# Reenvisioning Patient Education with Smart Hospital Patient Rooms

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Smart hospital patient rooms incorporate various smart devices to allow digital control of the entertainment — such as TV and soundbar — and the environment — including lights, blinds, and thermostat. This technology can benefit patients by providing a more accessible, engaging, and personalized approach to their care. Many patients arrive at a rehabilitation hospital because they suffered a life-changing event such as a spinal cord injury or stroke. It can be challenging for patients to learn to cope with the changed abilities that are the new norm in their lives. This study explores ways smart patient rooms can support rehabilitation education to prepare patients for life outside the hospital's care. We conducted 20 contextual inquiries and four interviews with rehabilitation educators as they performed education sessions with patients and informal caregivers. Using thematic analysis, our findings offer insights into how smart patient rooms could revolutionize patient education by fostering better engagement with educational content, reducing interruptions during sessions, providing more agile education content management, and customizing therapy elements for each patient's unique needs. Lastly, we discuss design opportunities for future smart patient room implementations for a better educational experience in any healthcare context.

CCS Concepts: • **Human-centered computing → Human computer interaction (HCI)**;

Additional Key Words and Phrases: smart hospital, smart patient room, smart home technology, accessibility, patient education

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## 1 INTRODUCTION

Smart hospitals leverage technology, sensors, and data to enhance patient care, improve operational efficiency, promote patient safety, and empower healthcare professionals with advanced tools for diagnosis and treatment. Our previous study of smart patient rooms (SPR) focused primarily on the patient experience [16]. In this study we look beyond the patient experience to examine the impact of these ubiquitous smart technologies on healthcare workers as well. For this project, we studied the rehabilitation educators employed by the University of Utah Health Craig H. Neilsen Rehabilitation Hospital (NRH) outfitted with SPRs (see Section 3.1 for details). The educators spend their day meeting with patients one-on-one in an SPR; therefore, they can provide insights into the experience of working with patients in this space.

The primary role of rehabilitation educators is to provide education (PE) for patients. PE — the process of teaching patients to maintain or improve their health through changes in knowledge, attitudes, and skills [55] — is important in all hospital contexts, but in a rehabilitation hospital, it is particularly complex due to the types of patients admitted for treatment [14]. We know from the medical literature that rehabilitation education can

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help patients significantly improve their health and independence. Simply teaching patients how to prevent pressure sores can help them avoid possible infection, sepsis, and death [13], in addition to another hospital visit costing between $500 and $70,000 in the US [9]. How educators implement health education can affect the scope of the patient's knowledge during and after rehabilitation [18]. Therefore, we are interested in how rehabilitation educators at the NRH are implementing health education using SPR technology as a medium for presenting educational material and as a logistical aid to support education. This study allowed us to peer into the future possibilities of PE conducted in smart hospitals.

Some prior work has explored different technology uses for PE, but none focuses on using smart home technology in this context. We explore this gap and report on how SPRs can support PE, focusing on the following research questions (RQ):

**RQ1:** How do educators use the features of the SPRs for rehabilitation education?
**RQ2:** How have the SPRs impacted educator tasks outside of the patient education session?
**RQ3:** How do SPRs help educators assist patients and caregivers in engaging with and managing information?

In this paper, we report our findings from observing 20 PE sessions in the form of contextual inquiries (CI) to examine the educator's workflow. After analyzing the CI data, we conducted semi-structured interviews with all four rehabilitation educators employed by the NRH to refine the themes and collaboratively brainstorm ways technology can be used for an improved PE experience. Our findings report on the many facets of using SPRs for rehabilitation education. This study contributes a new understanding of how smart home technology deployed in a hospital impacts PE and provides insights into how SPR technology can assist educators in engaging with their patients better, reduce interruptions during sessions, and provide a more agile knowledge management solution for tracking rehabilitation progress and helping the patient manage educational content.

## 2 BACKGROUND AND RELATED WORK

Prior studies have looked at some specific technologies that can aid PE and the challenges of implementing new technology into a hospital setting; however, using smart home technology in SPRs as a tool for rehabilitation education is unexplored. This section first provides some basic background on rehabilitation hospitals and PE. Then, we position our work among the related literature that informs our research questions.

### 2.1 Background on PE and the Rehabilitation Hospital Context

PE is defined as the process of influencing patient behavior and producing the changes in knowledge, attitudes, and skills necessary to maintain or improve health [55]. Effective PE is necessary because unhealthy lifestyles are linked to major causes of death in the US [52], and it also enhances trust and empowers patients in their healthcare. PE requires assessing patients' educational needs, overcoming barriers to learning, providing clear counseling, using various education materials, and finding effective ways to integrate education into the patient's treatment [55]. As such, education is an essential component for achieving rehabilitation progress during a patient's stay [14].

Patients in a rehabilitation hospital have busy schedules filled with occupational, physical, and speech therapy sessions. Rehabilitation hospitals employ occupational therapists, physical therapists, speech therapists, nurses, and other medical providers who all provide therapy and education to the patient. The NRH also employs four dedicated rehabilitation educators who focus specifically on the education aspect of rehabilitation. Having dedicated educators reduces the burden for therapists and nurses to perform education on top of their regular duties. As a team, all the providers for a patient help build an individualized curriculum. The curriculum contains a list of requirements for the patient to accomplish during their rehabilitation journey in the hospital, including topics such as fall prevention and prevention of urinary tract infections.

A rehabilitation hospital is a special type of hospital dedicated to treating patients recovering from any injury, illness, or medical condition resulting in reduced cognitive or physical function. They generally admit patients following stabilization at an acute care facility — like an emergency room or intensive care unit. The central goal of rehabilitation hospitals is to prepare patients for their life after discharge. Patients need to know how to manage their self-care activities and cope with any new changes to their bodies and abilities; this is all part of the education they receive throughout their inpatient time. In a rehabilitation hospital, the anticipated duration of a stay varies by the type of patient. A stroke patient might be discharged in as little as two weeks; however, for spinal cord injuries, the average patient stay is over 60 days [19]. Due to the severity of the injury, a supporting family member (informal caregiver) often accompanies the patient to provide support throughout the hospital stay. Informal caregivers can either commute to and from home or stay in the patient's room if desired. They will often accompany the patient to therapy and education sessions while visiting the patient.

## 2.2 PE Supporting Technologies, SPRs and the Challenge of Implementing New Hospital Technology

Hospitals have used a variety of technologies as a tool for PE. Previous literature looked at using off-the-shelf consumer technology, like iPads for telemedicine, as a feasible way to deliver care for spinal cord injury patients [42]. Technologies that facilitate asynchronous patient learning, such as on-demand video [30] or an online e-learning tool [65], have also been explored. Researchers have even built virtual assistants for healthcare consulting roles that help support PE [59, 64]. Beyond a focus on a specific new technology, other research has developed a design framework for PE websites [54] as well as general design considerations for creating PE technology [37]. Similar to how these examples investigated ways technology can improve the PE experience, in our study, we want to see if the SPR is also a valuable tool.

