# Hospital Employee Experiences Caring for Patients in Smart Patient Rooms

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## ABSTRACT

Smart hospital patient rooms integrate smart devices for digital control of both entertainment (e.g., television and sound system) and the environment (e.g., lights, blinds, and temperature). While primarily designed to enhance the patient experience, this technology also impacts the hospital employees who work in these patient rooms. This study explores hospital employee experiences with smart patient rooms. We conducted 23 interviews with rehabilitation healthcare professionals, including nurses, doctors, psychologists, and occupational, physical, and speech therapists, to understand their perspectives on working in smart patient rooms. Drawn from thematic analysis of the interviews, our findings offer insights into employees' current use of the technology, the benefits and drawbacks they encounter, and their suggestions for improving the technology. These findings shed light on the complex problem of building smart patient rooms that simultaneously support the needs of multiple stakeholders, including patients and employees; they also point to important considerations for future designs.

## CCS CONCEPTS

• **Human-centered computing** → **Human computer interaction (HCI)**; **Accessibility technologies**.

## KEYWORDS

smart hospital, rehabilitation hospital, smart patient room, smart healthcare, smart home technology, accessibility

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## 1 INTRODUCTION AND BACKGROUND

Smart hospitals leverage location recognition and tracking sensors, communication devices, wireless technology, IoT, smart sensors, wearables, AI, robot services, and extended reality [44] to improve operational efficiency, promote patient safety, and empower healthcare professionals with advanced tools. Some smart hospitals are now incorporating smart patient rooms (SPR) in their design [17, 18, 30, 64, 83], where users can control elements of the environment and entertainment with a tablet [2, 17, 64, 83] or voice assistant [2, 30]. Our prior work on SPRs focused on the patient experience of staying in an SPR [17]. However, patients are not the only users; many employees also interact with the SPRs. Physicians, nurses, health unit coordinators, physical therapists, occupational therapists, speech therapists, psychologists, and patient educators, to name a few, all care for patients who are living in these SPRs. Their experience working and caring for patients in SPRs is important and should also be explored. Understanding how employees use and perceive the SPR technology is crucial for ensuring these rooms are not only technologically advanced but also practical, user-friendly, and support clinician-patient interaction. This is vital because such interactions are key to how patients perceive the quality of care and their satisfaction [14]. Additionally, these employees are subject to use the technology in their workplace. Just as for employees in other contexts [78, 84], their experiences and perspectives are important to understand to ensure that employers are not unwittingly imposing an uncomfortable or problematic situation on these employees through the deployed technology. We seek to add the employee perspective to the smart hospital and SPR literature by sharing insights from their experiences.

To focus our effort, we developed the following research questions (RQ):

**RQ1:** How do hospital employees currently use SPR technology?
**RQ2:** From the employee perspective, what are the benefits and drawbacks of SPRs?
What has been done to overcome challenges?
**RQ3:** What are employees' suggestions for improving the SPR?
What are the design opportunities for future SPRs?

Conducting real-world studies based on actual user experiences is important in hospital settings [25, 46, 67]; yet, studies are rare because the complexity, cost, and safety concerns of deployment are prohibitive unless already planned by the hospital [25, 26, 34]. Because of this, it is challenging to research smart hospitals in situ. We were granted access to a newly constructed smart rehabilitation hospital for our research.

This paper reports our findings from 23 semi-structured interviews with hospital employees from nine occupational stakeholder groups. Our goal is to uncover how they use the current SPR technology, the benefits and drawbacks of the technology, and collaboratively brainstorm ways the experience can be improved. Our findings report on the many facets of the employee experience of caring for patients in SPRs. This study contributes a new understanding of how working in SPRs impacts employees, which gives insight into the complex problem of building dual-centric SPRs that



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

support patients and employees and points to design considerations for future smart workplaces.

## 1.1 Background on Our Research Environment

A rehabilitation hospital is a specialized medical facility that treats patients recovering from injuries, illnesses, or medical conditions that have led to decreased physical or cognitive function. The primary objective of rehabilitation hospitals is to prepare patients for life after they are discharged by helping them learn self-care, manage new changes in their abilities, and provide education during their inpatient stay. The length of stay in a rehabilitation hospital varies per patient, from two weeks for some stroke patients to over 60 days on average for those with spinal cord injuries [22]. Typically, a family member (informal caregiver) accompanies the patient and regularly attends therapy sessions in support of the patient. Rehabilitation patients follow packed schedules involving occupational, physical, and speech therapy sessions. Rehabilitation hospitals enlist various medical professionals, including doctors, psychologists, therapists, nurses, and rehabilitation educators, to offer comprehensive care.

The University of Utah Health Craig H. Neilsen Rehabilitation Hospital (NRH), where we conducted this study, is a public US university hospital that opened in 2020 and was built with technology in mind. This hospital 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 TV and soundbar, with cable, Apple TV, AirPlay, and bedside HDMI input for 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 on a personal device running Android or Apple iOS (Figure 1). The door can also be opened, partially opened, or closed in several rooms using the app. The smart room supports

different control modalities based on the patient's level of mobility — including capacitive touchscreen, voice commands, other assistive technology that works 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 the hospital using voice commands.

Note that "the concept of a smart hospital has not been rigorously defined" [45] because they can incorporate various key technological features. Woll and Tørresen [81] point out in a comprehensive literature review how some contributions assume using any IoT in a hospital makes it *smart*. This notion of implementing IoT or including only one smart feature is too broad for our use of the term *smart* for SPRs in this study. We consider the SPR we researched *smart* since it incorporated several IoT devices in each room and supported assistive technology features in its design, allowing patients with limited mobility to control the environment and entertainment in their room that they would not be able to do in a non-IoT-equipped patient room. In this sense, it is "equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provides services that respond to the needs of its inhabitants." [6] However, as the room is implemented now, it is not necessarily smart in the sense that it does not provide users with the ability to configure automations like trigger-action programming. Thus, considerable room remains to increase its *smartness*, and one objective of this study is to inform that effort.

## 2 RELATED WORK

To our knowledge, no prior literature examines hospital employees' experiences caring for patients in SPRs. To understand this gap, we look to prior literature on SPRs, hospital employee workflows, and the challenges of implementing new technology in a hospital setting to develop our research questions.

### 2.1 SPRs and Hospital Employee Workflows

Initial research on hospital environment smart spaces involved smart intensive care units [31–33, 66]. Here, the focus was on adding sensors that feed information to the providers rather than for the patient to use. Although these rooms were smart, they did not give the patient any control over their environment. Studies of commercially available smart technology in patient rooms were limited to lighting [24] and sound environments [38] but did not expand to other smart features. Another study specifically included a smart home technology package in the design, using a tablet, smartwatch, and voice assistant to transform the patient experience [2]. However, this study only used a prototype that was never installed in a room. SPR studies are usually limited in scope without access to a full smart hospital, e.g., prototyping a single room [50]. But it comes with limitations, like that room may be considered a *special* room and thus may introduce bias compared to being deployed across the hospital [12]. Additionally, with only one prototyped room, studying the effects on hospital employee workflows is difficult since it is not used naturally in a real hospital setting. Two of our previous studies were also conducted with the SPRs at the NRH; however, they focused on the patient experience [17] and patient education [18] whereas this study focuses on the experiences of hospital employees caring for these patients in SPRs.

