Authors’ post-print version

To be published as:

Annemans, M., Van Dyck D., Heylighen, A. (2024). How does the built environment affect patient safety in relation to physical activity? Experiences at a rehabilitation center. *Applied Ergonomics*

Please refer to the final published version.

**How does the built environment affect patient safety in relation to physical activity? Experiences at a rehabilitation center**


## Abstract

Physical activity benefits patients in rehabilitation yet comes with various safety issues. The built environment impacts on both safety and physical activity. We aim to explore the role of the built environment in safety issues related to being physically active in rehabilitation. We conducted a case study at a free-standing rehabilitation center for patients with Multiple Sclerosis, neurologic, or locomotor issues. Patients participated in two interviews supported by activity tracking data. Care professionals participated in focus group interviews respectively with two therapists and four head nurses. Accessibility and physical barriers, visual connections and (in)dependence, and spatial familiarity are important themes when identifying aspects of the built environment in relation to reducing safety issues patients encounter during physical activity. Raising awareness about each of these among care and design professionals could help them to balance safety issues in relation to physical activity and to communicate about them in a nuanced way.



## Keywords

Built environment, Patient safety, Physical activity, Qualitative research, Rehabilitation center


## 1. Introduction

Physical activity can refer to any bodily movement that requires energy expenditure or can be interpreted as a combination of intended and unintended movement, being part of a therapeutic program or resulting from common activities, such as household chores, using stairs, recreational or transportation activity (Caspersen et al., 1985). It is highly beneficial to functional recovery and symptom management for a variety of rehabilitation patients, like people with Multiple Sclerosis (e.g. Fortune et al., 2020), stroke (e.g. Simpson et al., 2021), or locomotor issues (e.g. Papalia et al., 2020). Nevertheless, many rehabilitation patients feel insecure when it comes to being physically active (Koenders et al., 2021). Although they are mostly encouraged to move independently, they frequently rely on care professionals for instructions and support, also for non-therapeutic activities. Rehabilitation therapists aim to support patients in improving their mobility and maximizing their independence. At the same time they are educated to guarantee a safe environment, aim for zero fall risk (Singh et al., 2021), and encourage patient engagement in achieving optimal safety (Chegini et al., 2021) by warning patients of fall risks. As these aims are difficult to reconcile, many therapists rather take a precautionary approach in stimulating physical activity among patients (Singh et al., 2021), sometimes even restricting patients' mobility (Aizen et al., 2015).

The World Health Organization (2021) defines patient safety as "the prevention and reduction of risks, errors, and harm that occur to patients during provision of health care". Within the specific context of a rehabilitation center, this definition needs to be refined. The risks, errors, and harm mentioned in the definition can have various causes ranging from clinical errors (e.g. regarding medicine use or surgical interventions), over communication flaws, to fall incidents. In the context of rehabilitation, falls are the most frequent recorded patient safety incident in the inpatient context and are more likely to occur when patients are physically active and at times when staff members are less able to observe them (McKechnie et al., 2016). Among the most likely to fall while being physically active are patients with stroke, brain injury, spinal cord injury, amputations and neurological disorders (Forrest et al., 2012; Wilson et al., 2020). At the same time, being physically active is an essential part of their rehabilitation process. Additional to fall risk, rehabilitation patients are also confronted with other cognitive and mental safety issues. This stresses the importance to consider safety in a broader sense (Niederhauser & Schwappach, 2022).

Studies related to healthcare building design and rehabilitation nursing point to the role the built environment plays in patient safety and physical activity. General studies in healthcare building design, foreground how building design – ranging from construction details, over materials, to spatial organization – impacts on patient safety through infection control, fall risk, and communication between patient and staff (Ulrich et al., 2008). Specifically for the context of rehabilitation, only few studies exist about the potential of the interior built environment and its close surroundings to influence patient behavior (Blennerhassett et al., 2018) regarding physical activity (Annemans et al., 2022; Åstrand et al., 2016; Lipson-Smith et al., 2020) or patient safety. When research on rehabilitation practices mentions the built environment, the focus lies on activities (e.g. using the bathroom) and locations (ward, therapy location, cafeteria/dining room) where incidents, such as falls, occur (Wilson et al., 2020) or shared rooms and lack of privacy impacting on communication (Chegini et al., 2021), not on specific aspects of the built environment that cause the incident.

This brief literature overview shows a close connection between safety (issues), (facilitating) physical activity and (the design of) the built environment in how patients are cared for in rehabilitation. It also points at the difficulties of balancing the risk of stimulating patients' autonomy in rehabilitation with optimally guarding their safety. With the evolution toward actively engaging patients in their care process, and specifically in managing safety throughout the rehabilitation process (Chegini et al., 2021), insight into how patients and care professionals perceive safety in rehabilitation is essential. Using a qualitative research approach to gain such insights can give patients and caregivers an active voice when balancing physical activity and safety in relation to the built environment. Consequently, we used a qualitative approach to explore the role of the built environment in safety issues related to being physically active in rehabilitation.