Studies on smart hospitals and SPRs are less prevalent in the literature. In 2014, there was initial work on smart intensive care units [24–26, 63], but the focus was on adding sensors to feed information to providers rather than for the patient to use. Other research on SPRs did include smart home technology; for example, using a tablet and watch withc voice assistance technology such as Amazon Alexa — to transform the patient experience [2]. Even more similar to our research environment, one study had an SPR where the lights, blinds, TV, and bed could be controlled through a touchpad device [40]. However, both of these example SPR studies only used one prototype room. In contrast, the hospital where we conducted this study has fully incorporated SPRs. Since we could observe real PE sessions in a functioning smart hospital setting rather than a lab study, we can better account for the user experience [44].

New technology introduced into a hospital setting can come with pitfalls and challenges. Fitzpatrick et al. highlighted that new technology may result in intended and unintended organizational consequences [20]. For example, early adopters of digital medical records found them to be useful for bureaucratic purposes but out of touch with the needs of clinicians [28], and using digital records seemed to freeze data in unhelpful or restrictive ways [27]. Additionally, giving a cart-on-wheels computing solution to nurses did not replace their use of paper artifacts as expected [66]. Other research highlighted how minor changes to nurse work practices and workflows resulted in lost information [36, 70]. Worse still, another study showed when employees encounter usability barriers with new technology, they may abandon it, as was observed in a study where Vocera mobile communication devices were introduced for nursing [67]. In light of this work, we want to explore all the benefits, challenges, and possible unpredicted outcomes of integrating PE with the SPR.

Beyond the challenges of introducing new technology, the hospital environment itself can affect education. A hospital is busy with many potential and unavoidable disruptions, which can derail PE sessions. Previous research has shown that interruptions and distractions can affect workers' productivity and well-being, especially if they occur during an inconvenient moment [46, 62]. These interruptions can come from other hospital staff following their regular workflow caring for the patient [69]; for example, nurses checking vitals, nutrition taking a meal order, or janitorial services restocking supplies. Any distraction can compromise patient quality of care [21]. Healthcare providers such as patient educators must learn to cope with these distractions [43]. We are curious to see if the SPR technology can help minimize distractions for educators.

To build on the previous work, we wanted to look at the impacts of SPRs as a tool for PE, including any challenges or barriers and ways the educators have overcome them. To examine the impacts, we propose the following research question **RQ1:** How do educators use the features of the SPRs for rehabilitation education?

### 2.3 Essential Rehabilitation Educator Tasks outside of Patient Care and the Technology That Supports It

Delivering education to patients is just one of several tasks, albeit the primary one, that rehabilitation educators execute as part of their workflow. Beyond working with patients, there are other essential tasks where the SPR technology might be able to assist. Patient charting is one task that can take a considerable amount of time. One study showed that physicians could spend on the order of 35% of their clinical time charting [38]. Because charting takes so much time, it can create a dilemma where healthcare workers must juggle between caring for patients and "caring for the medical record" [56]. Generally, the transition to electronic medical records from paper charting has been regarded as valuable to patient care and hospital operations [53] and is an important step if technology is going to assist with charting. Anytime there is a change in workflow with electronic records, like adopting a new electronic health record system, it can come with many challenges and pitfalls [31].

The idea of automated charting has been around since the 1980s [23], though the prediction that charting would be automatic without interfering at all with the healthcare worker's patient care is still a dream. Automated charting has shown the potential to decrease administrative burden and increase patient care time [4] and researchers are trying new ideas to automate charting, like using human activity recognition for nursing care records [32]. We want to expand on this work and investigate any workflow impacts, like a reduction in charting burden, that comes from having SPRs. Based on the prior literature, we ask **RQ2:** How have the SPRs impacted educator tasks outside of the patient education session?

### 2.4 Patient and Caregiver Engagement and Management of Education Information and Materials

Rehabilitation patients face challenges intrinsic to their condition and environment that impact engagement and learning. Prior work showed that the hospital's physical environment could be an isolating and lonely experience for patients and negatively affect their rehabilitation experience [3]. In HCI literature, Bickmore et al. even called the hospital inpatient experience "one of the most disempowering situations one can experience" [8]. In addition to being a patient in general, rehabilitation patients must grapple with the trauma from their injuries, and prior work has looked explicitly into the barriers and facilitators of PE during their stay [14]. Some of these barriers are caused by the patient's perception of their injury; those with spinal cord injuries have varying attitudes towards their condition, making engaging and learning difficult [1]. Other barriers to understanding information can occur due to the physical and cognitive barriers developed due to their medical condition [58]. Additional factors such as anxiety and distress, age-related memory function, and perceived importance of information can also affect the patient's ability to engage [41, 68]. When patients are engaged, it leads to better health outcomes and healthcare experiences [47]. Since patients staying in SPRs expressed feeling positive effects on their wellbeing [16], we want to explore if it affects engagement and learning during education sessions.

Since the education sessions are to prepare patients for transitioning to home, we know from Pollack et al. that there are three key elements to this process: knowledge, resources, and self-efficacy [57]. Three findings from this study specifically resonate with our own: 1) information transferred to patients occurs verbally, which makes it difficult for patients to process and remember; 2) patients lack the necessary expertise to integrate the knowledge back into their lives; and 3) patients and caregivers often have low self-efficacy [57]. Their results demonstrate the need for additional support tools, which we hope the SPR technology can provide. Other HCI researchers looked at ways of managing knowledge and resources by designing better health informatics systems to facilitate health information retrieval for patients [34, 35]. While researchers have identified the need for additional PE support tools, and some systems exist, there is a gap in research looking specifically at how smart technology might help educators assist patients in managing knowledge and resources provided during their hospital stay. To understand this dynamic, we ask the following question **RQ3:** How do SPRs help educators assist patients and caregivers in engaging with and managing information?

## 3 METHOD

We observed 20 patient education (PE) sessions — in the form of contextual inquiries (CI) — between educators, patients, and their informal caregivers. We took field notes during the CIs and then used thematic analysis to interpret the results. After analyzing the data from the PE sessions, we conducted semi-structured interviews with all four rehabilitation educators to validate our observations and discuss with the educators how they used the SPR technology and other ways technology might improve the PE experience. These interviews were also transcribed, coded, and included in the thematic analysis.

### 3.1 Research Environment: The Smart Patient Room

The NRH, where we conducted this study, is a public US university hospital that opened in 2020 and was built with technology in mind. It is just like any other in function; however, smart home technology is incorporated in all 75 patient rooms. The infrastructure for the smart features was built-in during the initial construction. Each patient room contains a smart television and soundbar, with cable channels, Apple TV, AirPlay, and a bedside HDMI input as entertainment options. Smart lights, blinds, and a thermostat allow for adjusting the patient room environment. All smart features are controlled through an app on a hospital-furnished iPad or the same app on a personal device running Android or Apple iOS (see figure 1). In some patient rooms, the door can also be opened, partially opened, or closed from the app. The smart room supports different control modalities based on the patient's level of mobility — including capacitive touchscreen, voice commands, other accessible controllers that work with Android or iOS devices, or traditional wall switches and remote controls. The hospital elevators are another feature outside of the patient room that the app can control. This allows patients with limited mobility in power wheelchairs to traverse any hospital floor using voice control with the app. The NRH's implementation of smart home technologies in the patient room is significant because it effectively turned every patient room into an SPR.