Some SPR research used technology similar to what is deployed in the NRH. Two studies examined smart bedside station systems [64, 83], comparable to the hospital-furnished iPad. Yet, once again, their results are patient-oriented, and they do not consider the symbiotic relationship between patients and employees with the patient room technology. Another study used voice assistants (Amazon echo dots) for patients to listen to music, control the TV, and make nursing-related requests [30]. Using voice assistants in the patient room allowed nurses to focus on healthcare-related tasks. We are interested in examining if similar workflow benefits are seen in the NRH's SPRs.

Looking specifically at hospital technology impacts on workflows, we know from prior literature that the design of the patient room can affect workflows [49], so the design of the SPR may also have impacts. Other studies have examined how workflows change to accommodate new technology, then settle into routines and develop necessary workarounds [27, 69, 71]. When examining hospital employees' interactions in the context of patient rooms, we can see how nurses are critical in promoting patient control based on how they leave the doors, lights, and blinds when patients cannot control them [3]. Since the SPR provides additional control to the patient, this might produce different results. Interviews with nurses revealed a complex relationship with technology in patient rooms: they acknowledge its importance, but it can also be a barrier to patient-centered care [76].

Looking at this prior literature on smart hospital environments and workflows, we are interested in **RQ1:** How do hospital employees currently use SPR technology?

### 2.2 Technology Impacts on Hospital Employees

The use of smart features in a hospital setting has the potential to benefit employees. Studies have shown how nursing staff who used a renovated room with noise mitigation, automatic lighting synced to time of day [24], and design improvements [68] believed the design of the room had a positive impact on their own well-being and caring behavior [68]. We want to see if there are similar benefits for the employees working in the SPRs.

However, introducing new hospital technology can also bring challenges. For instance, the transition to digital medical records was intended to streamline data but instead resulted in data becoming stagnant and restrictive [35]. Although digital records served bureaucratic purposes, they did not align with the needs of medical professionals [36]. Moreover, providing nurses with mobile computing carts did not replace their reliance on paper-based tools as anticipated [70]. Other studies emphasized how minor alterations to nurses' workflows and processes led to information loss [39, 85]. More concerning still, another study demonstrated that when employees encounter usability issues with new technology, they might discontinue its use. This was evident in a study where introducing Vocera mobile communication devices for nursing staff led to abandonment due to usability barriers [72].

Since prior literature contains numerous examples of the benefits and drawbacks of introducing new technology in a hospital setting, for SPRs, we ask the following **RQ2:** From the employee perspective,

what are the benefits and drawbacks of SPRs? What has been done to overcome challenges?

Based on the drawbacks, we asked participants to brainstorm ideas for improving the SPR. We look to discover **RQ3:** What suggestions do employees have for improving the SPR? What are the design opportunities for future SPRs?

# 3 METHOD

We conducted N=23 semi-structured interviews with hospital employees across nine occupational stakeholder groups to discuss the benefits and drawbacks of current SPR technology and how it can be developed to improve the employee experience. The interviews were transcribed, coded, and analyzed using thematic analysis.

## 3.1 Participants

All participants were employees at the NRH and were selected from nine categories of healthcare occupational stakeholder groups (Tables 1 and 2) including Rehabilitation Educators, Occupational Therapists (OT), Physical Therapists (PT), Speech Therapists (ST), Health Unit Coordinators (HUC), Psychologists, Nurses, Doctors, and an Information Technology (IT) Manager. For each category, our recruitment goal was 2-4 participants representing the two hospital floors, the 3rd floor (primarily spinal cord injury patients) and the 4th floor (primarily stroke and brain injury patients). The only exception was for the IT Manager since only one was employed in the hospital. Interview participants ranged in age from 22-55, with a mean of 37, which is a little below the national average of 42 for these occupations in the US [60]. Our participant population may have been a bit younger and thus perhaps more tech-savvy than average; however, we do note that the age range and self-reported expertise with technology did vary between participants. Following guidelines from our IRB about participant recruitment, stratified random sampling was not possible in the NRH; voluntary and snowball sampling enabled us to efficiently identify potential additional participants within each occupational stakeholder group. All participants signed a consent form following procedures approved by the University of Utah IRB.

## 3.2 Semi-Structured Interviews

We collected data through 23 audio-recorded semi-structured interviews, each lasting between 22 and 61 minutes ($\bar{x} = 37$). Interviews were recorded and transcribed with participant consent and included questions related to employees':

- job title and responsibilities
- comfort with SHT and technology in general
- use of the smart features in patient rooms, including the most and least used and thoughts on the integration
- methods used to control SPR features
- use and thoughts on the smart room app
- perception of how the SPR impacts their workflow
- perceptions of privacy and security of the SPR technology

## 3.3 Data Analysis

After recruiting two to four participants from each stakeholder group, we used Dovetail for qualitative data analysis, employing inductive coding and thematic analysis per Braun and Clarke [7, 8]. After familiarizing themselves with the data, the first and second authors created initial codes and met to discuss these after coding the first two interviews. In this meeting, they reviewed the codebook, discussed each code, and identified any to delete, reword, or merge. Both researchers used this codebook to code the rest of the interviews. Any code changes were discussed as a team throughout the coding process to maintain a shared understanding of the evolving codebook. The final stage involved conducting several interpretive sessions by the first and second authors to consolidate the data into 11 high-level themes — derived from 1369 quotes and 143 codes — that form our findings.

## 3.4 Positionality

An important aspect of our reflexive approach is acknowledging that our positionality likely influenced how we conducted our interviews and interpreted the results. First, we are all from the United States, and our background is in computer science and human-computer interaction. Although we have spent much time conducting research in a rehabilitation hospital, we do not have any first-hand experience as patients, caregivers, or hospital employees in a rehabilitation hospital. The NRH is new and integrates more technology than almost any other hospital we know in the United States, partly because hospital administrators have pushed to integrate these technologies into the hospital. This is also the hospital where we have conducted research previously, and thus, our perceptions of what is *normal* in a rehabilitation hospital are largely shaped by this particular setting. This likely influences our interpretation of the results because we may be acclimated to aspects of this setting that other researchers may find surprising or otherwise interesting.

Second, the authors all use and find value in smart home technology in our own homes; therefore, even though we have attempted to approach this work from an open perspective of "Do hospital employees see value in the SPRs, and if so, what is it?" we are likely predisposed to expect that these technologies provide value. However, we are also weary of techno-solutionism [57] and are careful to avoid falling into the trap of thinking that technology will simply "fix all of the problems" if deployed in just the right way. Because of our positionality, we also have a very limited ability to evaluate how these technologies might be received and perceived in a different setting, whether in a different hospital in the United States or elsewhere in the world, like in the Global South. We acknowledge our potential biases and make every effort to ensure our findings add relevant and transferable knowledge to the HCI community.