## 2. Materials and Methods

Patients' and care professionals' experiences regarding patients' physical activity and safety in relation to the built environment are personal and constructed through their interactions with others and the environment. Our study therefore aligns with a constructivist paradigm (Crotty, 1998), as it focuses on interactions – in this case between patients' and care professionals' experiences of patients' safety and physical activity, and the built environment. Instead of beginning with a theory and testing a clear hypothesis, we start with an examination of the empirical world (Esterberg, 2002), which can bring up insights regarding unexpected themes. In this case the analysis of interviews with patients and care professionals about the relationships between physical activity in rehabilitation and the built environment (Annemans et al., 2022) foregrounded the importance of safety.

The study took place in a free-standing rehabilitation center in Flanders, Belgium, situated in a green environment (Figure 1), affiliated with a general hospital in a nearby town (33 601 inhabitants, 401,07 inh./km$^2$). The center is surrounded by different types of housing for people with an impairment (mostly Multiple Sclerosis (MS)), ranging from group residences to family houses. Near the center there is an animal park with farm animals and a small forest with paved tracks.


*Figure 1. Aerial view of the rehabilitation center and its surroundings (source: open streetmap, with additions by the first author)*

The building consists of a ground floor where all activities take place and four identical floors where the wards are situated (Figure 2, Figure 3).

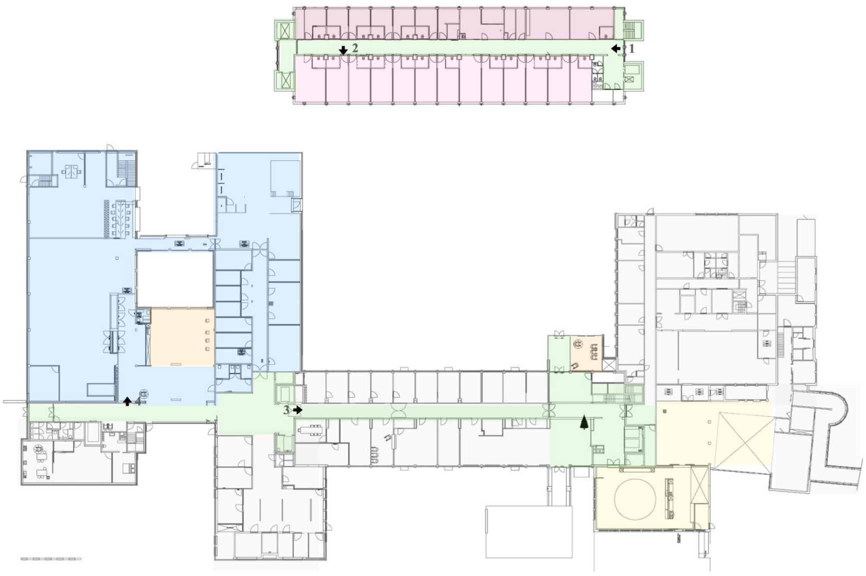

*Figure 2. Floorplans of ground floor and four wards (circulation: green, patient rooms: pink, therapy area: blue, recreation (hobby & smoking area): orange, public area (cafeteria): yellow. Scale indicated bottom left, total scale line = 10 meter)*

*Figure 3. Images of the building (top left: corridor on the wards, top right: double patient room, bottom left: corridor at therapy area, bottom right: corridor ground floor, respectively numbers 1, 2, 3, 4 on floorplans)*

Between October and December 2019, 16 patients were recruited, with various diagnoses and various abilities to move around the rehabilitation center and its surroundings (Table 1). Based on the criteria of being inpatients in the center for at least a week and the ability to participate in a face-to-face interview, head nurses provided a list of possible candidates, which they considered cognitively capable of participating in the study.

The study is set up as illustrated in the flowchart below (Figure 3). The first author (henceforth ‘the researcher’) approached each of the candidates and, after a brief introduction of the aim and set-up of the research, conducted a first explorative semi-structured interview with each participating patient. This interview focused on patients’ perception of physical activity and the built environment. At the end of the interview patients were invited to wear an activity tracker for 48 hours, measuring the amount and intensity of their activity. The 48 hours period was defined to cover both day and night as well as differences in therapy schedules - for example when patients had alternating therapies or rest days. During these days participants were provided with the opportunity to keep a diary (written or based on pictograms) to document their (physical) activity. After two days, the researcher retrieved the activity tracker to read out the measurements and consecutively conducted a follow-up interview discussing participants’ activity in the past days.

