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Transfer of ergonomics knowledge from participatory simulation events into hospital design projects

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Abstract

BACKGROUND: Participatory simulation (PS) is a method to integrate ergonomics and safety into workplace design projects. Previous studies have mainly focused on tools and methods for the simulation activities. The subsequent process of transferring and integrating the simulation outcomes into the design of workplaces is poorly understood.

OBJECTIVE: This study sets out to study the role of actors and objects in the transfer of ergonomics knowledge generated in PS events and in the integration of this knowledge into a design project. The study identifies factors that influence what part of the simulation outcomes are integrated.

METHODS: The empirical context of the study was six PS events that were part of a hospital design project. The events were investigated based on knowledge transfer theory, observations, interviews and document studies.

RESULTS: We identified actors and objects with abilities of transferring ergonomics knowledge from the PS events to the hospital design project. The study indicated that

persons producing the objects functioned as a filter, meaning that not all ergonomics knowledge was transferred from the PS events. The main influencing factors on the integration were: predetermined building dimensions and room interdependency.

CONCLUSIONS: We propose four recommendations for ergonomists and safety professionals when planning PS events.

Keywords: Participatory ergonomics, work system design, knowledge transfer, healthcare

1. Introduction

Design of new hospitals includes not only the design of the physical building, but also design of new work systems including work organization, technology, workspaces and work practices. Participatory ergonomics is an approach for integrating ergonomics and safety into the design of work systems, which involves the future workers in the design process [1-4]. Participatory simulation (PS) is a method in which future workers participate in simulations of their future workplace and work practices. PS has the following aims: to innovate the workplace design [5], to enable evaluation of future ergonomics conditions [6, 7], and to adjust the design to improve the future ergonomics conditions and safety [8-10].

Simulating work scenarios in full-scale mockups of the future workplace is one approach to PS. By combining the experiences and know-how of the different participants during the simulation, new knowledge is created [11], e.g. identifying ergonomics challenges or formulating design criteria and adjustments to comply with those challenges. The knowledge is “ergonomics” in the sense that it has a focus on improving the future workers’ well-being, safety and the overall workplace performance [12]. Subsequent to the PS, the created ergonomics knowledge has to be *transferred* and *integrated* into the hospital design. This can be seen as a two-step process. The first step is the transfer of the ergonomics knowledge from the PS events into the overall hospital design project. The second step is to integrate the ergonomics knowledge into the hospital design project, thereby making the knowledge from the PS events have a design impact. The research has mainly focused on how to set up and accomplish the

simulation activities and only to a minor degree on the subsequent knowledge transfer and integration, e.g. [4] and [13-15]. Yet the knowledge transfer and integration is a crucial step for the participatory activities to have an impact on the final workplace design.

Broberg et al. address the process of transferring the outcome of participatory ergonomics events into the design process [16]. The transfer seems to be supported by circulation of objects, such as final versions of layout diagrams and scale models. These objects are the outcome of the participatory events and can be circulated to architects and engineers in the design project. The aim of this explorative study is to investigate the role of actors and objects in transferring and integrating knowledge from PS events into hospital design projects.. A better understanding of this will provide new insights for ergonomists and safety professionals to take into account when planning and facilitating PS events.

The study is guided by the following three research questions:

- 1) How can ergonomics knowledge be transferred from PS events into hospital design by actors and objects?
- 2) What parts of the transferred ergonomics knowledge are actually integrated in the design of workplaces?
- 3) What are the main factors influencing the ergonomics knowledge integration?

In this study, ergonomics *knowledge transfer* is defined as the process of sending or bringing knowledge created during the PS events to architects and engineers engaged in the hospital design project. *Knowledge integration* is defined as architects and engineers interpreting, translating and applying the received ergonomics knowledge in the hospital design project.

The paper is organized as follows. First, we present the empirical context and theoretical foundation for the study. In the following method section we provide a methodological reasoning behind data collection and analysis. In section five we present the results according to the three research questions, leading to a discussion in section six relating the results to the theoretical concepts and providing recommendations for ergonomists and safety professionals.

2. The empirical context of the study

In a renewal program of the Danish public hospitals the Regional Councils funded several innovation centers, with the aim of involving physicians, nurses, secretaries, and other healthcare professionals from existing hospitals in the design of new hospitals. They were asked to take part in simulations of the future hospital workplaces in the centers. The simulation outcome was to be transferred to the architects and engineers in the hospital design offices in order to impact the actual design.