### 3.2 Participants

All four rehabilitation educators (see Table 1) volunteered to participate in both the CIs and interviews. As for the patients (referred to as P1-P18 in this paper), we drew a purposive and convenient sample from individuals receiving care at the NRH. The educators helped screen patients with cognitive impairments who were unable to consent. We also recruited the patients' caregivers since they participated in the PE sessions. The educators helped identify PE sessions to observe based on the following inclusion criteria for their patients:

(1) At a minimum, 18 years old
(2) Able to tolerate a 30 to 60-minute engagement (with breaks as needed) for an interview session
(3) Able to communicate in English
(4) Capable of making informed consent

The only exclusions we had from this study were stroke and complex brain injury patients who could not consent. This impacted CI opportunities with Mei and Safiya (pseudonyms, see Table 1), considering they primarily handle those types of patients. Still, we gathered valuable data on their experiences through the interviews. Since


Fig. 1. A smart patient room in the NRH. On the overbed table, a hospital-furnished iPad is running the smart room app. Each patient room is equipped with smart lights, blinds, thermostat, door, television, and soundbar that can be controlled with an app installed on the iPad or on a personal device.

this study is focused on the educators' use of technology to facilitate PE — and at the direction of the University of Utah Institutional Review Board (IRB) to maximize patient anonymity — we did not record patients' personally identifiable, protected health, or demographic information. The patients generally represented the breadth of patients that are served by the NRH. The IRB did allow us to collect demographic information for our primary participants, the educators (see Table 1).

Table 1. Interview Participants Details. Interview participants ranged in age from 34-48, with an average of 11.75 years of rehabilitation experience. Tech Level is their self-reported level of expertise with technology on a scale from one to five (one being little to no experience with technology, and five being an expert with technology); they all rated themselves as average to slightly above average with technology. They had a range of experience with smart home technology installed and used in their own home before working in the NRH with SPRs. The purpose of the last two columns is to show their basic technology comfort level and their prior personal experience with smart home technology before working in an SPR.

| ID / Pseudonym | Age / Gender | Education Level | Years in Rehab | Tech Level | Smart Technology Used at Home |
|---|---|---|---|---|---|
| E1 / Alia | 40 / F | Master's | 14 | 3 | Alexa, Thermostat, Lights, Switches, Locks, Smart TV |
| E2 / Carine | 34 / F | Master's | 9 | 3.5 | Alexa, Google Assistant, Thermostat, Lights, Switches |
| E3 / Mei | 38 / F | Doctorate | 16 | 3.5 | Alexa, Thermostat, Lights |
| E4 / Safiya | 48 / F | Doctorate | 8 | 3.5 | Smart TV |

### 3.3 Consent Process

At the start of the project, we obtained consent from the rehabilitation educators. Before the start of the PE session, we also obtained consent from the patients and caregivers. Communication can be a significant challenge for rehabilitation patients since their injury might affect their ability to speak, write, or point [39]. Due to these limitations, consenting patients with severe impairments can be difficult, but we wanted to be as inclusive as possible in our research. So, we offered some accommodations. One example is for consent; we reviewed the consent form aloud and then had the patient verbally agree or provide any other gesture of agreement — like nodding their head if speech is difficult. The IRB approved this modified procedure.

### 3.4 Data Collection and Analysis

We conducted CIs on 20 PE sessions (referred to as CI-1 through CI-20, see Table 2 for details) and follow-up semi-structured interviews with the four educators. The CIs lasted approximately 30-60 minutes — the time of the PE session plus some additional observation of tasks outside the session. Before the session, we would meet with the educator to observe them do any preparation tasks for the PE session. During the session, one observer from the research team would place themselves in a position to observe without interfering and would only interrupt to ask clarification questions. At the end of the session, the observer would ask follow-up questions to understand each participant's perspective. Following the PE session, they would continue to observe the educator perform post-session tasks. The CI would end once the educator had completed all their tasks and started preparing for the next session. Throughout the CI, the observer took handwritten field notes; then, following the session, transcribed them into a digital format. Then all three members of the research team would meet to help interpret the observer's notes drawing out any additional nuance.

Table 2. Contextual Inquiry Details. For each educator, we list how many CIs were conducted and how many unique patients and caregivers we observed during those sessions. For Carine, we conducted three separate CIs on different education topics with the same patient (hence 7 CIs and only 5 Patients). These three sessions were the only ones observed with the same patient. Mei and Safiya primarily handle stroke and brain injury patients; therefore, there was less opportunity for CIs since a lot of their patients are unable to give informed consent. A caregiver was present for nearly half of the CIs.

| Educator | CI Sessions | Patients | Caregivers | CI Session Details:<br>CI-Number:Patient Number/Caregiver Number (if present) |
|---|---|---|---|---|
| Alia | 9 | 9 | 5 | CI-1:P1, CI-2:P2/P2c, CI-4:P6, CI-6:P7/P7c, CI-11:P10/P10c, CI-14:P12/P12c, CI-15:P13/P13c, CI-17:P15, CI-18:P16 |
| Carine | 7 | 5 | 2 | CI-3:P3, CI-5:P4, CI-7:P5, CI-8:P8, CI-9:P4, CI-12:P4, CI-13:P11/P11c |
| Mei | 3 | 3 | 1 | CI-10:P9, CI-19:P17/P17c, CI-20:P18 |
| Safiya | 1 | 1 | 1 | CI-16:P14/P14c |
| Total | 20 | 18 | 9 | |

To analyze the data, we extracted critical observations from our field notes as 189 individual interpretation fragments. Then we analyzed the fragments using thematic analysis [10]. Taking a bottom-up inductive approach, the three authors collaboratively coded the fragments generating 60 codes. We discussed each code as a team to ensure it holistically captured the observation details, continually discussing its wording until we reached a consensus. We then grouped the codes into higher-level themes. Like the coding process, we would discuss the wording of a theme until reaching a consensus that it comprehensively represented all the codes in the grouping. We iterated on these themes multiple times, exploring different combinations of codes that brought out the nuance in the data. At the end of the CI analysis, we settled on seven themes.

Based on the observations, codes, and themes from our initial analysis, we developed questions to ask the educators during follow-up semi-structured interviews. According to Beyer and Holtzblatt, "The core premise of Contextual Inquiry is very simple: go where the customer works, observe the customer as he or she works, and talk to the customer about the work" [7]. During our CIs, we could go where the educator worked and observe them; however, since they were performing actual PE sessions, we limited our questions. Therefore, we conducted dedicated follow-up semi-structured interviews with the four rehabilitation educators to gather any missing data from the CIs. We targeted questions about their experience with the SPR technology, the value or drawbacks they see in it, and any ideas for improving the technology to enhance PE.

The four semi-structured interviews lasted an average of 43 minutes and were audio-recorded, transcribed, and coded using the same thematic analysis technique. The transcriptions resulted in 304 new quotes for coding. For the second round of analysis, the authors used the already established codebook from the CIs to code the new interview data rather than entirely inductive coding. Building on the original 60-code codebook, we merged two codes, modified two, and added 23 for a new total of 82 codes. Although there was an increase in codes, we developed only one new theme (bringing the total to eight) based on the interview data. The majority of the new codes bolstered the original seven themes. The interviews and further analysis were critical for interpreting, validating, and discovering additional nuances not fully brought out in the initial CI analysis.

## 4 FINDINGS

Through our analysis, we gained a rich, in-depth understanding of the educators' workflow and SPR technology usage. We developed eight high-level themes grouped into three categories according to what research question the theme helps to answer.