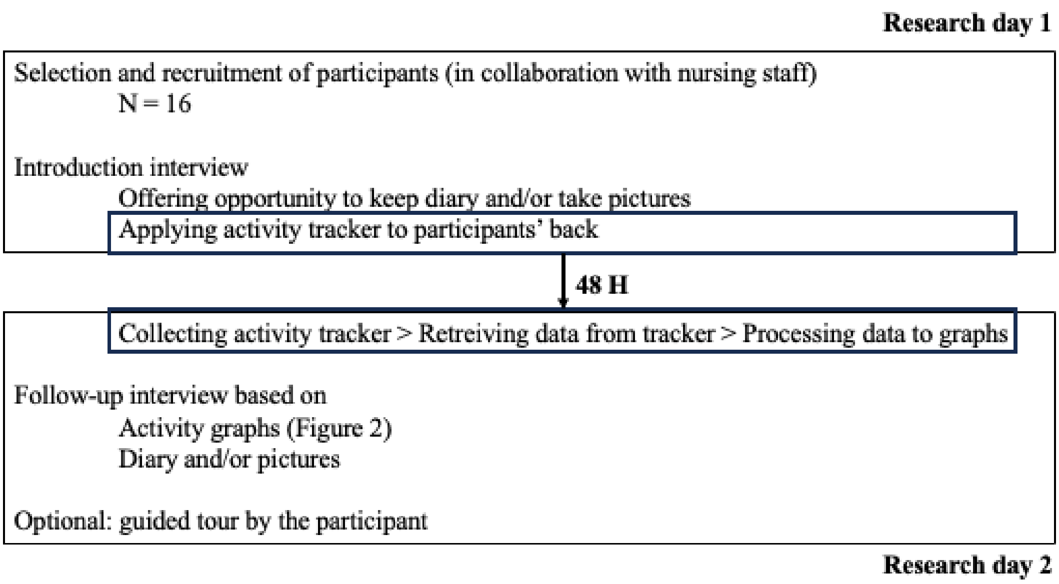


*Figure 4. Study's flowchart*

The graphs showing the measured activity (Figure 4) were used as a probe for a detailed interview about participants' activity. The diaries and measures complemented each other as the former gave insight into perceived activity whereas the latter showed, in detail, what participants had done. To facilitate talking about the built environment, the researcher asked participants to guide her through the building to show the spaces discussed during the interviews. During this guided tour, the participating patient took the lead.

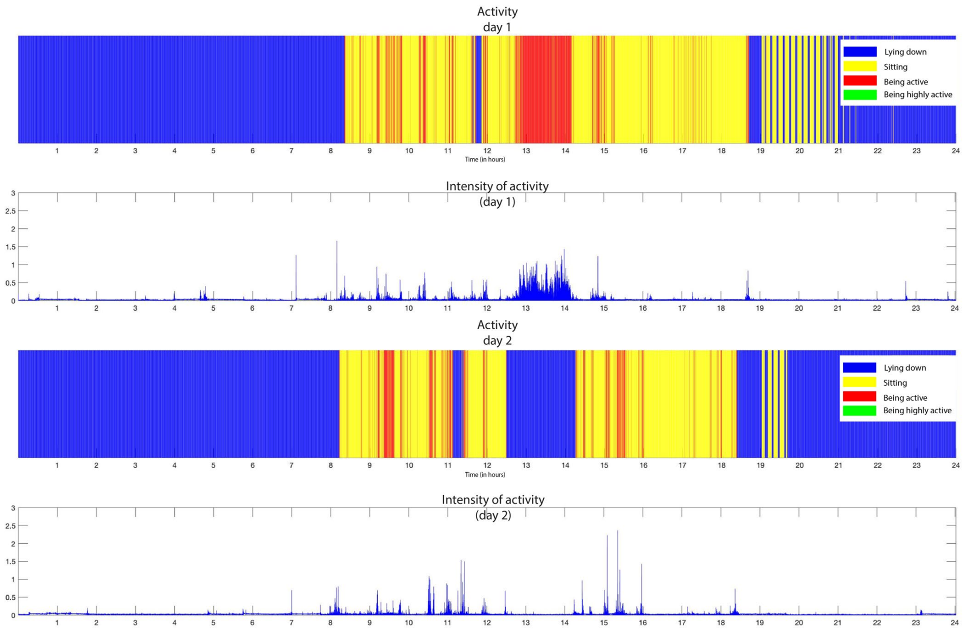


*Figure 5. Four graphs showing the type of activities and intensity over 48 hours. The first shows through a color code, over the first 24 hours of the measures (on X-axis), which activity (lying, sitting, being active) someone is undertaking. The second shows, over the first 24 hours of the measures (on X-axis), the intensity of the movement by indicating a line on the Y axis. The third and fourth graphs show respectively the same for the next 24 hours of the measures.*

The combined interviews lasted per person between 30 minutes and 1 hour and 21 minutes with an average of 58 minutes.

*Table 1. Overview of information on participating patients and collected optional documentation.*

| Pseudonym | Age bracket | Gender | Duration of stay (at first interview) | Diagnosis | Optional documentation |
|---|---|---|---|---|---|

| | | | | | |
|---|---|---|---|---|---|
| Mary | 60+ | F | 1 month (yearly) | Multiple Sclerosis | Guided tour |
| Eddy | 45-60 | M | 3 months | Multiple Sclerosis | Diary |
| Bill | 60+ | M | 3 months (yearly) | Multiple Sclerosis | Guided tour |
| Kelly | 30-45 | F | 6 months | Multiple Sclerosis | Diary and pictures |
| Sharon | 30-45 | F | 6 weeks | Multiple Sclerosis | Guided tour |
| Christine | 60+ | F | 11 months | Multiple Sclerosis | None |
| Ronny | 45-60 | M | 5 months | Multiple Sclerosis | Guided tour |
| Alma | 60+ | F | 2 weeks | Knee surgery | Guided tour |
| Dora | 60+ | F | 2 weeks | Knee surgery | Diary and guided tour |
| Bob | 30-45 | M | 3 months | Foot amputation | Diary and guided tour |
| Antonio | 60+ | M | 3 months | Shoulder, arm and leg injuries | Guided tour |
| Fred | 60+ | M | 3 weeks | Stroke | Guided tour |
| Steven | 45-60 | M | 8 months | Brain tumor and Parkinson | None |
| Suzanne | 60+ | F | 13 months | Stroke | None |
| Michelle | 45-60 | F | 5 weeks | Stroke | Diary and guided tour |
| Jenny | 45-60 | F | 3 weeks (after 8 months in a hospital | Stroke | Diary and guided tour |