# 4 FINDINGS

Our analysis provides an in-depth understanding of the employee experience of caring for patients in SPRs. We developed eleven high-level themes grouped by the research question they help answer. Our research questions are used as the section headings and the supporting themes as sub-headings.

**Table 1: Occupational Stakeholder Groups. This table provides the details for each stakeholder group, including the number of participants per group and a short description of their primary job responsibilities. The ID and a number will be used to reference participants throughout the paper.**

| ID | Stakeholder Group | n | Short Description of Primary Job Responsibilities |
|---|---|---|---|
| HC | Health Unit Coordinator | 3 | Handles employee and patient administrative tasks. In this hospital, they onboard, train, and perform initial troubleshooting for the SPR features. |
| IT | IT Manager | 1 | Helps with training and troubleshooting of the smart room features and serves as the next level of technical support for complex issues |
| MD | Medical Doctor | 2 | Hospitalist physician specializing in rehabilitation |
| OT | Occupational Therapist | 3 | Works on the patient's ability to perform activities of daily living |
| PS | Psychologist | 3 | Provides mental, emotional, and behavioral support and treatment |
| PT | Physical Therapist | 3 | Focuses on improving the patient's ability to move their body |
| RE | Rehabilitation Educator | 4 | Provides patient education and prepares them for life post-discharge |
| RN | Nurse | 2 | Nursing care (e.g., issues medication, vitals checks, and pain assessment) |
| ST | Speech Therapist | 2 | Evaluation, therapy, and care for speech and swallowing disorders |

**Table 2: Interview Participants Details. Interview participants ranged in age from 22-55 ($\bar{x} = 37$), with an average of 8.9 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 highly experienced with technology. They had a range of experience with smart home technology before working in the hospital with SPRs.**

| ID | Age / Gender | Education Level | Years in Rehab | Floor | Tech Level | Smart Technology Used at Home |
|---|---|---|---|---|---|---|
| HC1 | 37 / F | Master's | 8 | 3 | 4 | TV, Thermostat |
| HC2 | 24 / F | HS Diploma | 1 | 3 | 3.5 | TV |
| HC3 | 22 / F | Bachelor's | 1 | 4 | 5 | Google Assistant, TV, Thermostat, Lights |
| IT1 | 39 / M | Master's | 11 | 3/4 | 5 | Google Assistant, TV, Speakers, Thermostat, Lights, Outlets, Garage Door, Locks |
| MD1 | 55 / M | Doctorate | 22 | 3 | 5 | Apple TV, Apple HomePod, Doorbell |
| MD2 | 49 / M | Doctorate | 20 | 4 | 3 | TV |
| OT1 | 33 / M | Master's | 3 | 3 | 4.5 | Alexa, Doorbell, Cameras, Blinds, Door Locks, Outlets |
| OT2 | 37 / F | Master's | 5 | 4 | 4 | TV |
| OT3 | 36 / M | Master's | 13 | 4 | 4 | Google Assistant, TV, Speakers, Thermostat |
| PS1 | 25 / F | Bachelor's | 3 | 3/4 | 4 | Google Assistant |
| PS2 | 37 / F | Doctorate | 9 | 3/4 | 2 | TV |
| PS3 | 34 / F | Doctorate | 7 | 3/4 | 3.5 | TV, Google Assistant, Doorbell, Cameras, Thermostat |
| PT1 | 40 / F | Doctorate | 14 | 4 | 3.5 | Alexa, Lights |
| PT2 | 35 / M | Doctorate | 9 | 3 | 4 | Google Assistant, Speakers, Thermostat, Doorbell, Lights, Outlets, Garage Door |
| PT3 | 44 / M | Doctorate | 15 | 3 | 3.5 | TV, Alexa, Lights, Doorbell, Garage Door |
| RE1 | 40 / F | Master's | 14 | 3 | 3.5 | Alexa, Lights, Switches, Thermostat, Locks, TV |
| RE2 | 34 / F | Master's | 9 | 3 | 3 | Alexa, Google Assistant, Lights, Switches, Thermostat |
| RE3 | 38 / F | Doctorate | 16 | 4 | 3.5 | Alexa, Lights, Thermostat |
| RE4 | 48 / F | Doctorate | 8 | 4 | 3.5 | TV |
| RN1 | 51 / F | Bachelor's | 1 | 4 | 4 | Alexa, TV, Thermostat, Doorbell |
| RN2 | 32 / M | Bachelor's | 8 | 3 | 3 | TV |
| ST1 | 29 / F | Master's | 4 | 4 | 3 | TV |
| ST2 | 30 / F | Master's | 4 | 3 | 4 | TV, Alexa, Google Assistant, Cameras, Lights, Outlets |

## 4.1 How Do Employees Currently Use SPR Technology?

During the interviews, the employees highlighted how they use the SPR technology and which specific needs were supported by the current implementation.

*4.1.1 Preferred method for controlling the SPR.* The interviews showed that employees have different preferences when it comes to controlling the SPR — like the wall switches, the bedside remote, the iPad, or their own device. At the basic level, some employees prefer the wall switches since they are right by the door and don't need to access the iPad. For example, nurses are constantly in and out of the patient rooms at a frequency far greater than therapists; therefore, the speed and efficiency of using the wall switch when walking in the room is their preferred control method.

> *It [the wall switch] is right by the door. […] if you need it, you can turn it on right away, rather than going to the patient because usually it [the iPad] is by the patient.* (RN1)

Employees who spend more time in the patient room using the iPad during their sessions — like OTs, STs, and rehabilitation educators — are more comfortable using the iPad to control the room and prefer it over other methods.

> *I prefer the iPad; I feel most comfortable with it. I know where it is, what it looks like, and how to operate it well. […] if the patient has it on their phone, we can do it from that, but I definitely prefer the iPad.* (RE2)

Conversely, some employees do not use the iPad because they feel it belongs to the patient. IT1 chooses to use the app on his personal device for this reason.

> *I just don't like having to touch or use the patient's iPad, if possible, because it's kind of their property when they're here. Sometimes, people feel a little bit anxious and don't like others to look, check, or scroll through their iPad when their information is on there. So, I prefer to use my own device.* (IT1)

This finding is discussed more in section 5.2 concerning the privacy of patient's personal information on the iPad. On a related matter, IT1 clarifies that the intent behind the SPR is not to force its use. It can still be controlled completely using standard wall switches and remotes, but the technology is there if the patient or employee wants to use it.

> *It's subtle, and the technology behind it will not hit you in the face. If you don't want to use it, that's fine; you don't have to use it. This is good because I didn't ever want to force people to use the technology.* (IT1)

When it comes to the app on a personal device, it is not the most convenient for employees since they have to sync it with every room they walk into, which is an added step in their workflow. So, they resort to using the wall switches.

> *I feel like the iPad is for the patient, not necessarily for me, so they always have it close by. It's always in their bed or whatever, and I'll just walk past the bed, hit the switches, and control it that way.* (OT3)

Overall, MD1 commented on how the technology has become second nature.

> *After people have been here a while, just like for us, the technology actually seems to vanish. And even though they're doing it differently than before […] it becomes very second nature.* (MD1)

As we can see, this hospital's implementation of the SPR provides multiple capabilities and methods of controlling the room to fit the differing preferences of the employees.