### 4.1 Educators Developed New Techniques for Patient Education (PE) Using the SPR Features

The educators deliver content to the patient, primarily through regularly scheduled PE sessions. The data we collected yielded numerous insights into how the SPR technology is currently used, challenges and pitfalls, and opportunities to innovate on the smart technology for PE. The three themes — used as the subsection titles — help answer **RQ1:** How do educators use the features of the SPRs for rehabilitation education?

*4.1.1 How educators use the SPR technology for PE and the challenges they faced.* For managing and displaying educational content for the PE sessions, educators used a combination of their laptops with the smart home technology in the room. In her interview, Carine provided good background context by explaining how education was done before SPRs,

> *When we were doing rehab education in the old building, it was always just on a small laptop screen. And so that was definitely an issue like the battery would die, or like it's a small screen. And I would remember like, my arm would just burn because some sessions, I just hold it the whole session for like, multiple sessions in a row.* (Carine)

Carine would hold the laptop to easily change slides and avoid intruding on the patient's space by placing it on their bedside table. With this description of how PE was done before, how can the features of the SPR improve the experience? It became evident that the SPR provides some advantages for PE over typical hospital rooms.

Each SPR has a dedicated iPad, primarily for patients to control the room's environment and entertainment, but we observed that educators also use the iPad to display educational content. As an example, during CI-13, the caregiver asked to see the slideshow too. So, Carine helped the patient AirPlay the iPad to the smart TV. Similar uses occurred in eight other sessions we observed. Basically, anytime the educators needed a larger display, they used AirPlay to screencast content from their laptops or the SPR iPad to the Apple TV in the room.

> *When I'm doing education, so, I'll use the iPad to control the patient's TV, put it on Apple [TV] mode, and then I'll project my PowerPoint presentations from my laptop to the patient's TV, so they can see it larger on the big screen in their room.* (Mei)

Based on follow-up questions we asked the patient during the CI, we found that AirPlaying on the TV's larger screen was more engaging and allowed their caregiver to see and participate as well. As Alia stated during her interview, "It fosters, I feel, more engagement. More than me, just like talking." Though, they can still use the smaller screen of the iPad or their laptop if they are trying to be discreet for sensitive topics. Despite the positive reaction to using AirPlay, educators identified that it is not designed for an enterprise setting like a hospital. All Apple TVs on the network show up in the AirPlay list, raising concern from Mei, "My biggest fear is that I'm going to AirPlay on to the wrong TV." They noted that it was easy to accidentally airplay to the TV of somebody else, and they were sensitive to the disruption that it could impose; AirPlaying to someone else's TV might cause it to turn on, or if it is already on, it will interrupt the viewing experience to show the AirPlayed content. Additionally, since all AirPlay devices on the network show in the AirPlay list — whether controlled by the hospital or not — educators say they sometimes see inappropriately named devices. As Mei stated, "That one network that comes up a lot is 'Don't F**king AirPlay Here.' And the patients can see that." Beyond an iPad and smart TV with AirPlay capability, the SPR also allowed educators to create an environment conducive to the education session using smart lights, thermostat, and blinds.

> *I also use the smart app for lighting in the room for adjusting the shades when I'm going to deliver education if there's a glare or the patient looks uncomfortable.* (Safiya)

Interestingly, some patients use the iPad to prepare for a PE session. As Carine highlighted,

> *I have had some patients, though, who they want to use their voice control to turn on the TV or turn on the Apple TV. And are proficient and can do that all themselves during our sessions. [. . . ] They're like, oh, you're here. So, they're like, they turn off their cable, they get the Apple TV going, and they know I'm going to stream to it.* (Carine)

The SPR gives patients with limited motor function the ability to assist the educator in setting up the learning environment; this is something that could not be done in a traditional hospital room. Mei explained why she thinks patients want to use the SPR features to help set up a session,

> *[. . . ], it gives them a sense of contribution and productivity and the satisfaction that they are able to help someone else [the educator], while they have likely only been on the receiving end of help since their injury until that moment. While this in itself is a relatively small task or contribution, I like to think this contributes to a more global realization that as they reintegrate into the community following rehab, that they will be able to contribute to home, work, or other meaningful environments via technology.* (Mei)

With these benefits, the educators also voiced challenges. When the SPR technology did not work as planned, it created visible frustration for the educator and patient and delayed the education session.

> *When it doesn't work how it should, it can be very time-consuming. And then it takes away from the time I'm able to spend with the patient doing meaningful things. [. . . ] And so, if I'm spending 15 minutes trying to fiddle around with AirPlay, I still need to get to my next patient in 15 minutes. So, that's just education that that patient is missing out on that needs to be made up another day. And then I think it decreases patient experience, patient satisfaction. Because it's wasting their time, it's wasting my time.* (Mei)

Despite some frustration when the technology doesn't work, Mei clarified that the SPR technology is truly beneficial for PE, "The benefits do outweigh the challenges because it works, I would say, 90% of the time."

*4.1.2 How smart technology can address some difficulties of doing PE in a hospital setting.* The patient room environment is challenging for PE because it accommodates several uses: the patient's temporary home, a treatment space for providers, and a makeshift classroom for PE sessions. Since the room is multi-use and multi-function, we observed numerous disruptions during the CIs. We found that it was common for other hospital staff to interrupt PE sessions to perform their duties: nutritionists taking the patient's meal order (CI-3, CI-13, and CI-17); environmental services cleaning and restocking supplies (CI-2); nursing to adjust oxygen levels, provide medication, and conduct vitals checks (CI-2, CI-13, and CI-19); and other therapy staff or physicians, unaware of the patient's schedule, would occasionally drop in (CI-19). Safiya provided insights into the problem,

> *I've had a little head-to-head with some that don't understand that them being in the room when I'm with a patient, particularly a cognitively impaired patient, [. . . ] it's distracting for me, and it's a lot of times very distracting for the patient. So, and they'll say, oh, I just want to mop, or I just want to get the garbage. No! And I'll say, please come back.* (Safiya)

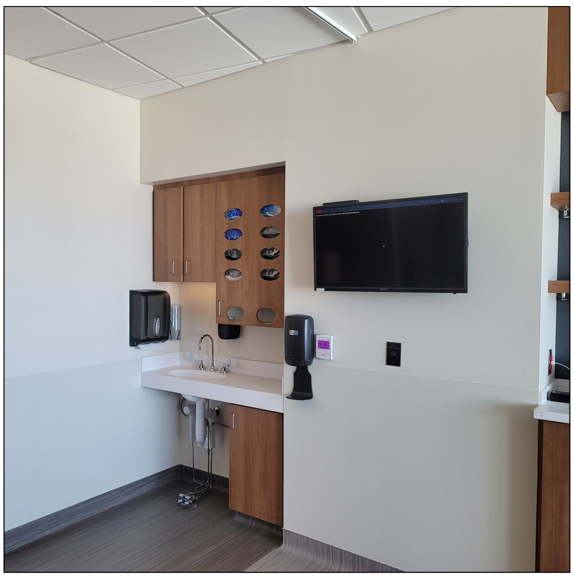

Fig. 2. As part of the smart patient room technology, ordinary whiteboards were replaced with digital whiteboards that link directly to the electronic medical record. These smart displays are updated automatically with the patient's schedule, notes, and patient and provider information.