Additionally, the researcher conducted two online focus-group interviews (FG) with care professionals, one with the head therapists (of physiotherapy and ergotherapy, n=2), the other with the head nurses of the four wards (n=4) respectively in July and December 2020. Each lasted approximately 1.5 hours. These interviews focused on the impact of the built environment in relation to the organization's care vision (including safety) on patients' physical activity.

The interview guide for the first semi-structured interview (Table 2) was based on previous experience (with qualitative research about the built environment in other healthcare contexts), insights from preparatory observations, and relevant literature and focused on the impact of the built environment on participants' physical activity. Safety was not particularly addressed in the interview questions but was implicitly and explicitly foregrounded by participants.

Participating patients' physical activity was registered based on their bodily position (lying down, sitting, or moving) and intensity of movement. To do so Axivity AX3 activity trackers were used (Axivity, 2015). The approach was informed by the outcomes of a pilot study(Annemans et al., 2020)).

The data of the activity trackers were processed in MATLAB (2019). Participants' bodily position was derived from the registered angle of their back. From this position we then derived their type of movement (laying down, sitting up, walking) and its intensity. These were represented in two graphs respectively showing type and intensity of movement over time (Figure 5).

All interviews and guided tours were audio-recorded, transcribed verbatim, and pseudonymized. Observations were documented with field-notes, The information collected through the activity trackers, the diaries, and the pictures was used as a conversation starter in the follow-up interview with the participants. As such it was not analyzed separately but integrated in the analysis of the interviews. Transcripts were analyzed according to a grounded theory based approach, in line with the Qualitative Analysis Guide of Leuven (Dierckx de Casterlé et al., 2012), following an iterative process of coding, memo-writing and developing concepts and categories. Transcripts and complementary material were imported into qualitative data management software NVIVO 12 to support the data analysis. Relevant themes were identified in the data individually and compared and combined later to mitigate possible biases. After a first overall analysis of the data collected with a focus on patients' perception of physical activity and the built environment (reported in(Annemans et al., 2022)), themes related to safety came to the fore under various overarching codes such as personal sensitivity, motivation, activities, and building qualities. In a second analysis themes related to safety were explicated.

*Table 2. Interview questions and themes*

| **Selection of questions in interview guide that resulted in responses related to 'safety'** | **Themes (first overall analysis)** | **Safety related themes** |
|---|---|---|
| DAY 1 | | |
| Expectations & first impression<br>• How do you experience the rehabilitation center compared to other healthcare facilities?<br>• Why did you opt for a single/double room? | Building qualities<br>Activities<br>Personal sensitivities | Accessibility (e.g. bathrooms being highly accessible)<br>Connection (e.g. people within reach) |
| Physical activity & built environment<br>• What supports or hampers you to be physically active?<br>• Which obstacles do you encounter when being physically active?<br>• (discussed / space participants use during their stay) | Building qualities<br>Activities | Accessibility (e.g. one floor, elevators)<br>Barriers (e.g. doorstep)<br>Obstacle (e.g. slippery floor)<br>(Dis)comfort (e.g. cold)<br>Occurred falls |

| | | |
|---|---|---|
| | Personal sensitivities and/or motivation | (In)dependence (e.g. going outside by themselves)<br>Connection/familiarity (e.g. falling or getting lost and not being seen) |
| | **DAY 2** | |
| Based on results activity trackers<br>• What did you do at this point?<br>• Where were you at this point? | Activities | Occurred (or prevented) falls<br>Risks (e.g. going for a smoke)<br>Familiarity (e.g. when going outside) |
| Reflection<br>• How is the way you move (e.g. with mobility aid) related to how you experience space? | Building qualities<br><br>Activities<br><br>Personal sensitivities and/or motivation | Obstacle (e.g. distance > being tired)<br>(Dis)comfort (e.g. going outside with wheelchair)<br>(Un)ease (e.g. getting tired) |
| Guided walk<br>• Why do you bring me here?<br>• How does this space support/hamper you?<br>• What is the meaning of this space for you?<br>Is there a place you would like to show me but cannot go? Which? Why? | Personal sensitivities and/or motivation<br><br>Building qualities | (In)security (e.g. of getting back in after smoking)<br>(In)dependence (e.g. taken, yet opportunity to ‘escape’)<br>Familiarity (e.g. unknown destination, getting lost)<br>Obstacle (observed):<br>Orientation/wayfinding (e.g. getting lost) |

Quotes were translated from Dutch to English by the authors.

Approval for the study was obtained from the Social and Societal Ethics Committee of KU Leuven, Belgium, and the hospital's ethics committee.

