autonomy and control	Protecting yourself, being in control of yourself, being in control of your life, making good choices, rising above, being independent, clearing your mind, letting things go, work-life balance, and "normal" behavior	Safety, stable home life, long drives, freedom, and money
Goals and purpose	Perseverance, being motivated, setting goals, working toward something, planning, hoping for the future, and recognizing your achievements	Receiving awards and prizes, having purpose or a purposeful lifestyle, and having hobbies
Being engaged and challenged	Learning, going to school, travelling, exploring, discovery, living in the moment, taking risks, learning from your past mistakes, being outside comfort zone, and competition	A career
Self-esteem and confidence	Body language, believing in yourself, self-acceptance, being confident, being yourself, being free of embarrassment, and no judgment	Not applicable

The following response was given when a workshop moderator asked the trigger question, "What does it feel like when you don't have well-being?"

> *I picture it [well-being] like a plank of wood...when life sucks, it's splintered, but when it's not, it's like smooth, yeah collected.* [R4 site participant]

Subthemes

Subthemes that emerged in the rural groups, but did not feature in the metropolitan group, related mainly to the role of place in young people's lives and the concept of *fitting in*. Rural participants spoke about challenges specific to farming and how they found it difficult when people "from the city judged" their way of life. They commented that although diversity was good, there was also the small-town mentality that being "different is evil." Themes related to nature (eg, keywords like *the sea*, *walking on the beach*, *outdoors*, *camping*, *lakes*, and *environment*) occurred only in the metropolitan group and not at all in the rural groups.

Discussion

Principal Findings

Although the workshops were conducted in five separate locations, similar themes around how well-being is conceptualized by young people emerged in each group. The findings from this study confirm that well-being is indeed multidimensional, with each of the seven themes identified well-supported by previous research [24,25,37]. Both the pursuit of activities leading to positive experiences that satisfy their desires (ie, hedonic) and a focus on autonomy, purpose, social connectedness, and achieving goals (ie, eudaimonic) contributed to young people's conceptualizations of well-being [38].

Comparison With Prior Work

Keyes' general well-being categories, for example, social, emotional, and psychological well-being [36], were broadly reflected in this study's results. Our study revealed that young people place high importance on the theme of social connectedness and altruism, which forms part of Keyes' social well-being construct [36]. This theme is also reflected in Bourke and Geldens' relationships dimension [25], Armezzani and Paduanello's relational style of well-being [24], and the relationships component of the *positive emotion*, *engagement*, *relationships*, *meaning*, and *accomplishment* (PERMA) model [37], which emphasizes a person's relationships with family, friends, colleagues, and community. The workshop participants, especially those from the rural workshops, spoke of connecting with others and maintaining friendships online (eg, via social media or online gaming). This is consistent with prior research on online interactions, which found that the social interactions in online gaming form a considerable element in the enjoyment of playing, with a high percentage of gamers making long-term friends and meeting partners [39].

The importance of physical wellness for well-being among the participants is consistent with Bourke and Geldens' [25] physical dimensions. This is also consistent with Armezzani and Paduanello's [24] healthy style of well-being, which focuses on reaching a state of physical balance and avoiding situations

that could be a source of physical disorder (eg, smoking, an unhealthy diet, drugs, alcohol, and stress). The workshop participants described physical health as the absence of illness (eg, "not going to the hospital"). These findings highlight how youth-centered understandings of well-being contrast with a disease model, in line with previous research by Graham [40], who found that the discourse around well-being was inherently medical. As a result, what it means to be *well* comes to be defined by the absence of physical symptoms; in other words, to be well is to be not *unwell*. Although themes related to physical health have emerged strongly elsewhere [24], the theme of physical wellness did not particularly dominate in this study. The importance of language in studies of this nature should not be overlooked. In Singletary's [29] study on young people's perceptions of mental and physical health, the term *well-being* was not used when surveying participants. Singletary's findings differ from this study in that only 8% of the young people interviewed perceived being healthy to mean being physically healthy. Another study by Easthope and White [41] found that young people associated the term *health* with things like maintaining a good diet, exercising, and avoiding bad habits, such as smoking and binge drinking; in contrast, *well-being* was strongly associated with social relationships. This suggests that for young people, the terms *well-being* and *health* are conceptualized quite differently, with *well-being* encompassing the broader, holistic human experience and *health* being more limited to physical factors.

This study found that young people generally only think about their well-being in times of stress. Similarly, Bourke and Geldens' [25] holistic dimension of well-being views well-being as linked to emotional responses to problems that occur in a young person's life. Similarly, Heady and Wearing [42] propose that stable well-being occurs when individuals have the psychological, social, and physical resources they need to meet a particular challenge. When individuals face more challenges than resources, their well-being is adversely affected [43]. The challenge for programs designed to improve well-being, therefore, is how to help young people address and monitor their well-being before it becomes compromised. This might be achieved by proactively encouraging the development of good habits and increasing resilience by helping young people to think more about caring for their physical and mental health as a matter of routine.