Fig. 3. As part of the smart hospital technology, real-time locating system sensors are installed on the ceiling of the hallways and above the patient doors. These sensors can track the movement of the patients, providers, and equipment throughout the hospital.

Having witnessed these interruptions, later in the educator interviews, we asked if they had any technological ideas to help manage them. One solution Carine offers is to mount a screen outside the door that displays the same patient schedule as the digital whiteboard inside the room (see Figure 2), so anyone about to enter can see if there might be another staff member in the room.

> *We have the digital electronic whiteboard with the schedule, but then having like the schedule visible on the outside of the room, [. . . ] seeing that without having to pop in to see it, could be nice.* (Carine)

Building on their idea of having a screen outside the room, the educators talked about leveraging the real-time locating system (RTLS) (see Figure 3) to make the information on the screen more accurate. In healthcare, RTLS can provide real-time tracking and management of medical equipment, patients, and staff [22]. The NRH has an RTLS system installed, but it is not used as a sensor for the SPR. One idea for reducing interruptions is to integrate the RTLS sensors with a display outside the room to show the patient's daily schedule and the real-time status of staff members and patients in the room.

> *We could use that [RTLS] sensor, and that it shows we're in there as a way to help staff understand that, like when you see this, please don't go in.* (Safiya)

Seeing the patient's schedule and who is in the room would increase other staff members' awareness, hopefully managing interruptions. Besides managing interruptions, educators noted how the RTLS system would also help find missing equipment, other employees, or patients without exhaustively searching the hospital.

> *And so actually knowing, just being able to tell, like, the patient is in the second-floor gym right now, it would really help us, particularly with rounding.* (Safiya)

However, with RTLS, the educators quickly pointed out some concerns. They did not like the idea of managers using the data to micromanage their time.

> *I guess it's the idea that somebody could be that invasive, [. . . ], that somebody could like, just see oh, like, she spent 10 minutes here, what was she doing? Right? And like having to, like, have that conversation with your boss.* (Alia)

All four educators expressed some uneasiness about RTLS, with Alia, Carine, and Safiya even using the term "Big Brother" to describe their feelings. Although, the educators expressed they would feel more comfortable if management clearly stated how they use the data.

> *I feel like if I was assured that it's purely just for ease of, you know, communication to peers on where you are, and like, less interruptions, but that you're not like collecting it and measuring it.* (Carine)

Ensuring users' privacy concerns are addressed, RTLS can be useful and offer more capability when combined as ubiquitous sensors for the SPR. With the idea of integrating SPRs and RTLS, we can see applications for automating smart room features and medical charting as well (see Section 6.1).

*4.1.3 Patients vary considerably, the SPR technology is agile and adaptive enough to meet most PE needs.* Several factors affect how patients engage with educational content: the severity of their injury, perceptions of their outcome, overall attitude toward education, and general comfort with technology. The diverse characteristics of patients and caregivers require educators — and the technology they use — to be flexible and customizable. Carine spoke specifically about the varying types of patients she works with,

> *I specialize in spinal cord injury patients. However, we see other diagnoses as well. And we cover each other, so I'll see traumatic brain injury, strokes, amputee, on the spinal cord injury team, we'll see Guillain Barre as well as a variety of like MS [. . . ].* (Carine)

Since there is a range of conditions and a disparity of comfort with technology from patient to patient, educators need to account for this when they are using the SPR to help facilitate education sessions.

> *I mean, it just has so much to do with tech literacy, too, for some people. And, and diagnosis too, I mean, obviously, our tetraplegics. They need voice control; they need everything set up for them to be via voice or eye gaze. So those are the two big ones that I can think of that would be really helpful for certain patients.* (Safiya)

Helping patients with limited abilities is where the SPR can notably impact PE. By using voice control or other accessibility controllers with the iPad, patients can engage with the content themselves without relying on educators to do it for them. While illustrating how the SPR can adapt to patients with varying conditions, Safiya provided inventive ways the SPR could assist complex brain injury patients with therapy and healing.

> *But environment, particularly in brain injury, is a huge factor in how we help these patients get better and heal. [. . . ] The room could really help in setting up an environment that helps those patients. You know, just heal and not be overstimulated. And if we can reach that point, which I think we can, I don't think it's out of the realm of anything at all because a lot of it has to do with lighting, audio.* (Safiya)

Safiya offered a good insight; since the environment can all be controlled digitally, there is an opportunity to set limits on features like lighting, sound, or even blinds to assist patients that medically require stimulation limits. This example demonstrates how SPRs can help educators control the environment to be more conducive to learning as required by the varying conditions of their patients.

## 4.2 SPR Impacts Beyond the Patient Education Session

Although the PE session is the focus of an educator's job, we also looked at ways the SPR impacts tasks done outside the session, such as how they chart in the electronic medical record (EMR) and how they store, customize, and update educational content. We developed three themes that help to answer **RQ2:** How have the SPRs impacted educator tasks outside of the patient education session?

*4.2.1 With new technology comes new tasks.* When the smart hospital opened, the rehabilitation educators had to learn how to use the new smart room features and incorporate them into their workflow. Since the educators were responsible for providing the bulk of education to the patients, the administration initially tagged them with training everyone to use the SPRs.

> *So when the hospital first opened, I think it was maybe a little bit of an oversight that, like, we have this really smart hospital, but like, not everyone knows how to use it. And so they were like, oh, you guys are rehab educators; why don't you educate patients on it? And so initially, they wanted us to be like the trainers for everyone. We're like, well, we haven't been trained on it.* (Carine)

The SPR technology will see limited use if the patients and hospital employees do not know how to use it [6]. This problem was an initial oversight in the transition, but the hospital administration quickly adapted to the new SPR training and troubleshooting tasks. Their solution was to convert one of their occupational therapists into a new position called the Information Technology Manager (ITM), responsible for training and troubleshooting the SPR technology. Safiya explained how the ITM initially introduced the educators to the SPR and the capabilities it could provide them for PE.

> *The ITM just gave us a tutorial on one of the empty rooms. And then, you know, he took us in and showed us how to with our laptops, how to connect via AirPlay and, and then along the way, has helped troubleshoot.* (Safiya)

Over time, the hospital has developed procedures for how the patient is onboarded into the SPR. The onboarding task is not normally on the educators, but if there is a delay in the training, the educators now feel comfortable enough to assist patients in controlling the SPR with the iPad.

> *And then we didn't end up being the primary people to educate patients on their iPads in the end anyway, but I definitely still do that in some capacity. Depending on when I'm seeing the patient and I'm one of the first people in the room, I want to make sure they know that they don't have to just stare at a big screen; if they want to use it, and stream, or do things like that they can.* (Mei)

During CI-17, we observed Mei troubleshoot AirPlay between the iPad and AppleTV. Although the fix was simple — she restarted the iPad — it demonstrated how troubleshooting the SPR features requires additional training and changes to some workflows and tasks that are not required in a traditional hospital.

*4.2.2 Patient charting is a workflow requirement, educators brainstormed ways SPRs could streamline it.* Although the study's primary focus was on the SPR impacts on rehabilitation education, as part of the CIs, we observed the educators' use of all technologies, including outside the patient room, to find potential ways to integrate them into the SPR. During CI-1, CI-7, CI-11, CI-15, and CI-17, we observed how charting in the EMR can be time-consuming and cumbersome for educators. The EMR is intended for general healthcare information management of patient records and charting, which educators must do; however, it can take valuable time away from seeing patients. During the interviews, we asked them to brainstorm ways that technology could help support this task. The educators came up with some ideas of how the SPR could aid in their workflow. One idea was using the SPR technology to make automatic charting entries in the EMR. Carine talked about an example where educational videos could get assigned to patients on the SPR iPad, and once the video was viewed, it could automatically report back to and record completion in the EMR.