## 3. Results

An essential requirement for participants to be physically active, autonomously or during therapy, is to feel safe, physically and mentally. The experience of falling or getting lost or the idea that it could occur keeps them from taking initiative. The built environment of the rehabilitation center impacts on participants' safety through physical circumstances, (visual) connections, and spatial familiarity.

### 3.1 Accessibility and (physical) barriers

In contrast with the outside world, including their own home, participants consider the interior of the rehabilitation center extremely accessible. Having staff constantly within reach is experienced as really reassuring in case something happens. As such the building supports their sense of safety when they undertake daily activities and motivates them to take initiative to be physically active.

> *[Eddy]: For example, the bathroom, you have a sink where you can wheel underneath. You'e not sitting like this [shows a sideways movement], it's not like at home. At home you have to sit sideways on a chair, with your hands in the sink, whereas here, you can sit straight, completely straight.*

People who have difficulties lifting their feet, use a walker or wheelchair, or have (one sided) limited sight – together covering almost the entire patient group at the center – need a high level of accessibility. Although most participants also describe the building as almost perfectly accessible, they still point at some physical obstacles in the interior that hamper their safety when they are physically active.

Careless and ad-hoc adaptations can result in unexpected obstacles that cause participants to fall or clash. Cables of fitness equipment can easily become a hurdle when the equipment or the cables are moved from their original, intended location (Figure 6). New objects in a room can easily become an obstacle especially for people with limited vision. For Suzan, a participant who has only one-sided sight, the Christmas tree in the hall, was a serious obstacle. Since she was not used to it being there and could not see it, she bumped into it when she turning to the elevator (seen indication on floorplan, Figure 2).

*Figure 3. Cables of fitness equipment can become a hurdle (left: ad hoc placement of equipment on the ward, right: orderly placement in the therapy unit)*

Construction details and materials require specific attention of participants to avoid falls. The doorsteps of the outside doors are only millimeters above the floor level. Especially at the door towards the smoking area (Figure 7), which is frequently used by people only going outside for a cigarette, the step is mentioned as a big hurdle.

*Figure 4. Even a small doorstep can be a hurdle*

The completely even PVC floor material is experienced as slippery. At least one participant referred to its speckled design as glimmering and as such disorienting.

.


*Figure 5. Detailing of outdoor environment (Left: Small unevenness in pavement. Right: efforts made for optimal accessibility e.g. no or covered gutter*

The detailing of the outdoor environment surrounding the center is aimed at optimal accessibility (Figure 8). Nevertheless, even a small ridge (Figure 9) can result in an experienced wheelchair user tripping, as Bill experienced:

> *[Bill]: Here I tripped with the scooter […] and I lay there and couldn't see anything […] Nobody had seen me. Then after a while, half an hour later,*

*someone came, three women […] You're lying there, eh, I couldn't get up, nothing.*

*Figure 6. Ridge that caused Bill's wheelchair to trip*

When participants are confronted with such safety issues, this impacts not only on their physical but also on their mental well-being. Once participants have fallen, they often fear it happening again, hampering them to undertake (physical) activities.

*[Antonio]: [as I experienced the risk of this slippery floor before] now, it's less dangerous, but when I first came here, when I had to [walk], then I thought by myself 'take care not to fall here', because I want to heal, I don't want to stay here longer [than necessary].*

Even risks they have not encountered themselves, but only heard of from fellow patients or staff, keeps participants from taking initiative or impact on the choices they make.

*[Steven]: For the sake of safety, I've always made them shower me in a stretcher, even though they had foreseen to do so in a wheelchair.*

*[Researcher]: And why do you choose this stretcher?*

*[Steven]: Yes, why? Fear of falling, I guess.*

Participants mention a lack of control over these physical circumstances in the built environment as an important reason not to use the outside areas surrounding the center. They consider unevennesses in the pavement or unexpected obstacles along the way as a too high fall risk.

### 3.2 (Visual) connection and (in)dependence

Even participants who are physically capable and allowed to move independently through the building and its surroundings, often refuse to do so because they fear not to be seen by staff or others if something happened. Especially regarding going outside, participants stress the importance of being seen from inside to feel safe. As a result most of the outdoor equipment is not used, except when patients are accompanied by relatives (or staff as part of an activity).

*[Kelly (when asked whether she uses the outdoor training area, Figure 10)]: Well, not on my own initiative, you're allowed to go up there, up the hill, but I don't want to walk on stairs by myself, so I prefer not to. If I fall, I'd be laying there, outside.*

*[Dora]: Yes, you have to know what you're capable of, obviously. When I'd go for the 1.8 km walk in the woods, then I let the nurses know, and a family member accompanies me.*

*Figure 7. Outdoor training area only faced by closed off windows on the ground floor.*

Participants need the reassurance of someone taking care of them in case something goes wrong. As such they remain dependent on others to be physically active outdoors.

The fear of not being noticed is not unfounded, as Bill experienced (see his quote in 3.1). When the risk of patients leaving the building and getting lost is too high, staff do not allow them to leave the ward, aiming to keep them continuously in eyesight. Nurses from the neurological ward mention in one breath the benefit and downsides of 'surveillance doors', doors that can be opened only on the upper part so people cannot leave their room. As the head nurse from the ward explains, this may be a solution to keep people from wandering, it comes with other safety risk.