*4.1.2 Using the SPR technology in their workflow.* Although the SPR was intended primarily for controlling the environment and entertainment of the room, we discovered that hospital employees are also using it as part of their workflow. At the most basic level, having a smart TV with AirPlay capability allows employees to use a larger screen to easily cast content to the TV while working with a patient.

> *Oftentimes, we call the family to do a FaceTime call or a video conference call where they walk us through the home […]. Ideally, we try to get that phone call pulled up on the big-screen TV in the room so we can all see each other, have a bigger screen, and communicate better.* (PT3)

The OTs, rehabilitation educators, and STs discussed using the SPR beyond basic room control and have integrated it into their therapy sessions. ST2 provides such an example,

> *I'll put it up with my laptop on the computer, on the TV, so they can actually see from the TV what their swallow's like. […] it's way more convenient and a lot easier to get multiple family members involved.* (ST2)

We have also seen how different features of the room support other needs for therapy sessions. ST1 uses voice control on the iPad with her patients to provide feedback for their speech.

> *Sometimes, we'll have them practice to see if the iPad can understand them. […] if nobody can understand you, voice-to-text really can't understand you.* (ST1)

Conversely, some occupational stakeholder groups don't use the SPR in their workflow. Due to their specificity, PT sessions are performed less in the room and thus less likely to be supported by the SPR technology. As PT3 stated, "It's pretty rare to do therapy in the patient room. If I can help it, we can make it more therapeutic, usually out of the room."

Even within a profession like medical doctors, we see how one employee might use the technology more than another. MD1 uses the technology to set the room environment conducive to performing his job as a clinician.

> *We are mostly adjusting lights; as a professional and clinician, I'm usually adjusting the volume down if they're watching television. […] Usually, the patient is aware enough of how to utilize the room that they recognize that that's a barrier to our conversation.* (MD1)

MD2 declares that he is not using the technology at all and cannot envision meaningful ways to improve his practice as a clinician with it.

> *I don't use the smart features hardly at all. [...] The smart features in my mind are not for me. [...] I'm fully supportive of the smart room features, and I think it's a game changer for many patients, but I can't think how I could use them to have a better experience.* (MD2)

## 4.2 What Benefits Do SPRs Provide?

During the interviews, employees highlighted several benefits provided by the SPR technology. Besides the functional room control and therapy support mentioned in the preceding section, the SPR's added value revolved mainly around patient care and satisfaction.

*4.2.1 Patient and employee satisfaction.* We know from the prior medical literature that hospital employees' and patients' experience and satisfaction are inextricably linked [41, 54]. PT1 highlights how something as simple as controlling the room's temperature with the smart room app can improve the patient and employee experience.

> *There are so many times you go into a patient room, and it feels like you're stepping into Florida. [...] If they're uncomfortable, you're uncomfortable, everyone's uncomfortable. So, I think having it connected to climate control has been really nice for the patient experience. From a therapist's standpoint, nice too.* (PT1)

HC1 spoke about how if patients can control the environment and entertainment of the room, especially for those patients that need the SPR's accessibility features, it reduces the number of times a healthcare worker has to enter the room to do it for the patient.

> *If it's too bright in the room, they can close the blinds, and if they're bedbound, it's really easy for them because they can do it right there. They don't have to worry about someone coming in to do it for them. So it's good, it gives them ease of access.* (HC1)

Additionally, MD1 provides a great example of how he thinks the SPRs foster a better experience and, in turn, increase patient and staff satisfaction.

> *I think part of this is not just patient satisfaction and care; it's also staff satisfaction. [...] a staff member would enjoy working here more because of the technology. It made their job easier. It gave the patient more satisfaction, which gave the nurse more satisfaction to be a part of a team that provides that level of care. [...] I mean, my perspective now is the building has a lot to do with satisfaction.* (MD1)

*4.2.2 Patient independence, autonomy, and control.* For patients, the SPR fosters independence, autonomy, and control. Our participants (IT1, MD1, MD2, OT1, OT2, PS3, PT2, PT3, RE1, RE3, RN1, RN2) corroborate the findings from our prior patient-focused study [17] that SPRs provide independence, autonomy, and control. Here, we present two examples to demonstrate this point. First, RN2 describes how he witnessed that the SPRs can give back lost control and feelings of independence for patients.

> *If you have lost control, even being able to get any control, even if it's adaptive, is better than having no control over your environment. They can have that bit of independence.* (RN2)

Second, OT2 highlights how smart technology provides autonomy to patients.

> *The best thing about the smart room technology is really the autonomy that it brings to our patients, especially those that are very impaired mobile-y. I think it's very empowering for them to turn on their TV without calling a nurse and waiting 15 min or more. [...] When you can give them something as simple as a way to adjust their blinds. I think that's really big; it's huge for their self-esteem and outlook on life. [...] Once they get it, they really love it, they really do. Because it gives them that autonomy back.* (OT2)

The patient's interests in an SPR are primarily about gaining back lost control. With the technology, they can control their environment and access entertainment options that would be more difficult to access in a traditional hospital.

## 4.3 What Are the Drawbacks?

We discovered that the NRH's implementation of SPRs still has some drawbacks. This section highlights common issues with the SPR technology and the employees' thoughts on privacy and security. Privacy and security were not obstacles for the employees; however, they did express common concerns from the patient's perspective.

*4.3.1 Common SPR issues.* Despite employees being generally positive about the SPRs, the technology has some drawbacks. Based on the interviews, the smart environment features (e.g., lights, blinds, and thermostat) are the most reliable. However, the entertainment features require the most troubleshooting. This is concerning since technical problems can strongly impact the user experience [47]. Employees discussed issues with AirPlaying from devices to the TV, the soundbar not working with the TV, issues signing into streaming services, and latency issues with switching inputs on the TV. As an example, HC1 described the many issues she troubleshoots with the smart TV.

> *Most of the time, it will be the IR cable. It's detached. [...] It could just be that the Apple TV itself wants to be difficult, and we have to reset it. It could be that the iPad is completely locked up and won't control Apple TV.* (HC1)

Even though there are established HUC and IT Manager positions to troubleshoot the SPR technology, many employees will take time to help patients with the technology. All but two employees (PS1 and MD2) spoke about troubleshooting for patients. As an example, OT3 describes, "Setting up their device to cast onto the TV is all I've had to help them do. But it was mostly that they weren't able to do it, not that there was a problem; I just had to show them."

There are varying levels to which the employees will spend time troubleshooting an issue. As PT2 stated, "I do very little [...] if it's beyond a 60-second fix, I say, 'Oh, okay, we'll deal with that later. Because we gotta go and work on your functional mobility instead.'" PT2 could move on with his workflow despite the issue; however, it's more problematic for employees, like rehabilitation educators, who rely on the technology as part of their workflow. Here, issues can cause frustration and reduce the time available for patient care.