> *If there's like a video system where, like, patients get assigned videos when admitted to the hospital [. . . ]. And then, it gets documented in their EMR that they watched the video so that they can say they have that education.* (Carine)

She noted that currently if there is a video for the patient to watch, they use up valuable time to show it to them. If she could instead assign videos on the iPad that are automatically documented in the EMR when viewed, this would save valuable PE session time for more meaningful topics. Carine took the idea even further: if the SPR could sense any content, not just videos, being presented on the iPad or TV in the SPR and automatically chart these in the EMR. Safiya looked even further into the future of potential automatic charting. What if the SPR can sense even complex tasks and automatically chart them for the healthcare providers?

> *One of our biggest issues with charting from them is I&Os, what goes in and what comes out. [. . . ], particularly the outs, getting charted. I have no idea how we automate that.* (Safiya)

Since charting is a required time-consuming task, any automated charting would give healthcare workers valuable time to reinvest with patients. Future work on SPRs should look at different sensors and features to assist with automated charting.

*4.2.3 Educators customized content for patients and brainstormed ways technology could assist this endeavor.* As part of their workflow preparing for their next PE session, the educators spend time customizing the educational content for the patient. We observed them factor medical condition (CI-2, CI-12, and CI-17), content importance (CI-12), and even the patient's preferred language (CI-4) into the planned curriculum. Safiya provides a good description of the requirement to change, update, and upload educational content easily.

> *We do like to change and update our materials as needed. And sometimes, I customize material for a patient, particularly for TBI. I will customize based on their functional anatomy, right, or what I think maybe is more important to a certain family or a patient, or I'll add something in that we know we really need to drive home [. . . ].* (Safiya)

As Safiya pointed out, they frequently build customized content for patients. Though, sometimes they have to recreate content due to problems with organizing and storing the customized presentations.

> *That's what I like about having it on the S: drive and in the file, is that I can spend 30 minutes doing something for a patient. And I have a little folder called Patient Customized Presentations, and I cue that up before I go in on my laptop, and then I show them their presentation with their name on it and everything. It's great. They love it. But I really struggle with how our team organizes all the files within S: drive. I really like to have everything very well organized and easy to find.* (Safiya)

One way technology could help educators is by streamlining knowledge management to organize their custom content better, potentially leveraging the SPR technology. The root problem is that educators store educational material in several locations, and keeping files organized and up-to-date is a real challenge. As Alia stated, "Yeah, right now, it lives in so many different places, and it's really hard for all of those different places to talk." We asked the educators to brainstorm ways technology could help. Carine discussed having a single repository for educational content that can be accessed directly from the SPR iPad. The educators have already started building a patient resource webpage, but Safiya would like to have all their content available there.

> *And so one thing with the patient education, or patient resource webpage, we are trying to get our video links on there. And then we've talked about having some of our, like modules, PDFs of our presentations available there. And so if it was all there, we could just click it from there. [. . . ] From the iPad, or really anywhere on the internet.* (Safiya)

This idea of having a single repository tied into the SPR would streamline the process of managing and displaying educational content. We build on this idea further in the discussion section (see Section 6.3).

## 4.3 SPRs Helped Educators Assist Patients in Engaging with and Managing Information

Rehabilitation hospitals prepare patients for life after discharge, helping patients to take in and manage critical information. We found that patients deal with complex emotions regarding the perception of their condition, which can affect how they engage with content as an inpatient. The educators provide knowledge and resources to help patients manage and organize information vital to living outside of the hospital. We discovered that SPR technology could, directly and indirectly, help educators prepare their patients for life post-discharge. As we analyzed the data from our CIs and the semi-structured interviews, we developed two themes that help to answer **RQ3:** How do SPRs help educators assist patients and caregivers in engaging with and managing information?

*4.3.1 Patients have a lot to learn; yet, there lacked a good technology solution to help them manage this information.* It was evident from our CI observations that patients understood that recalling educational content later would be critical to their self-care post-discharge. Patients would regularly ask the educators to print out material (CI-4, CI-6, CI-12, CI-14, and CI-16) or email it to them (CI-2, CI-8, CI-12). Surprisingly, only once did we see either a patient or caregiver take hand-written notes (a caregiver during CI-13). This is understandable for most patients since note-taking can be difficult due to their condition, but caregivers were generally capable. When we tried to explore the nuance further with questions during the CI, the common response was that since the information was critical, they would remember it. This mentality highlights the importance of providing continued access to knowledge and resources [57] for patients and caregivers even after discharge.

Organizing paper printouts and emails was a challenge for patients and their caregivers. Emails sent by the educators would regularly get lost in the patient's inbox, or patients did not know how to access their email (e.g., CI-3). We specifically observed email management issues during four CI sessions. For instance, during CI-12, Carine asked P4 to open a document she wanted to review with the patient during the PE session. However, the patient couldn't find the email in their cluttered inbox until Carine helped search for it. Using email for document management, a task it is not designed to do [17], highlights the need for a better document-sharing solution.

During the CIs, we asked many probing questions to understand the nuance of how educators use email with patients to help manage information. Based on our questioning, the educators recognized that email might not be the best way for patients to store educational material. In the time between our CI analysis and the semi-structured interviews, the educators had already changed their workflow. We found out during the interviews that they started offering MyChart — a patient-focused view of the EMR available through the web — as an alternative option to share content so that it would all be maintained in one location for the patient. Alia spoke specifically about how they recognized the issue from our initial CIs and came up with their own solution,

> *And so trying to figure out ways based on the feedback from [the research team's] initial study of just like email management being an issue, I think that that was really helpful to then at least give patients that option now. Like, would you like this sent to you via MyChart or via email? Because we recognize that you might be getting a lot of emails, and then this way, it's all in a centralized place that you can*

> *look related to your hospitalization. And a lot of people have been liking MyChart, so it's not perfect, but it's a step in some direction.* (Alia)

MyChart is one solution for a single repository to store information customized for each patient, but the educators want to incorporate the SPR technology, like the iPad, to help store and manage information.

> *But one of the thoughts that we had, or I had a while ago was like, you know, a menu of topics [on the iPad], right? [...] in my mind to be like, okay, electronically, like select the topics [...] So yeah, having an easier way to just like boom, play or present something or have it available for them to see it ahead of time* (Carine)

As we discovered, email can be clunky for storing and recalling information for patients, especially considering it might be vital for self-care post-discharge. The potential exists for the SPR iPad to be a single source where information is stored, referenced, and displayed to help patients better retain and recall the required knowledge they learned during their time in the hospital. In the discussion (see Section 6.3), we build on the educators' ideas and propose an ideal solution that tackles many of the challenges identified through this study.