> *[Headnurse neuro ward]: We now have a number of rooms with surveillance doors at the ward, that's a big help for some rehab patients, actually a reassurance for the nurses. But we've noticed that isn't all-encompasing. There are people who climb over such door by taking a chair. So then we should make it almost like a prison, with nothing inside, where the chair is*

*put inside only when they have to eat. So actualy, that's not ideal yet, we still have some work to do.*

Participants who smoke take considerable risks to avoid being noticed by staff when lighting a cigarette, especially at night when the smoking area is closed. They climb through the window (FG nurses) or find their way to an emergency exit, risking being locked out for the night, for example by using a paving stone to keep the door open (interview Jenny) (Figure 11).

*Figure 8. Heavy emergency exit door with a paving stone (left) to keep it open at night.*

### 3.3 Spatial familiarity

Especially patients with MS have often been coming to the center for many years, making it a familiar environment. Despite many spatial changes over the years, some participants, like Sharon, consider the center their safe space.

*[Sharon] When I first came here [32 years ago] it was very different, it reminded me of the house of my grandparents [...] now it has all been*

*renovated since a couple of years. […] [But] when you feel that it's not going well, then you can always come here. You always have place to return to.*

Navigating the building or its surroundings can be challenging, even for participants who are allowed to move independently. Both during the interviews and the guided tours, it became clear that participants prefer to follow familiar paths to avoid getting lost.

One of the participants, Fred, guided the researcher to show the different places he used. After each destination, he returned to his room on the ward to start again, even if two destinations were only one corridor apart.

Although the wider neighborhood of the center is mostly accessible for patients with mobility aids, few dare to go further than its direct premises. As one participant, Ronny, explains, he only takes his scooter out to places he knows.

*[Ronny]: Yes, you want to see something, but there's not much here actually, or you have to make a tour in the woods and I'm not from here, I'm from [Hometown], so I don't know the way around here. So I have to balance a little, where I go and what I do.*

Despite initiatives to improve wayfinding on the paths in the adjacent woods (Figure 13.), only two participants have ever been that far. Dora has walked the track in the woods accompanied by a family member but fears not being able to get back if she went by herself (cf. citation above, example of dependence). Michelle has gone on a Saturday night torch walk on the walking track organized by the activity support group. Yet, she cannot recall having been in the woods.


*Figure 9. Accessible paths in the woods (left) with indications to find the way back to the rehabilitation center (right).*

## 4. Discussion and Conclusion

Most studies on patient safety are conducted from a care perspective in which the built environment plays a minor role. Taking the perspective of the built environment in patient safety related to being physically active in rehabilitation as a starting point, foregrounded how a building and what it affords can hamper or support safety during physical activity and impact on patients' physical and mental well-being.

Research on rehabilitation in relation to safety issues limits information about the built environment to where incidents occur (Wilson et al., 2020). Our study provides insight into the extent to which detailing and material choice as well as spatial organization impact on being (motivated to be) physically active due to the perceived sense of safety on top the actual safety risk. Regarding interpersonal connections, our study shows that the impact of the built environment on mental safety goes beyond privacy to assure patient communication (Chegini et al., 2021). Being seen when being physically active outside (visual connections) or providing sufficient orientation points (spatial familiarity) are just as important. Such insights into how patients and care professionals perceive safety and how the built environment impacts on their interaction in rehabilitation are essential, especially when aiming toward actively engaging patients in their care process, and in managing safety throughout the rehabilitation process (Chegini et al., 2021).

Control – whether keeping control or being controlled – is a key concept to understand the connection between safety, physical activity, and the built environment in rehabilitation. Physical circumstances and being familiar with the building impact on participants being in control of daily physical activities like washing hands or going outside by themselves. Visual connections allow visual control from staff, reassuring participants that being physically active is safe. After having fallen or gotten lost, participants mention being afraid of ending up into the same or a similar situation again and not being able to escape it. Staff like to be in control of situations at all times, to reduce safety risks (Singh et al., 2021). Often this reduction also means restricting patients' mobility (e.g., by closing rooms), which is not beneficial to their recovery (Aizen et al., 2015). While some participating patients expressed their wish for independence, others needed the reassurance of being able to depend on care professionals. Care professionals experienced a constant tension between balancing supporting patients' independence and providing a caring and safe environment (Singh et al., 2021), as our study confirmed.

The built environment can contribute to creating places that are physically safe – by avoiding physical barriers – and experienced as such – by allowing visual connection throughout and around the building and providing a clear building organization. Currently staff communicates very explicitly about safety risks with respect to the built environment, pointing out fall and navigation risks in the building and its surroundings.  Strategies to deal with these risks are rarely addressed. Neither are patients explained how and where they can use spaces in and around the building safely, e.g. which places outside are easily accessible and visible from inside.