> *If I'm spending 15 min trying to fiddle with AirPlay, I still need to get to my next patient in 15 min. So that's just education that the patient misses out on that needs to be made up another day. And then, I think it decreases patient experience and satisfaction because it wastes their time and my time.* (RE3)

But despite the issues RE3 has encountered trying to set up AirPlay for education sessions, she clarified that the technology is well worth the effort. She stated, "The benefits outweigh the challenges because it works. I would say at least 90% of the time."

*4.3.2 Privacy and security concerns.* As Distler et al. [21] pointed out, "As the use of digital technology evolves, so does the number and the type of risks to which users and their data are exposed." This rings true when it comes to the SPR. The SPR introduces many privacy and security risks for patients and employees. A camera and microphone are being used on the hospital iPad, and a camera/microphone combo is installed in every patient room as a monitoring tool for high-risk patients. We asked questions during the interviews to see if privacy and security concerns were obstacles to using the SPR technology.

No employees were concerned about the privacy and security of the smart room features; some even saw them as a positive for safety reasons. However, they did mention instances of patient concerns and possible mitigation measures. ST2 spoke about patients bothered by the room camera.

> *Many patients get bothered by not being able to tell if the camera is recording them or not. [...] People might enjoy having a physical cover that goes over it that's clearly opaque where it's like, "Oh yeah, that camera's not in use right now."* (ST2)

Additionally, technology may cause privacy concerns based on the patient's diagnosis and mental state.

> *If you get someone with schizophrenia or a brain injury that they think they're being held against their will or something like that, they're actually paranoid. You add a camera to the equation, and it's like, "Well, that just made me more anxious about it." [...] more of a behavioral concern, not a privacy concern.* (OT3)

Some employees indicated nuanced reasons why they are not concerned, assuming the technology is only used with good integrity, for patient-centric or safety reasons. As PT1 explained, "I have to assume it's within good integrity [...]. Historically, our culture is very patient-centric, so I want to believe that it's patient-centric." RN2 added that cameras in the room could be considered positive for safety reasons, "Say you have a patient who says, 'This nurse hit me.' [...] There could be evidence like, 'Oh, they didn't,' or 'Oh, they did.' So there are safety benefits."

IT1 provided background on some privacy and security mitigation measures they use in the hospital.

> *I know the steps we've taken to create a private space. The iPads are all completely erased after discharge. Even if you move rooms, the iPad knows when you've left the room, and it will discharge that; it will clean the iPad off and the Apple TV. Our voice control system doesn't leave the room; it stays within our own devices in our network, and it doesn't get taken out to the cloud. So everything that we've done is very room-specific. That's one benefit of having everything wired and not using the cloud or any interface to connect two devices together. All the interfaces are wired or Bluetooth, a secure location-based communication system between devices. So, as far as privacy and security go, that's a pretty safe space to be in.* (IT1)

Even though some employees relayed privacy concerns from the patients during their interviews, no employees expressed concerns about the privacy and security of the SPR.

## 4.4 What Has Hospital Administration Done to Overcome SPR Challenges?

The hospital administration has taken steps to ensure the SPR is properly supported. They created two new job roles focusing on the SPR technology, and they have implemented feedback mechanisms for continual improvement.

*4.4.1 New job roles to support SPRs.* Adding SPRs to the NRH created a new technology support requirement that is not needed in a traditional hospital. As part of the solution, the hospital created two new job roles. First, the hospital instituted a new health unit coordinator (HUC) [73] position. HUCs can be found in some hospital settings, but this job position was not utilized until they switched to the new building with SPRs. The HUCs are assigned to be the first source for training and troubleshooting the SPR technology. HC1 describes her job duties as a HUC in this hospital.

> *Our responsibility is to go in and educate the patients and their family members on how to use the application for the smart room. We show them how to operate the blinds, do the lights, do the TV, and access Apple TV. We have to go in and troubleshoot when these things don't work.* (HC1)

Incorporating the HUCs was an afterthought after opening the new hospital. At first, the initial training and troubleshooting were placed on the therapists.

> *In the beginning, we didn't have the aides. It was kind of upon us to teach the patient how to use the smart room app. Now, the HUC and other people take care of that for us. So that was a newer way. I didn't feel overwhelmed by it necessarily, maybe because I'm comfortable with technology a little bit.* (OT2)

The hospital administrators recognized that there needs to be a link between the healthcare workers, the HUC, the app developers, and the technology team. So, the hospital converted one of their OTs to the new role of IT Manager to fill this position.

> *I'm not a traditional IT Manager [...]. My main job in this hospital is to help patients use and access the technology in their rooms. So, teaching them access methods, training staff and other people how to use the technology at some level, and troubleshooting issues. So, if there's a problem in the patient rooms or a glitch in the systems, I'm the first line of defense. I am not always the one who will fix it, but I know who to contact. So my background is not necessarily in IT.* (IT1)

The HUC and the IT Manager fulfill the support role so the other healthcare workers can focus on patient care.

*4.4.2 Hospital employees should be trained to use the SPRs.* Our patient-focused study showed that onboarding, initial training, and retraining were important for patients staying in an SPR [17]. The same holds true for hospital employees. When they switched from the old building to the new smart hospital, the IT Manager conducted several group training sessions for the employees to show them how to use the smart features of the SPR. However, for new employees, there is no codified training plan. There are four primary ways the employees learned how to use the SPR. Some met directly with or watched videos created by the IT Manager, while others learned on their own or from fellow employees. Without a codified onboarding, training, or retraining plan, some employees feel they were not fully trained on the room's capabilities. For example, PT1 was part of the transition to the new smart hospital but highlighted the gaps in educating the staff.

> *I think there are definitely gaps in how we educate our staff. [...] When I first started, I wasn't even sure what the app was called. When I turned on the iPad, I wasn't quite sure where to go.* (PT1)

Even though PT1 attended training with the IT Manager, there were features she did not know how to use. The app is intuitive enough that employees can use most of it, but there are some features they might miss without instruction.

> *I think it's fairly intuitive if you're willing to be uncomfortable for a few minutes and some people aren't. [...] I think I could've totally figured it out on my own, but a little bit of extra input to help because I would've missed some of the features on my own.* (ST2)

Even if employees attend training, one session may not be enough, as it is easy to forget information. As PS2 noted, "I went to a voluntary training with [the IT Manager], and he showed a bunch of us [...] how to use the room. But I probably remembered it for a week and then didn't remember it anymore." Since remembering the information presented in the training can be an issue, hospital administration should provide opportunities for follow-up training.

> *I guess a follow-up training would always be nice. You always want to do the initial one and then use it for a while. And then inevitably you're gonna have questions and concerns, things didn't work well, so being able to come back again a few months later and talk about things that were difficult for you, things you want to be able to do that you couldn't do right now easily, let us walk through how to do that.* (PT3)

It was evident from our interviews that since SPRs add additional technology not found in a traditional hospital, and the technology is not completely intuitive, there needs to be a solid plan to onboard, train, and provide opportunities for retraining employees on using the SPRs.