The center in this study was located in a hall at the construction site of a new hospital. The hall provided the necessary space for building full-scale mock-ups of the future hospital workspaces. The mock-ups consisted of movable chipboard walls, foam bricks

and standard hospital furniture, as illustrated in Figure 1. In cases where the project owner or the architects had doubts about the appropriateness of a room design, the room was built as a mock-up and tested through PS by healthcare professionals from the existing hospital. Several of the PS events also involved staff from the project owner department, and engineers and architects from the consulting design consortium. The PS events were facilitated by two center staff members from the project owner organization - one with a clinical background and one with a background in occupational health and safety (OHS). At the time of this study, the hospital design process was approaching the detailed design stage, and thereby the simulation activities were focussed on room dimensioning and layout.

Figure 1

A typical PS event in the innovation center started with an introductory meeting for the 5-12 participants at which the center staff presented the room to be tested by showing the architectural blueprints. The presentation was followed by a discussion among the event participants, with a focus on the possible ergonomics and safety challenges due to the design. This typically included critical work postures, accessibility or conditions influencing the quality of treatment. The challenges were then the starting point for the PS, which took place in a full-scale mock-up of the specific room. The mock-up was constructed beforehand by the center staff and in accordance with the architectural blueprints. During the simulation, the participants acted out and discussed future work scenarios to explore the ergonomics challenges, e.g. simulating the work postures and movements of orderlies handling beds within a corridor. During the PS event, the

participants adjusted the mock-up by moving the walls and furniture to improve the ergonomics conditions. After the PS event, the identified ergonomics challenges and the design adjustments were documented in text or drawings with the purpose of being communicated to the architects and engineers in charge of designing the particular room.

3. Theoretical foundation: Concepts of knowledge transfer and integration

Knowledge transfer may be defined as “the conveyance of knowledge from one place, person or ownership to another” [17]. Integration may be defined as happening “when knowledge that originates in one context or location is used and applied in another” [18]. The process of knowledge transfer can also be seen as a communication in which information is disseminated from a sender to a receiver [18-20]. A successful knowledge transfer is when the receiver assimilates the knowledge as the process of knowledge integration [17]. However, this understanding has been criticized for being too simple. Instead the process of knowledge transfer and integration has to be studied in light of being situated within and depending on the contexts of the sender and receiver. In the transfer, the knowledge has to be contextualized to be valuable in the new setting. This process is often defined as translation, transformation or interpretation [17,20]. This means that the receiver interprets and translates the knowledge according to his own context and experiences [21,22].

In this approach to knowledge transfer and integration the role of intermediaries is highlighted as they have the ability to circulate among different settings and actors and hence transfer knowledge [21]. The two intermediaries in this study are *actors* and

objects. Actors can carry embedded knowledge from one setting into another setting, and translate this according to the new context [18,23). Some actors may even have the role as boundary spanners, meaning that they can introduce elements of one context into another [24]. Objects have the ability to codify and represent the knowledge of the producers and can be exchanged between actors [25,26]. Examples of objects that can transfer knowledge are architectural blueprints, sketches, and lists of ergonomics guidelines. Objects can be open or closed [26,27]. Open objects represent knowledge open for interpretation and exploration, e.g. the first sketches done by an architect for a new hospital department. Closed objects represent knowledge which is ready to handle and is unquestionable, e.g. the final blueprints of a hospital department, which are supposed to be translated unchanged into the actual construction.

4. Method

The research questions were investigated in studies of six participatory simulation events accomplished in the hospital innovation center. In two previous studies some of the events have been analyzed with the aim of investigating (i) how the simulation media, in this case the fullscale mockups, influence the simulation outcome [7] and (ii) how the knowledge creation process during the simulation events could be modelled [28]. However, after initial studies of simulation events we started wondering how the outcome was transferred to the hospital design project and if design proposals or challenges were actually integrated. Hence, this aim was incorporated into the study of the six simulation events. The overall design of the study is illustrated in Figure 2.

Figure 2

In the following we first present the six participatory simulation events, and then the methods for data collection and analysis.