Since safety concerns, especially fall risk, also impact on staff (Bok et al., 2016), they too will benefit from adaptations to the built environment. Buildings designed to reduce this risk through improved construction details (e.g. small ridges), materialization (e.g. floor materials that are not (perceived by patients as) slippery), and spatial organization (e.g. clear building structure and easy navigation), could help staff and patients in finding the much needed balance between reducing safety risks and supporting patients' autonomy (Singh et al., 2021). Insight into patients' experience could help finding a suitable design solution, not creating a new safety risk by solving the original one as was the case with the surveillance doors. Introducing the role of the built environment in staff's education on patients' safety, is likely to allow them to communicate this to patients when engaging them in achieving safety (Chegini et al., 2021). Since patients often rely on staff for instructions and support, also for non-therapeutic activities (Koenders et al., 2021), patients will likely be more inclined to be physically active when staff points not only at risks, but also at how the built environment supports being physically active in a safe way.

The insights gained have implications for both design and care practice. Achieving a physically and mentally safe environment for patients entails more than meeting the basic required building standards of accessible buildings. When patients perceive a situation as potentially harmful, they tend to refrain from them, a conscious consideration of material choice and detailing can help to avoid such perception. At the same time, a rehabilitation building should provide sufficient visual and physical connections between patient and staff areas, to allow informal contact throughout the day, independent of therapy or care moments. Even if the built environment is highly supportive of patients being safely physically active, care professionals still play an important role in encouraging them to be. Part of the therapy could be to explicate to patients how the design of the built environment supports them in safely being physically active. Such an explanation will most likely increase patients' sense of mental safety.

This study has some limitations. The analyzed interviews focused on physical activity in relation to the built environment. The topic 'safety' was not intentionally addressed in the interview questions but came to the fore throughout the conversation and became apparent through the analysis.  Addressing the topic explicitly may have allowed a more profound exploration. The current approach however guarantees that what has come up is truly a concern from participants and not hinted towards by the researcher. While the limited number of participants did not allow drawing conclusions for all rehabilitation patients, nor for a particular patient group, it facilitated the combination of multiples methods, which contributed to engage profoundly with participants and exploring unexpected topics.

Insights gained show potential to be further explored in future research. Balancing safety issues and physical activity is a continuous challenge for rehabilitation patients, also in a hospital environment and at home. Exploring how (the design of) the built environment plays a role in these contexts could contribute to creating a more supportive environment. Moreover, realizing public spaces where physically or cognitively challenged people can safely be physically active, would benefit a population far beyond rehabilitation patients. This study could provide a starting point of how to approach such study on the design of safe public spaces and which topics to address.

The research suggests that safety issues, although not always addressed explicitly, play a major role in patients' engagement to be physically active in a rehabilitation center. As shown, the built environment impacts on how safe patients feel, physically and mentally, while being physically active. These insights show potential for further exploration from a nursing and design perspective.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Acknowledgments

The authors thank all participating patients and staff members for sharing their time and insights and the management of the care organization for their support and Erik Verbeke for the support in programming the MATLAB code. We also thank our funding source, the Research Foundation Flanders (FWO) under grant Q5 number 12Y6519N.

## References

Aizen, E., Lutsyk, G., Wainer, L., & Carmeli, S. (2015). Effectiveness of individualized fall prevention program in geriatric rehabilitation hospital setting: A cluster randomized trial. *Aging Clinical and Experimental Research*, *27*(5), 681–688. https://doi.org/10.1007/s40520-015-0330-7

Annemans, M., Van Dyck, D., & Heylighen, A. (2020). Introducing Activity Tracking in Healthcare Settings: The Merit of Self-reflection. In P. Langdon, J. Lazar, A. Heylighen, & H. Dong (Eds.), *Designing for Inclusion* (pp. 79–86). Springer International Publishing. https://doi.org/10.1007/978-3-030-43865-4_8

Annemans, M., Van Dyck, D., & Heylighen, A. (2022). What affects physical activity in a rehabilitation centre? Voices of patients, nurses, therapists, and activity trackers. *Disability and Rehabilitation*, 1–10. https://doi.org/10.1080/09638288.2022.2118873

Åstrand, A., Saxin, C., Sjöholm, A., Skarin, M., Linden, T., Stoker, A., Roshandel, S., Dedering, Å., Halvorsen, M., Bernhardt, J., & Cumming, T. (2016). Poststroke Physical

Activity Levels No Higher in Rehabilitation than in the Acute Hospital. *Journal of Stroke and Cerebrovascular Diseases*, *25*(4), 938–945. https://doi.org/10.1016/j.jstrokecerebrovasdis.2015.12.046

Axivity. (2015). *AX3 Data Sheet: 3-Axis Logging Accelerometer*. https://axivity.com/files/resources/AX3_Data_Sheet.pdf

Blennerhassett, J. M., Borschmann, K. N., Lipson-Smith, R. A., & Bernhardt, J. (2018). Behavioral Mapping of Patient Activity to Explore the Built Environment During Rehabilitation. *HERD: Health Environments Research & Design Journal*, *11*(3), 109–123. https://doi.org/10.1177/1937586718758444

Bok, A., Pierce, L. L., Gies, C., & Steiner, V. (2016). Meanings of Falls and Prevention of Falls According to Rehabilitation Nurses: A Qualitative Descriptive Study. *Rehabilitation Nursing*, *41*(1), 45–53. https://doi.org/10.1002/rnj.221

Caspersen, C. J., Powell, K. E., & Christenson, G. M. (1985). Physical activity, exercise, and physical fitness: Definitions and distinctions for health-related research. *Public Health Reports (Washington, D.C.: 1974)*, *100*(2), 126–131.