*4.4.3 Feedback is critical for improvement.* The SPRs in this hospital are ever-evolving. The hospital administration is always looking for new technology to invest in, and they have their own development team for app changes. During MD1's interview, he mentioned that this building is special. When asked to clarify, he responded,

> *Because we have a team of scientists, clinicians, and IT specialists that all decided to work together and change things in real-time based on real-time information. And I think that does not happen in many places, so that's the secret sauce.* (MD1)

The hospital has implemented feedback mechanisms to ensure the system is continually being improved. IT1 spoke about how feedback has helped greatly to improve the SPR.

> *That's why it's good to get this outside feedback and why it's good to have people like asking patients and why I'm with patients, and I get feedback from them saying this doesn't make sense. And I can then go take it back to the UI team and say, "Hey, this didn't translate like we thought it was going to." So let's figure out how we can do this differently in our iterations from the first version to this version, which has been guided by that process. So that's something I like about it. It is growing and can continually be adjusted and adapted on a day-to-day basis if we want it to be. And it's very, it's a living app that is totally based on patient feedback and what we can do to help our patients.* (IT1)

Despite the challenges of implementing new technology in the hospital, they have a method for patients and staff to provide feedback on the app, improving the experience of living and working in an SPR.

## 4.5 What Are Employees' Suggestions for Improving the SPR?

During the interviews, employees regularly discussed improvements they wanted for the SPR. This section provides the employee's ideas on improving the SPR with additional technology and their ideas for automation.

*4.5.1 Improving the existing technology.* Although the SPRs in this hospital are fully functional, the employees showed enthusiasm when brainstorming ways to improve the current SPR technology or new technology that could help them perform their jobs. They considered how other technology — e.g., robotics, AI, or voice assistants — could be integrated. As an example of how employees see the same patient challenges and brainstorm similar solutions, a robotic iPad mount was suggested several times in our interviews (RE2, MD1, IT1, ST2, PS2). The heart of the problem is that for the iPad's voice control functionality to work, it has to be close to the patient to detect their voice properly. IT1 describes this problem,

> *The biggest issue is that you always have a screen in your face. People don't want that; they don't want to have a screen 18 inches from their face all day, every day. But if you don't have it, you can't communicate [...]. But that would be so helpful in improving access and control of the room, just giving them access to the technology they want when they want it.* (IT1)

ST2 proposed a robotic arm mount to move the iPad in and out automatically, depending on whether the patient needs to use it.

> *I think a robotic arm that you could pull forward and pull back would be great because then I'm in bed, and I know I need the nurses to come help me, I can have the arm put away, the nurses help me, and then I pull it back out later when I want to.* (ST2)

Several employees (IT1, MD1, PT2, and PT3) discussed ways AI could support employee workflows. For example, PT3 explained how high-risk patients are monitored using the SPR camera by an aide sitting at the nurses' station but questioned whether AI could do this task more efficiently.

> *Instead of having a human watch all these screens constantly, have a robot or whatever AI technology watch 'em, and if someone gets up and there's a movement that's appreciable, then have it call the nurse [...] With an AI watching 'em constantly, it's always watching, and it's always alerting people when the concerning thing happens. So they could use that potentially to make that process faster.* (PT3)

Using AI to assist with tasks would thus allow employees to devote more time to patients.

Another idea often discussed in participant interviews (MD2, OT1, OT3, RN1, RN2, ST1) was expanding the voice control on the iPad to be more of a global always-on voice assistant that can be used anywhere in the room. Currently, voice control only works with the app for the smart features of the room, but employees want to perform actions, or even other tasks like charting, by using voice commands. The first idea, from PT3, is simply adding a voice-controlled nurse call feature to the smart room app. She wants the ability to say, "Hey Alexa, call my nurse, please." And it activates the nurse call light. OT2 expands the idea and asks for a more global voice assistant that can be activated anywhere in the SPR and provides an example of needing to call for help.

> *The ability, if I'm in trouble, to have voice control in the background. If I'm saying a command to get help because I'm transferring a patient, and they're about to fall, or they have fallen, I can't reach over and press the call button. And we resort to screaming basically for help. So I think having something where I could say, even just a phrase or something to turn on that light, like "Hey, I need help in here."* (OT2)

Beyond using the voice assistant as a nurse call, MD2 liked the idea of using the voice assistant to chart in the electronic medical record (EMR) because it would allow him to quickly chart in the room while the patient and caregiver were listening. This would provide a more efficient workflow since he could talk to the patient and have it charted simultaneously instead of speaking to them first and then completing the EMR entry later.

> *So if I, after my interview and exam, said, "Hey Epic, chart this, [example doctor note ...]." So that would be a good subjective part of our note, and I think it would create increased communication between the patient, the medical team, the nurses, and the family members so that everyone is on the same page.* (MD2)

These are just some ideas mentioned during our interviews regarding additional technology employees think will help create a better experience and improved workflow.

*4.5.2 SPR automation ideas.* In our interviews, automation using the SPR technology frequently came up. The employees' ideas generally fall into two categories: automating the environment and automating tasks. One sensor mentioned by the employees that can be used to help automation is the Real-time Locating System (RTLS). In healthcare, RTLS can provide real-time tracking and management of medical equipment, patients, and staff [28]. In the NRH, a system is installed, but it is not used as a sensor for the SPR. The hospital administration has been talking to the employees about the RTLS system and potential automation, so participants were already thinking about its possibilities. IT1, who is very closely tied to the development of the RTLS/SPR integration, provides an example of using it for sustainable energy savings.

> *RTLS has some real opportunities, [...] It will know when you leave the room; at that point, the room can go into more of a sleep or hibernation state to save energy. [...] And then when they come back to the room, the building will know when they're maybe four or five doors down from being there, and everything can come back up where they left it.* (IT1)

Another idea is to have the room automatically adjust the environment when a particular employee enters the room. This feature is particularly important for doctors doing their rounds since both MD1 — "Being able to have the room automatically recognize me entering or exiting the room, and it potentially adjusting, you know, lighting and sound accordingly for conversation." — and MD2 — "So TV off, blinds up, and lights on, automatically. Yeah, I'm thinking that's clearly within the system's capability." — mentioned it during their interviews. However, as pointed out by ST2, if this capability was implemented, customizing the automation by the employee is important to ensure it meets their needs.

> *It'd be nice to customize my own, especially for my coworker, he's always working with the TBI patients, so he would probably need things quieter, softer, darker. And I don't always have those restrictions because my population is so different.* (ST2)

Related to this comment, PS1 suggested including an environment-limiting feature in the app where the clinicians can set limits on the room's lights, blinds, volume, or temperature to avoid overstimulating certain patients.

> *Certain traumatic brain injury levels require different levels of stimulation to be productive. If there were a room setting for that to automate it, I could see that being really helpful because the different protocols involve different amounts of light and different amounts of volume.* (PS1)

Besides automating the environment, employees also thought about automating tasks. The idea that came up most often is finding ways to automate charting in the EMR. The EMR is intended for general healthcare information management of patient records and charting, which healthcare professionals 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. Our participants came up with ideas about how the SPR could aid their workflow. One idea was using RTLS/SPR integration to make automatic charting entries in the EMR. ST2 thought about how this integration could help automatically chart her time in a patient's room.