*4.3.2 There are emotional and psychological aspects that can affect learning and rehabilitation.* Due to the nature of a rehabilitation hospital, the patients are in the recovery phase of their care. Nearly all patients are recovering from a traumatic life-altering event; sometimes, they are not in the best physical or cognitive state for effective learning and retention [58]. Educators must consider the patient's emotional stress and overall psychological well-being. In addition to physical and psychological barriers, there are physiological limitations as well. Patients can be sensitive to high workloads and tire easily. The educators thus manage each patient's individual needs. We observed them shorten, modify, or even cancel PE sessions because the patient was fatigued or purely to help the patient save energy for other rehabilitation activities scheduled later in the day. For instance, during CI-15, P13 was very tired, so Alia allowed the patient to sleep to have energy for the other therapy sessions. Instead, she presented the relevant material just to the caregiver.

Some patients are unreceptive to PE because they think it is unnecessary; as Alia noted, "They feel they will be the miracle case." Because they have difficulty accepting their injury and a new way of life, they do not engage during education sessions. While some patients do fully recover, many do not. Educators must deliver education while navigating patients' perceptions and acceptance of their condition.

Despite the challenges, SPRs positively support psychological well-being; Carine noted, "I think it gives them a lot of independence, and they enjoy it!" We witnessed this positive effect during our observations, and educators discussed it during interviews as well.

> *I feel it is really important, especially for those people who really don't have very much control over anything, to feel they can do something for themselves. They just have this complete total loss of control. And now, they don't have to call the nurse to turn the volume up on the TV. I think that helps them feel a little bit more autonomous or a little bit less dependent on everybody.* (Alia)

She went on to discuss the difference the SPR provided to patients as compared to a traditional hospital room.

> *At the other hospital that I worked at, you just had to call for literally every single thing. It's too hot in the room; you had to call the nurse to get them to come in to turn on the thermostat. It's the blinds; the sun is in my eyes. So can you please turn the light on? Can you please do that? So they felt like they were always a hassle or a burden on staff, [...].* (Alia)

The SPR can improve patients' psychological well-being by giving back some control and independence — helping them cope with the new reality of their condition. This morale boost can help educators overcome the learning barrier earlier in the patient's stay so that they will be more receptive to education while at the hospital.

## 5 DISCUSSION

The findings above show that educators and patients have adopted the SPR technology in several aspects of the education experience in this hospital. Addressing our research questions, we discuss our findings in relation to the existing literature and examine how SPRs might generalize to workflows in the broader healthcare context.

### 5.1 RQ1: How do Educators Use the Features of the SPRs for Rehabilitation Education?

We know from the related literature that technology can be a valuable tool for PE. Khong et al. demonstrated how an iPad with proper accessibility features could be used to help educate spinal cord injury patients [42]. Although in their study, they highlight that adoption may have been negatively impacted because the iPad used by the patients only runs one application specifically for conducting PE. In our findings, we can see the widespread adoption of the iPad since it has many uses in the SPR, for example, as an accessible control hub for the various SPR smart features, as an educational tool for PE, and many other relevant functions of an iPad like browsing the internet and checking email. As an educational tool, educators in our study would have the patient watch videos and view resources on the iPad or even AirPlay content from the iPad to the TV. This usage of the iPad became central to the education sessions and preferred by all four rehabilitation educators because they believed it created a better PE experience. This aligns with prior education literature that TV-based experiences can be effective for informal education [5]. The smart TV provided a larger display, making engaging with the content easier for the patient and caregivers. Since the smart TV can be controlled using the accessibility features of the app, it allows patients with limited abilities to help set up for the PE session, fostering better engagement (see Section 4.1.1). In addition to AirPlay, controlling the room environment helped educators set the ideal conditions — adjusting the temperature, lighting, and audio levels — for learning. As shown in prior education literature, having the proper environment can affect motivation, engagement, and learning [12].

### 5.2 RQ2: How have the SPRs Impacted Educator Tasks outside of the PE Session?

Outside of the PE session itself, we learned that SPRs don't significantly impact educator workflows except for having to troubleshoot the technology occasionally. The educators noted that the technology works great most of the time, but any technical difficulties during a session take time away from the patient to troubleshoot.

Since we found that SPRs do not significantly impact the educator's workflow outside the session, our observations and interviews focused on design opportunities for the SPR technology to assist these workflow tasks better. Through our observations, we saw how charting is time-consuming for the educators. Charting is a challenge in healthcare and can take up to 35% of clinical time [38], creating a dilemma between spending time with patients and spending time charting [56]. The introduction of electronic health records resulted in unintended consequences for clinicians, including significant increases in documentation time, potentially leading to burnout [48]. This likely explains why our educators — when thinking about ways to leverage SPRs to improve efficiency — brainstormed ideas for SPR technology to help ease their charting burden. As the current implementation of SPRs in the NRH does not support any charting tasks, ideas brought up by educators do not reflect their current practice but reflect potential design opportunities rooted in their experiences on the job (see Section 6.1).

Some of the educators' ideas for automatic charting involved using the hospital's RTLS system as a tracking sensor. Though, this raised several privacy concerns about being tracked, which has been documented in prior work [33]. Schaub et al. [61] brings up how augmentation of the physical world with smart devices reintroduces a physical dimension to privacy. Because employees' and patients' locations would be tracked to help with automation and find other employees and patients in the hospital, the hospital administration should be clear about how they use the data. If the system is used solely as a sensor to automate functions, they should explicitly state this in a policy. The educator's privacy and security concerns were mostly related to RTLS, not the smart home technology used in the patient rooms. This complements the findings from our previous patient-focused study [16] that since the hospital is a trusted place, patients were not concerned with the privacy and security of the SPR technology.

### 5.3 RQ3: How do SPRs Help Educators Assist Patients and Caregivers in Engaging with and Managing Information?

For RQ3, we discovered that the educators were not fully leveraging the potential of the SPR technology to help patients engage with and manage information. On the positive side, the findings showed increased feelings of empowerment for patients where the SPR helped them be more receptive to education. This relates to two prior studies by Bickmore et al. [8] and Adler et al. [1] that the inpatient experience can be disempowering and patient attitudes toward their medical condition can make engaging and learning difficult. The educators highlighted how giving patients control of the entertainment and environment with an SPR provided patients with feelings of empowerment, mirroring findings from our previous patient-focused study [16]. However, the data we collected cannot speak to whether these feelings of empowerment resulted in a measurable difference in patients' comprehension or retention of the material.

On the other hand, the educators continued their pre-SPR practices of presenting knowledge verbally and providing resources such as printouts or emails instead of using the iPad. These traditional techniques are not ideal since printouts can be lost, and some patients don't sign in to their email on the iPad. So even the little support the SPR tech might have given for ease of checking email was thwarted. Pollack et al. [57] highlight how difficult it is for patients to process and remember verbal information and the need for a good system to support their progressive development over the transition period to home. Educators were nevertheless cognizant that their way of presenting information could be improved by leveraging the SPR technology; the dialog around issues with the current system — and ideas to improve it — provided insights into design opportunities, which we discuss further in Section 6.3.