Chegini, Z., Arab-Zozani, M., Shariful Islam, S. M., Tobiano, G., & Abbasgholizadeh Rahimi, S. (2021). Barriers and facilitators to patient engagement in patient safety from patients and healthcare professionals' perspectives: A systematic review and meta-synthesis. *Nursing Forum*, *56*(4), 938–949. https://doi.org/10.1111/nuf.12635

Crotty, M. (1998). *The foundations of social research: Meaning and perspective in the research process*. Sage Publications.

Dierckx de Casterlé, B., Gastmans, C., Bryon, E., & Denier, Y. (2012). QUAGOL: A guide for qualitative data analysis. *International Journal of Nursing Studies*, *49*(3), 360–371. https://doi.org/10.1016/j.ijnurstu.2011.09.012

Esterberg, K. G. (2002). *Qualitative methods in social research*. McGraw-Hill.

Forrest, G., Huss, S., Patel, V., Jeffries, J., Meyers, D., Barber, C., & Kosier, M. (2012). Falls on an Inpatient Rehabilitation Unit: Risk Assessment and Prevention. *Rehabilitation Nursing*, *37*(2), 56–61.

Fortune, J., Norris, M., Stennett, A., Kilbride, C., Lavelle, G., Hendrie, W., de Souza, L., Abdul, M., Brewin, D., David, L., Anokye, N., Victor, C., & Ryan, J. M. (2020). 'I can do this': A qualitative exploration of acceptability and experiences of a physical activity behaviour change intervention in people with multiple sclerosis in the UK. *BMJ Open*, *10*(3), e029831. https://doi.org/10.1136/bmjopen-2019-029831

Koenders, N., Marcellis, L., Nijhuis-van der Sanden, M. W., Satink, T., & Hoogeboom, T. J. (2021). Multifaceted interventions are required to improve physical activity behaviour in hospital care: A meta-ethnographic synthesis of qualitative research. *Journal of Physiotherapy*, *67*(2), 115–123. https://doi.org/10.1016/j.jphys.2021.02.012

Lipson-Smith, R., Zeeman, H., & Bernhardt, J. (2020). What's in a Building? A Descriptive Survey of Adult Inpatient Rehabilitation Facility Buildings in Victoria, Australia. *Archives of Rehabilitation Research and Clinical Translation*, *2*(1), 100040. https://doi.org/10.1016/j.arrct.2020.100040

*MATLAB* (Version R2019b). (2019). [Computer software]. The MathWorks Inc. https://www.mathworks.com/help/matlab/ref/rand.html

McKechnie, D., Fisher, M. J., & Pryor, J. (2016). The characteristics of falls in an inpatient traumatic brain injury rehabilitation setting. *Journal of Clinical Nursing*, *25*(1–2), 213–222. https://doi.org/10.1111/jocn.13087

Niederhauser, A., & Schwappach, D. L. B. (2022). Speaking up or remaining silent about patient safety concerns in rehabilitation: A cross-sectional survey to assess staff experiences and perceptions. *Health Science Reports*, *5*(3). https://doi.org/10.1002/hsr2.631

Papalia, R., Campi, S., Vorini, F., Zampogna, B., Vasta, S., Papalia, G., Fossati, C., Torre, G., & Denaro, V. (2020). The Role of Physical Activity and Rehabilitation Following Hip and Knee Arthroplasty in the Elderly. *Journal of Clinical Medicine*, *9*(5), 1401. https://doi.org/10.3390/jcm9051401

Simpson, D. B., Jose, K., English, C., Gall, S. L., Breslin, M., & Callisaya, M. L. (2021). "Factors influencing sedentary time and physical activity early after stroke: A qualitative study". *Disability and Rehabilitation*, 1–9. https://doi.org/10.1080/09638288.2020.1867656

Singh, H., Collins, K., Flett, H. M., Jaglal, S. B., & Musselman, K. E. (2021). Therapists' perspectives on fall prevention in spinal cord injury rehabilitation: A qualitative study. *Disability and Rehabilitation*, 1–10. https://doi.org/10.1080/09638288.2021.1904013

Ulrich, R., Zimring, C., Zhu, X., MS, J., Seo, H.-B., Choi, Y.-S., Quan, X., & Joseph, A. (2008). A Review of the Research Literature on Evidence-Based Healthcare Design. *HERD : Health Environments Research & Design Journal*, *1*(3), 61–125.

Wilson, A., Kurban, D., Noonan, V. K., & Krassioukov, A. (2020). Falls during inpatient rehabilitation in spinal cord injury, acquired brain injury, and neurologmusculoskeletal disease programs. *Spinal Cord*, *58*(3), 334–340. https://doi.org/10.1038/s41393-019-0368-z

World Health Organization. (2021). *Global patient safety action plan 2021–2030: Towards eliminating avoidable harm in health care*. World Health Organization. https://apps.who.int/iris/handle/10665/343477