Despite only thinking about their well-being during times of stress, young people in this study were able to give examples of specific actions and things that lead to positive well-being. Honey et al [44] found that young people identified *activities* (eg, study, sport, and parties) and *having things* (eg, food and money) as two important foundations of well-being. Lal et al [45] also found that an important part of the youth experience of well-being was engaging in certain types of activities or *action-oriented states* (eg, exercising). The list of examples described during this study was extensive, stretching across all of the key themes and elements that encompass characterization of well-being.

Linking such key elements of well-being with existing actions and behaviors that young people are familiar with has implications for the design of interventions to promote the active pursuit of well-being. The key to intervention design may be to not promote well-being per se—because clearly young people already know it exists and know what to do to maintain it—but rather to use a strengths-based approach to build on existing practices (eg, running, listening to music, and connecting with friends) in ways that enhance and increase young people's capacity for well-being. In line with McLeod and Wright [31], findings from our study show that the term *well-being* is a conceptually diverse term for young people. In light of this, it may be more effective for interventions to focus less on the term *well-being* and more on the concrete categories into which elements of well-being can be divided and, in particular, target the actions that can lead to specific improvements. The aims of well-being interventions should perhaps be reframed to resonate with young people's own views of what they consider as valuable and meaningful ways to achieve and maintain well-being.The finding that themes related to nature (eg, keywords such as *the sea*, *walking on the beach*, *outdoors*, *camping*, *lakes*, and *environment*) occurred only in the metropolitan group and not at all in the rural groups may simply be because young people in rural areas take being close to nature (eg, more space, more greenery, and smaller population) as a normal part of life; therefore, they may not have felt the need to mention it as something which contributes to their well-being. The metropolitan group may have felt a greater sense or *need* to frequently visit more *natural* places, due to residing in more built-up, less *green* areas. These differences between the rural and metropolitan groups warrant further comparative research. It should also be recognized that the young people from the metropolitan workshop were older on average than those from the rural sites. This could possibly account for the few differences in well-being conceptualization, as the young people were at different stages in their lives (ie, high school and starting university) [29].

Limitations

This study had a number of limitations. There was an uneven representation of participants from metropolitan and rural sites. As well, the rural participants were primarily sampled from inner regional sites and were, consequently, unrepresentative of young people living in outer regional and remote Australian locations. Therefore, any findings related to location should be understood in this context. In addition, the method of data collection differed between the metropolitan and rural sites with different questions and stimuli used (eg, the metropolitan group was asked to bring in photos while the rural group was not). However, the different methodologies were not compared in terms of their effectiveness, but should rather be viewed as complementary. These differences in approach between the rural and the metropolitan groups reflected logistic difficulties in setting up workshops at the rural schools. In the rural schools, time constraints meant we were only able to have one session with the participants and it was not possible to have them bring photographs to the classroom using the photovoice approach. For this reason, the World Café style of workshop was adopted.

The data were analyzed as a whole for each group, with no distinction made between comments or terms expressed by participants of differing gender or ages; as well, the socioeconomic status of individual participants was not gathered.

While it may have been interesting to investigate differences in conceptualization of well-being between male and female participants and between participants of different ages, this was not the primary focus of the study. Despite the slight variations in method and relatively small sample size, the data derived from the workshops were comparable in that they both involved activities designed to generate participants' concepts of well-being.

Conclusions

The findings from this study suggest that well-being is a multidimensional concept when conceptualized by young people, with each of the seven themes identified—positive emotions and enjoyable activities, physical wellness, relationships and social connectedness, autonomy and control, goals and purpose, being engaged and challenged, and self-esteem and confidence—being well-supported by previous findings [24,25,36,37]. Young people's concepts of well-being were diverse and personalized, shaped by ongoing individual contextual experiences related to physical and mental health, along with ecological and social factors.

Since it appears young people think mostly about their well-being in times of stress, the challenge with online well-being interventions is how to get young people to monitor their well-being before it becomes compromised. A more proactive focus may be the key here, that is, linking the overall concept of well-being to everyday, concrete actions or activities young people engage in and encouraging the creation of routine good habits.

The aims and design of online well-being interventions should resonate with young people's own views. Well-being should be reframed not in terms of a deficit-based response to a problem, but rather as something that can be proactively fostered. Further research could investigate more about what young people would value most in an online well-being intervention and what factors might best trigger its use.

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Authors' Contributions

NB, MW, GV, VB, SO, and GA conceived of and designed the study, contributed and supervised data collection, analyzed and interpreted the data, and drafted the manuscript. MN contributed to the design and analysis of the metropolitan workshops. GS contributed to the design of the study and performed the critical revision of the intellectual content. All authors read and approved the final manuscript.

Conflicts of Interest

GV and VB work at Young and Well Cooperative Research Centre. GS works at Country Health South Australia. MW and NB work at Flinders University.

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Abbreviations

PERMA: positive emotion, engagement, relationships, meaning, and accomplishment

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