> *One of the things I have to do is keep track of the exact minutes I spend doing something, and so that could be a really nice involvement of, "Oh, I walked in the room at this time and walked out."* (ST2)

What if the SPR can sense even complex tasks, like charting intake and output, and automatically chart them?

> *People are really busy running from room to room sometimes. The big things that are missed would definitely be intake and output. So like bathroom trips, meals completed, or fluid drank, if that could somehow be tracked and automatically charted, that would help save time. And if it was automated, it would keep someone from having to remember.* (RN2)

Additionally, MD1 feels automated charting would positively impact employee satisfaction and patient care.

> *Because charting is three-quarters of a nurse's life [. . . ]. As soon as you give that time back to clinicians, I think you'll start to see some satisfaction, better patient care, and better engagement.* (MD1)

Since charting is time-consuming, automated charting would give healthcare workers valuable time to reinvest with patients, potentially increasing employee satisfaction.

## 5 DISCUSSION

Our findings show how employees currently use the SPR technology, the benefits and drawbacks, and their suggestions for improving it. Here, we discuss how these findings help answer our RQs and provide insights from our findings that apply to smart workplaces.

### 5.1 Expanding SPR Utility from Basic Room Control to Therapy and Rehabilitation

While looking at RQ1 (How do hospital employees currently use SPR technology?), we discovered that employees use the technology for more than just controlling the room; they also use it for rehabilitation. Several studies have demonstrated how prevalent app use is for therapy and rehabilitation [16, 63, 65]. Our findings corroborate this since therapists, psychologists, and rehabilitation educators regularly use the iPad apps in their therapy sessions.

One of the OTs' objectives is to help patients learn how to use assistive technology to build their digital competence. As the world undergoes a digital transformation, digital competence also becomes more important [48]. Akyurek et al. [1] expresses the importance of teaching technology to patients as part of their rehabilitation in the hospital. The SPR is a great tool for rehabilitation because it allows the OTs to showcase and teach patients how to use smart technology that has real-world implications for their own independence and quality of life.

The SPR is predominantly utilized by the HUCs, IT manager, OTs, rehabilitation educators, and STs, and was utilized less by other stakeholder groups. The variation in technology adoption among different groups seems to be influenced by how much the technology aligns with their specific job functions. For instance, PTs — requiring specialized therapy tools — prefer using a therapy gym over the SPR, while OTs find the SPR features conducive to demonstrating assistive technology. Additionally, technology usage varies within each group based on individual familiarity and comfort with smart technology. The contrasting behaviors of the doctors exemplify this. MD1, accustomed to smart technology in his home and positive about the SPR, frequently utilizes the features. In contrast, MD2's limited experience with smart technology and perception of its irrelevance to his work likely led to his much lower utilization. To maximize the benefits of the SPR for all stakeholder groups, it is imperative to explore SPR technology beyond basic room control and see how it can be used for more complex functions that directly support therapy and healing.

There is a real opportunity for SPRs to support healing and therapy since the SPR environment can be reconfigured, updated, and customized through software. PS1 highlighted that patients grappling with severe brain injuries need a controlled environment. Providing a low-stimulation environment is often key for an agitated patient with a brain injury [11]. In a traditional hospital setup, caregivers can only manually control the environment by turning off the TV, dimming lights, or closing blinds. Yet, it is hard to set limits on these functions. Since the SPR's smart features are managed by software, it is possible to set limits programmatically. For instance, healthcare providers could use the smart room application to set limits (brightness of the lights, maximum TV volume, or the ability to raise the blinds). Unintentional over-stimulation from family members — like turning on bright lights or too much TV volume — could be avoided through such limits. By restricting the room's smart features, patients, caregivers, and staff can still use the SPR technology while ensuring they stay within the prescribed stimulation parameters. Another opportunity would be to design Just-in-Time-Adaptive-Interventions (JITAIs) that leverage the sensors and controls of the SPR to help patients remember aspects of their self-care, such as being active and performing pressure reliefs [58]. However, the design of JITAIs is a challenging endeavor [42], and further work is needed to explore that design space. These examples highlight how the SPR's utility extends beyond regular smart-home-type functionality, instead contributing to a patient's therapy, rehabilitation, and recovery process.

### 5.2 Convergent and Divergent Interests between Patients and Employees

For RQ2 (From the employee perspective, what are the benefits and drawbacks of SPRs? What has been done to overcome challenges?), we found hospital employees corroborate the findings from our patient-focused study that SPRs do provide the benefit of independence, autonomy, and control for patients [17]. We also saw that bugs and other issues with the technology still occur. Perhaps most interesting is that not all of the benefits of SPRs from employees' perspectives converge with the needs or preferences of patients; employee and patient interests sometimes diverge. For example, the SPR camera to monitor high-risk patients. Employees see its safety

value, even for lower-risk patients; however, some patients are concerned by its presence. How should we decide what functionality is implemented in SPRs when patient and employee interests conflict?

Hospital design literature identifies potential conflicting needs between patients and employees in patient rooms. Quan et al. [62] identified 23 design goals that each map to design considerations and features. One relevant design feature from that work is "Patient control of adjustable temperature, varied/dimmable lighting and shades, and entertainment within reach of patient bed and chair." Within these guidelines, they note that patient control is potentially in conflict with an employee goal, "efficiency of care," which prioritizes staff control of the patient room. This conflict is impactful, especially because of the authority and power imbalance hospital employees can have over patients [37]. Prioritizing the staff over the patient in a smart environment can be seen in prior work (e.g., [31–33]). Their smart ICU was designed "to display data in a variety of formats, convert data to actionable information, use data proactively to enhance patient safety, and monitor the ICU environment to facilitate patient care and ICU management." This design supports the employee in caring for the patient but does not provide anything directly for the patient to use. In our findings, the SPR supports some patient-focused needs, and others that are useful to patients and employees alike. In this hospital, using the iPad to watch TV is purely a patient-focused benefit of the room. Yet, some features benefit both patients and employees, like controlling the lights and the blinds or using the iPad as a therapy tool. In these situations, the technology is supporting both parties.

The most interesting example of divergent and conflicting needs is the hospital-furnished iPad. On one side, employees reported that the iPad was their primary method for controlling the smart features of the room, basically using it as if it were standard hospital equipment. The problem is that patients are encouraged to log in to their personal accounts — e.g., personal email, social media, and streaming media services — on the iPad and use it as if it were their own. This creates tension when an employee wants to use the iPad to control the room; the patient may have sensitive emails or other content from their personal accounts that they do not want others to see. We know from Karlson et al. [43] that people are quite protective when sharing a device with applications that contain personal information, such as voicemail, notes, files, email, SMS, and calendars. By encouraging patients to log in and use their accounts, the iPad is essentially turned from hospital equipment into a personal device. Understandably, employees must use the iPad for some room features because there is currently no viable alternative. Only a few employees recognized this sensitive situation and chose not to use the iPad. More interestingly, this reveals that the employees may not recognize the problem fully. Besides discussing the clunky option to use the iOS or Android app on their own device, no one brainstormed an employee-focused solution to the iPad problem. With that in mind, we still believe that providing employees with a version of the room control application that more directly matches their needs would increase their usage of and satisfaction with the SPRs. Such a tool could facilitate some of the therapy-related functions and enable employees to set limits on the usage of the smart room in service of patients' health and rehabilitation as described in sections 4.1.2 and 5.1.