### 5.4 Expanding the Idea of SPRs beyond a Rehabilitation Hospital to the Broader Healthcare Context

While initially, we did not question how SPRs might be adopted more broadly in healthcare contexts; our findings indicate this might warrant further exploration. Smart home technology used ubiquitously in any hospital environment is a new concept, and much work remains to draw out its full potential; yet, as the technology supports aspects of PE well in this environment, the same benefits could potentially transfer to other healthcare contexts. Using smart features to adjust the environment and set up a large display for showing content could be useful for PE in medical facilities ranging from acute care hospitals to outpatient treatment facilities. However, some considerations exist when expanding SPRs into other healthcare applications. Like with any technology — especially in ubiquitous environments — problems and unintended behavior can occur [15]. Other hospitals contemplating similar SPRs should consider the technology's reliability as a key factor and how they will train their employees to learn a new workflow, troubleshoot common problems and develop a strategy for technical support. Despite the learning curve to getting this right in the NRH, the capabilities and benefits that the SPR brought to PE clearly outweighed the challenges. The educators' positive feelings imply that the trust, usefulness, and convenience of the SPR make it worth adopting [50].

### 5.5 Limitations

Although our work provides insight into SPR technology for PE, we recognize two main limitations. First, the educators are rightfully empathetic to topics that might be embarrassing or sensitive — like bowel and bladder management, and we were not permitted to observe those sessions. However, the study focus was on how they used the SPR technology for PE in general. Our findings are not tied to particular topics; they could manifest in any education session. The second limitation is that we only had one observer for the CIs — a collaborative decision between us and the educators. Having the caregiver(s), educator, and multiple observers all confined in a small patient room may become overwhelming and distracting for the patient. Since the CI observations aimed primarily at informing the interview questions, we were willing to cope with potential bias from a single observer to facilitate a more comfortable environment for the patient. To mitigate this bias, all three authors met after the observation session to review the field notes and draw out additional nuance from the observer.

## 6 DESIGN OPPORTUNITIES

The findings in this study revealed some design opportunities that have the potential to impact patient and provider experiences in the hospital positively.

### 6.1 Integrating SPRs with RTLS, a Common Ubiquitous Sensor Found in Hospital Environments

During the interviews, educators brainstormed how technology can help manage interruptions. One simple idea was to install, outside the room, a display allowing the staff to check the patient's schedule unobtrusively. However, the schedule is not always accurate, which may result in staff interrupting anyway. Potential legal privacy concerns could likely be remedied by only showing compliant information. Regarding interruptions, RTLS integration with the SPR could help. Many hospitals have RTLS systems to track the location of assets, patients, and staff using chip cards and a sensor network. The idea is not new [45], yet using RTLS to trigger complex actions with the SPR technology is novel. When a patient or provider enters the room, RTLS could update the status board. Before entering, staff can check the display to see if the patient or a provider is in the room and check the patient's schedule for a time to return. RFID-based systems have already been used similarly to manage interruptions [51]; therefore, adding this capability into an SPR is entirely feasible.

Another way integration can improve hospital workflows is by easing the burden of charting. In our findings, the educators mentioned that SPR could increase their efficiency by sensing their time in the room (similar capability to the Mayo Clinic's Saint Marys Hospital [51]), what content was delivered, then automatically chart it in the EMR. The SPR's ability to sense activity could build off other research on human activity recognition [11, 29, 49]. There would still need to be a human in the loop to validate the entries and to add data that cannot be sensed by the room — like the educators' assessments or outcomes — but basic data would be automatically recorded.

Additionally, RTLS/SPR system integration could offer context-aware automation. When the educator enters the room, the SPR can adjust the blinds and lighting, connect the AirPlay, and cue up a selection screen on the iPad for education content. Each provider could set the default environment for their specific tasks so that the SPR can automatically provide an optimal working environment. There would need to be a balance between the benefits gained by allowing patients to control the environment on their own and fully automating the environment; the tradeoff between these two priorities is a compelling topic to explore in future work.

### 6.2 Using SPRs as a New Tool for Healthcare

Since the SPR environment can be controlled programmatically, it opens up possibilities to use it beyond basic smart features. As described by Safiya, patients with severe brain injury must be placed in a low-stimulation controlled environment. In a traditional hospital, providers have very basic control; they can turn off the TV, dim the lights, and close the blinds. There is, however, no way to limit control of the environment further. Since the smart features of the SPR are controlled through software, there is an opportunity to set environment limits for the room. For example, providers could use the smart room app to limit its functionality (e.g., brightness of the lights, ability to raise the black-out blinds, and TV volume). Informal caregivers could accidentally overstimulate the patient, for example, by having the lights too bright or the TV too loud. If limitations are placed on the smart features of the room, patients, family members, and staff could still use the technology while ensuring the patient remains within the appropriate stimulation protocol.

SPR and RTLS integration could help automate the environment-limiting feature. If the patient leaves the room, RTLS could sense their absence and remove the limitations so that other stakeholders can have full access to the smart features. Then when the patient reenters the room, the SPR will revert back to the low stimulation settings. This is one example of how the SPR can be used beyond just the control of smart features — like in a traditional smart home — to address use cases that assist with the patient's healing and therapy. We hope this dialog inspires further investigation into smart hospital applications.

### 6.3 A Digital Knowledge Management Solution for Supporting PE

The educators recognize that the self-care activities they teach are critical to a patient's health post-discharge. However, patients may not realize the importance of self-care activities until they are home, which is why it is critical but also challenging for educators to provide knowledge and resources and build patient self-efficacy before discharge [57]. We observed how email or printed products are ineffective for keeping important educational information. Based on the ideas generated by the educators, we propose a single-source online knowledge management system — customizable by healthcare providers — that leverages the SPR technology.

We envision a tool with a bank of educational content updated by educators. Using the tool, educators create a customized education plan for newly-admitted patients. From the tool, the educational plan topics would link directly to the content. Building on Pollack et al.'s [58] recommendation of tailoring, patients would have an individual log-in so that it will only display content applicable to their rehabilitation and self-care needs. Using the tool for every session could help build positive habit transfer for patients on accessing the content. Additionally, this would streamline the educators' workflow removing the requirement to bring a laptop to the session and set it up. This digital tool could help patients with their transition out of the hospital by providing a single web-based reference accessible at home while maintaining collaborative clinician involvement [60]. It would also solve the issue of patients losing emails or paper printouts. For patients without access to a personal device, a stable internet connection, or uncomfortable with technology, the educators could still provide a printout of all content during discharge. Any time the provider updates content, there could be a reminder to print the latest version.

Based on the related literature and our experience and interactions with the educators, the ideal digital PE solution should: 1) Allow collaboration between clinicians, educators, patients, and caregivers to communicate and report the patients' progress; 2) Provide a single-source and easily accessible location to search and view relevant educational content that can be customized to the patient's needs; 3) Leverage technology, like that found in the SPR, to make it easier to access, manage, and display content for a better PE experience; and 4) be available post-discharge for continuing patient support. Since PE is a critical component of any hospital stay, building digital solutions with these attributes could be impactful in many healthcare contexts.

## 7 CONCLUSION

Patient education is just one part of the complex inpatient experience in a rehabilitation hospital. In this study, we set out to discover how SPRs can support PE and how further refinement of the technology can foster a more positive experience. Our findings show that the SPR technology allows educators to set up an environment conducive to learning and then AirPlay to a larger smart display for better visibility and inclusion. Through voice control with the smart room app, patients with limited mobility can exercise independence and autonomy by assisting educators with setting up the education session. The findings also helped us to identify design opportunities for future smart patient room implementations, like automatic patient charting, room status board updates to minimize interruptions, and automated environment controls for patient therapy. Future work exploring *smart hospitals* should expand these insights beyond PE to improve healthcare worker and patient experiences across the entire healthcare spectrum.

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