4.1 The participatory simulation events

The six PS events are presented in Table 1. Each event was studied by the first author following the same scheme. First, naturalistic observations of the simulation event were carried out. All events were planned and facilitated entirely by the center staff members. The events were not in any way manipulated or controlled by the investigator. Second, after the event the investigator performed semi-structured interviews with event participants. Third, the investigator asked permission to see notes and documents describing the event outcome. Fourth, the investigator was permitted access to selected architectural blueprints in both pre-event and post-event versions.

Table 1

4.2 Data collection and analysis

We collected different types of data with the purpose of conducting triangulation [29] through the analysis, which was guided by the three research questions.

4.2.1 Data collection and analysis 1: Ergonomics knowledge transfer

We defined ergonomics knowledge transfer to be the process of sending or bringing knowledge created during the six PS events to architects and engineers in the hospital design project. To investigate the transfer, we focused on actors and objects, and the

transfer of those from the innovation center to the design office. An overview of the data materials are presented in Table 2. The observations were guided by an observation guide [30] including three main sections: before the simulation, during the simulation, and after the simulation. Before the simulation included activities, actors, and objects. During the simulation included participants, procedure, type of simulation and simulation media, ergonomics issues, and results and documentation. After the simulation included plans for the subsequent transfer of the documented results. The interviews were conducted with PS participants selected on the criteria of maximum variation [31], that is, representing a variety of professions. The interviews were semi-structured [32] and based on an interview guide with four main sections: background of the interviewee, before, during and after the simulation. Before the simulation focused on the interviewee's expectations and preparation. During the simulation included simulation focus, simulation media, participants, outcomes, results and documentation. After the simulation focused on what happened to the documented results. The documents were selected based on having a possible role in knowledge transfer.

Table 2

The data were analyzed by applying the concepts of actors and objects as a theoretical frame [33]. The analysis followed three steps. First, the data was coded in order to identify actors or objects possibly involved in ergonomics knowledge transfer. Second, the coded data was examined in order to analyze how the actors involvement possibly enabled knowledge transfer. This included analysis of their role of linking the PS events and the design process. Third, the coded data was examined in order to analyze how

objects possibly enabled knowledge transfer. This included analysis of the created ergonomics knowledge in the events, how this knowledge was represented in the identified objects, and the transfer of these objects.

4.2.2 Data collection and analysis 2: Ergonomics knowledge integration

We defined ergonomics knowledge integration as the process in which architects and engineers interpreted translated and applied the received knowledge in the hospital design. By application, we refer to the process of making changes to design documents in accordance with the transferred knowledge. We expected that the transferred knowledge was integrated through changes in the architectural blueprints. Hence, we identified the changes in the blueprints by comparing the pre-event blueprints, the knowledge transferred by the objects and actors, and the post-event blueprints. This enabled us to identify integrated and non-integrated parts of ergonomics knowledge generated in the PS events.

4.2.3 Data collection and analysis 3: Factors influencing integration

To identify factors influencing the integration of ergonomics knowledge, we expanded the focus to the overall hospital design project. We interviewed key actors of the hospital design project, see Table 3. They were selected on the basis of fulfilling one of the following criteria: project owner representatives, actors receiving and applying knowledge from PS events, or representatives from the consortium. The interviews were semi-structured [32] and included the following main sections: background of interviewee, received ergonomic knowledge from the simulation, application of the ergonomic knowledge, the design organisation, the design process, and the designers'

aim. The interviews were transcribed and coded to identify factors influencing the ergonomics knowledge integration.

Table 3

5. Results

In the following sections the results for each of the three research questions are presented.

5.1 Analysis 1: Actors and objects enabling ergonomics knowledge transfer

Table 4 presents the ergonomics knowledge created in the form of ergonomics challenges and mock-up adjustments. The table further presents the actors and objects, which possibly transferred the created knowledge.

Table 4

5.1.1 Actors

The actors identified were the architect and project engineer in PS event 1. The other PS events did not include actors with ergonomics knowledge transfer characteristics. The architect and engineer both participated in PS event 1 and had a role in the hospital design project. The architect described the obtained ergonomics knowledge as an awareness of how adjustments of the corridor dimensions could improve the work posture of the orderlies handling beds in the corridor. He described the awareness:

“When the orderly rotated the bed at the most narrow area [of the corridor], he got a twist in his back and arms. The flow of beds will be approximately 50 per day. This means that he is going to make that movement 50 times a day... The mock-ups made me ascertain that in the worst case scenario of rotating the bed, the wall to the ventilation room had to be moved one meter.”