## 5.3 Automation to Improve Employee Workflow

For RQ3 (What are employees' suggestions for improving the SPR? What are the design opportunities for future SPRs?), we found that the employees had numerous ideas for improving the SPR. The most common suggestion employees mentioned while brainstorming was automation. From smart home literature, we can see opportunities (e.g., increased communication, awareness, and functionality [23]) and potential obstacles (e.g., exploiting sequences of actions [15], intimacy of routines [19], and supporting routines [75]) for automation in SPRs. The value of automation to an employee of a smart hospital is likely limited by their personal preferences and the needs of their particular role in the hospital. We know from prior literature that users identify and refine ideas for useful automation by living — or potentially by working — in the space [19, 52, 53, 59]. In our findings, employees brainstormed ideas for possible automation that could improve their workflow, but these ideas were very limited in scope to two areas: automating the environment (e.g., automatically adjusting settings when they enter the room) and automating charting (e.g., automatically entering time spent with a patient into the EMR).

Developing more intricate automation that can significantly impact workflow in the complex environment of a smart hospital requires the up-front investment of time and effort to understand and interpret sensor values [55, 56, 74] and then to ideate, implement, iterate, and debug the automation [9, 19, 23, 40]. One key reason this level of authoring is required for smart homes is that every smart home is unique: the hardware that is deployed, the layout of the home, and the people who inhabit the space all matter. SPRs hold some of these variables constant; therefore, it is conceivable that sharing automation could be more useful in this context. For example, common automation could be shared or set as an optional default employee setting. This is especially helpful because it removes authoring as a barrier to getting value from automation.

Value can also be gained from SPR automation through increased sustainability. Wang et al. [77] states that smart buildings "are expected to address both intelligence and sustainability issues." Smart hospitals with automated SPRs can optimize energy consumption by adjusting lights, blinds, thermostat, and other energy-consuming devices based on room occupancy and time of day, reducing the environmental footprint. Additionally, using telemedicine services — e.g., AirPlaying family meetings on the smart TV — can reduce unnecessary travel.

Also related to automation, incorporating human-robot interaction (HRI) into SPRs can enhance both patient experience and employee workflows. Existing HRI research indicates that robotics can facilitate accessibility [4, 61], offering solutions for individuals with limited dexterity to control the robots through alternative modalities like voice or standard accessible controllers. As noted in our findings, an issue in SPRs is the positioning of iPads for patient use; a robotic arm could increase patient autonomy and decrease nurse call frequency by allowing patients with limited abilities to position the iPad where they want. We hope that these findings provide a useful starting place for future research to discover new workflow and sustainability improvements gained through SPR automation and HRI.

### 5.4 Future Smart Workplaces

As seen from this hospital's implementation of SPRs, using smart home technology in a smart workplace (i.e., a smart space that may be occupied primarily by one user, yet employees may also use the space to perform job functions) is becoming more common. But an SPR is just one example of such a space. Future smart workplaces might include patient rooms in other types of hospitals, assisted living residences, hotels, co-working offices, or even short-term rentals (e.g., Airbnb). Smart home research from the human-centered perspective is extensive [82]; however, smart workplaces such as the SPR do not map well to this existing literature. Dey et al. [20] highlight the tensions between hosts and guests of an Airbnb and the benefits of smart home technology versus privacy; this research resonates with our results.

Based on our insights into smart workplaces, the following are some considerations when designing smart spaces. First, we know from smart home literature that smart technology within a shared space introduces its own social concerns like surveillance and privacy [10, 13]. With respect to workplace privacy, Mathur et al. [51] highlighted how employees were unsure if their personal data was being accessed by management, and these concerns extend to the working environment [5]. Past work has even emphasized that such data ought to be easily accessible to these users [29, 79]. We see similar employee concerns in the SPR environment, where any data collected in the SPR is expected to be used "within good integrity" (PT1, section 4.3.2). Yet it would be helpful if management would state how the SPR data is being used in a policy. Another way to mitigate privacy concerns can be as simple as physical covers on the SPR cameras. Just as with smart homes, designing smart workspaces requires recognizing and mitigating privacy concerns. However, a key difference from smart homes is that these decisions are often made on an institutional level, and the building inhabitants might not have the same level of access to and influence over decision-makers as they would in a domestic setting.

Second, smart technologies in the workplace may require employee training and troubleshooting support. From our previous patient-focused study [17], one design consideration for future SPRs is that the technology needs to be "properly supported." Our findings show how the hospital administration recognized this need and established new job positions to support these smart spaces. But even so, introducing smart technology in these environments imposes some additional work on staff as they support others in these spaces. The same requirement to provide training and support for smart technology should be considered when designing shared workplace smart spaces; all building inhabitants should have easy access to resources that facilitate their training and support with respect to the technology integrated into the building.

Third, the design must consider all stakeholder perspectives. This is obviously important in healthcare since patients, caregivers, and clinicians may have differing needs [80], and yet our findings show that the SPR we studied is clearly focused on the needs of patients over those of hospital employees. Employees and patients use the SPR differently, and even different employee types do not control the room the same. The design of the SPR includes multiple control modalities to meet users' individual needs. This should be considered in other smart workspaces. For example, an Airbnb has hosts, guests, housekeeping, and maintenance personnel as potential users, and each type has different needs to control the smart workspace. As a design consideration, there should be multiple control modalities, for example, so housekeeping does not need to use a device considered private or sensitive — such as a host-provided iPad — to control the smart features.

Based on the discussion above (Section 5.3), our last consideration proposes that designers should envisage some default, yet customizable, automation options when building smart workplaces. For example, the same sustainability benefits we see for SPRs could also be extended to this space. Integrating similar IoT-connected devices like lights, blinds, and thermostats with sensors to detect room occupancy and time of day can enable energy conservation by transitioning unoccupied rooms into a low-energy "sleep" state.

### 5.5 Limitations

While the present study provides insight into hospital employees' experience of SPR technology, we recognize several limitations. First, due to the rather unique implementation of the NRH's SPR, we sampled employees from a single hospital. Although we observed variations in their workflow and needs, there is likely more homogeneity in employees' practices when being sampled from a single institution. Second, despite mitigation precautions, voluntary and snowball sampling involved interviewing employees who were more likely to use the technology or had a favorable attitude toward it. They also were more likely to recommend talking to other employees equally comfortable with the room technology.

## 6 CONCLUSION

While SPRs in this hospital context are primarily used for patients to control their environment and entertainment, this technology also impacts the hospital employees working in these patient rooms. Through semi-structured interviews with 23 hospital employees, we gained valuable insight into employee experiences with SPRs. Our results offered insights into 1) the employees' current use of technology, 2) the benefits and drawbacks they encounter, and 3) their suggestions for improving the technology. Based on our analysis, we discuss the complex problem of building SPRs that support patients and employees and suggest design considerations for future smart workplaces. Future work exploring smart hospitals should expand these insights to improve hospital employee and patient experiences.

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