The architect explained that he was going to apply the knowledge of the one-meter corridor adjustment by changing the architectural blueprints upon returning to the design office. The engineer described the ergonomics knowledge she obtained in the same way as the architect, but she indicated another intended application of the knowledge:

“The testing [of the mock-ups] in the innovation center will contribute to fine-tuning the requirements specification.”

The architect and the engineer proved to have different integration intentions - one making very specific blueprint changes and one having a more general application on a managerial level.

5.1.2 Objects

The objects identified in the six PS events included three different types: personal notes, descriptive documents and hand-drawn 2D sketches. The three types of objects represented the ergonomics knowledge in different ways, see Table 4. The personal notes, taken by the architects in PS event 1, mainly focused on the corridor dimensions.

The descriptive documents and the hand-drawn 2D sketches were produced by the center staff facilitators as a summary of the overall simulation outcome. The descriptive documents included several focus points identified during the simulation. The hand-drawn 2D sketches showed the final mock-up after the adjustments introduced during the simulation, see Figure 3 for an example. However, the objects did not fully represent all of the created ergonomics knowledge. Some parts were not included, as shown in Table 4.

Figure 3

The objects were all transferred to the hospital design project. The architect in PS event 1 physically transported his personal notes to the architectural office. The descriptive documents and hand-drawn 2D sketches were transferred to the design office by being uploaded to a web-based platform, functioning as an interface between the project owners and the consortium. The platform enabled the architects and engineers to download the descriptive documents and hand-drawn 2D sketches when needed.

5.2 Analysis 2: Integration of ergonomics knowledge

By comparing the blueprints before the PS events, the objects, and the blueprints after the PS events, we identified integration and non-integration as shown in Table 5.

Table 5

5.3 Analysis 3: Main factors influencing ergonomics knowledge integration

From the coding and analysis of interviews with key actors in the design project (Table 3) two main factors emerged as having influence on the integration of ergonomics knowledge. They were predetermined building dimensions and room interdependency.

5.3.1 Predetermined building dimensions

The outer walls and bearing walls were defined in the early phases of the hospital design project. This meant that in the detailed design phase, the building dimensions were predetermined. In some situations, the received ergonomics knowledge from the PS events showed not to fit the building dimensions. For example, during the simulation of the reception area, the participants decided to increase the depth of the back office without decreasing the front office respectively, see Figure 4. However, the new dimensions made the total depth of the two rooms exceed the depth of the building. This was not realized during the simulation, and the increased depth was decided and transferred to the designers through a descriptive document.

Figure 4

The architect could decrease the width of the corridor and provide space for integrating the new total room depth after all. But the possibility of decreasing the width of a several meter-long corridor was emphasized as a rare case by the architect. He explained his usual strategy in cases in which he would receive ergonomics knowledge which could not be directly integrated in the already-set building dimensions.

“If I get information which doesn’t fit the building shape and format, I need to analyze it... I analyze what I think their [the facilitators of the simulation] intentions are and then try to press it into the square I have available. I analyze it with my experience as the foundation and the knowledge of the department I have after all.”

However from the project owner’s point of view, the building dimensions seemed not to be as set. One of the center staff members described the project owner’s expectation as:

“Sometimes it is hard to get the architects to see the room’s function. We had never imagined that it should be the physical frame that decided the function. It’s now we have the chance to let the function decide the physical frame.”

The project owners worked with the function as the determining factor during the PS events, and the designers worked with the building dimensions as the determining factor during the knowledge integration. This difference was recognized by several of the interviewed architects and engineers, who defined the situation as the consulting design consortium and the project owner approaching the hospital design process in opposite ways.

5.3.2 Room interdependency

Room interdependency showed up as an influencing factor in two ways. First, in the form of the fixed number of total square meters for each floor and second in the form of bearing walls, stairwells and elevator shafts across floors. The fixed square meters meant that when increasing the dimensions of one room, other rooms on that floor had

to decrease respectively. An example of this was the corridor in PS event 1. The knowledge transferred was new dimensions of the corridor to improve the work posture of the orderlies. The new dimensions meant a one-meter relocation of one corridor wall, as illustrated in Figure 5. This relocation would have implications on the neighboring ventilation room.

Figure 5

The architect described the situation as:

“The engineers have a huge [ventilation] facility placed behind that wall, including an area in front for servicing. When I need to move that wall, I have to confer with them [the engineers] about whether the wall can be an obstacle for the guy servicing the facility, because then I can’t move the wall.”

The interdependency between the corridor and the ventilation room revealed the interdependency between the architect and the ventilation engineers. Earlier in the design process, the ventilation system showed not to occupy the entire ventilation room. The engineers were able to introduce small adjustments, which made the wall relocation possible. However, the architect emphasized that if the relocation had been more than one meter, the ventilation room had to expand into neighboring rooms, resulting in a ripple effect.

The second interdependency of the bearing walls, stairwells and elevator shafts resulted in interdependency across floors. The engineer in charge of the construction provided an example:

“We had an entrance area, which the workers thought was a little squeezed because of a concrete wall. Their wish was, ‘Can’t we just move that wall?’ ... But this is a high-rise building with eight floors, and that wall was a bearing wall... It would take at least 250 hours to make the calculations on this [how to move the wall], and at that time we couldn’t even say if the wall was actually possible to move. So it looks like something small [to change], but it’s not, it’s just not.”

In this way the engineer emphasized that small changes within one room can have consequences for several floors and the engineers and architect in charge of designing those floors. In this situation, the interdependency resulted in the construction engineer rejecting the relocation of this particular wall.

6. Discussion

The results of the study highlighted that the transfer and integration of ergonomics knowledge from PS events into the design project is a complex process including actors, objects, and two influencing factors. The overall implication for ergonomists and safety professionals when planning PS events is that they should not only focus on the facilitation and execution of the PS events, but also take into account the subsequent process of knowledge transfer and integration. In more details the results indicate the following recommendations:

R1: Actors from the design project, e.g. architects and engineers, should participate in the PS events with the aim of encouraging them to take roles in the ergonomics knowledge transfer.

R2: Actors from the design project should actively take part in the production of knowledge transfer objects. This provides more than one perspective when documenting the knowledge created during the PS events.

R3: For a more direct process of knowledge transfer and integration to take place it should be based on a combination of actors and objects.

R4: Before running the PS events design constraints should be clarified with actors from the design project. In this way, constraints can be taken into account during the PS events and not solely in the moment of knowledge integration.

In the following sections we discuss the findings including the ones that support the four recommendations.

6.1 Actors enabling ergonomics knowledge transfer (R1)

The architect and engineer in PS event 1 had the ability to transfer ergonomics knowledge from the events to the hospital design process. They had boundary spanner characteristics [24], spanning over the boundary between the PS setting and the design setting. However, the actors had different application intentions of their obtained knowledge. The architect intended to apply the ergonomics knowledge directly in his

work on changing the architectural blueprint. The engineer intended to apply the knowledge as part of the managerial coordination of the requirement specification. The different intentions showed how the individual actors translated [21] the knowledge in accordance with their specific context whether that was designing the hospital through architectural blueprints or through management and coordination.

Ergonomists have been identified as having the ability to mobilize knowledge from different domains [34], work across organizations, and facilitate meetings between actors [35,36]. In this study, the center staff member with the OHS background could be seen as taking such a role - facilitating the PS events with several actors having different professional backgrounds. However, in the subsequent knowledge transfer process the architect and engineer took the operational role indicating that actors in the hospital design project also can take the role of transferring ergonomics knowledge. The design actors have the advantage of being able to execute the hospital design, and in this way, they have the possibility to translate and apply the transferred ergonomics knowledge into the design. This is in contrast to the ergonomists who often are not executing the design. Hence, when planning PS events it is important to consider how design actors can be encouraged to take roles in the knowledge transfer process.

6.2 Objects enabling ergonomics knowledge transfer (R2)

The objects identified were personal notes, descriptive documents and hand-drawn 2D sketches. These objects codified the knowledge created during the PS events [21]. The codification was initiated by the actors who produced the objects. The objects in the PS event 1 were produced by the architect, and in the other PS events by the center staff.

The architect included solely the specific adjusted corridor dimensions in his personal notes and left out less tangible ergonomics focus points on safety issues for the technical staff. The center staff included a mixture of specific adjusted dimensions and less tangible ergonomics focus points, e.g. the discretion of patient data while still sustaining an efficient work practice in the reception area. However, the center staff left out the reasons behind the specific dimension adjustments. The architect's documentation of dimensions only can be attributed to his background in building dimensioning and construction. The center staff's documentation of both dimensions and ergonomics can be attributed to one of the center staff's background in OHS. In this way, the producers of the objects may act as a filter in the transfer process. Exactly how the filter works seem to rely on the actors' individual experiences, backgrounds and position in the design project.

Barcellini et al. describe that results of simulations can take the form of "requirements that can be taken over by the designers." [37] Broberg et al. describe that results of participatory activities can take the form of objects that "articulate a piece of design that has been materialized and can then be circulated in the organization," [16] e.g. in a design organization. This study adds the challenge that the actors producing these objects may have a filtering impact on the codified knowledge. A collaborative production of objects between ergonomists and design actors could utilize both the ergonomists' understanding of ergonomics focus points and the design actors' understanding of more tangible design constraints and opportunities. Therefore, when planning PS events, it should be considered to involve design actors in producing the objects that translate simulation outcomes into codified knowledge.

6.3 Integration of ergonomics knowledge (R3)

In PS events 1 and 5 all parts of the transferred ergonomics knowledge were integrated into the architectural blueprints. In the PS event 5 the integration was “overdone” in the sense of not only replacing one bed with a chair, but in replacing all beds in the treatment room with chairs. The knowledge integration from PS event 1 had a more direct nature without “overdone” parts. The direct integration could be attributed to the fact that the actor producing the personal notes and the actor integrating the transferred knowledge were the same - namely the architect. This double role of an actor was not observed in any of the other PS events. In the other PS events the center staff were the object producers, and architects, who did not participate in the PS events, were the knowledge integrators. Within the knowledge management field, the combination of actors and objects has been recognized as promoting knowledge transfer and integration, e.g. [20]. The direct integration of knowledge from PS event 1 could be an indication that such a combination might also be relevant in the transfer and integration of ergonomics knowledge from PS events to hospital design. Hence, the combination of actors and objects is relevant to consider in PS planning.

In PS events 2, 3, 4 and 6, parts of the transferred knowledge were integrated and others were not. The non-integrated parts were both intangible ergonomics focus points and more tangible specific building dimensions. Research on integration of ergonomics guidelines in engineering design shows that ergonomics principles or general recommendations are hardly integrated by designers [38,39]. This corresponds to the intangible ergonomics focus points of this study. An example from PS event 2 was the

non-integrated considerations of how discretion of patient information in the reception area could influence the work conditions. In contrast to general ergonomics principles and recommendations, specific ergonomics guidelines have shown to be more applicable by designers [39]. However in this study, specific dimension adjustments were still left out of the integration, e.g. the new position of a workstation in PS event 4. Non-integrated dimension adjustments were transferred to the design process through both hand-drawn 2D sketches and descriptive documents. Therefore, our results indicate that the type of ergonomics knowledge and the type of objects do not influence on the integration. This encourages the further investigation of hospital design projects to identify other influencing factors.

6.4 Influencing factors on ergonomics knowledge integration (R4)

Two main influencing factors were identified: the predetermined building dimensions and the room interdependency. Both factors were results of early design decisions on the number of square meters per floor and the shape of the building. Those decisions were governmentally approved and therefore hard to change. The influencing factors were related to the nature of the hospital design process and can be conceptualized as contextual constraints [40] or lock-ins [35]. Both concepts describe the constraints, which the designers had to work within when integrating ergonomics knowledge in the hospital design. These constraints sometimes led the designers to transform the knowledge to make it fit within the constraints [21,22]. However, this transformation was not expected by the center staff, who instead expected the function of the room to be the main design constraint. From the center staff's point of view, the knowledge created in the PS events was seen as joint decisions and somehow unquestionable. The

objects codifying these decisions were understood as closed objects [26]. In contrast, the designers had to interpret and explore the ergonomics knowledge in order to transform it in accordance with the design constraints. The designers treated the received objects as open objects [26].

Different kind of objects have been recognized as having the same knowledge transfer abilities as identified in this study [16, 35, 41-43]. This study indicates that the design constraints influence how the actors perceive the objects and transferred knowledge. Therefore, in the planning of PS it is important to aim for a continual dialogue between the producers of the objects and the designers. Instead of solely relying on objects as one-way communication, a dialogue might foster a matching of expectations of the close or open nature of the objects. Furthermore, taking into account design constraints prior to PS events could lead to creation of ergonomics knowledge that demands less design changes.

6.5 Limitations of the study

The study is based on six PS event cases as part of a large-scale, complex hospital design project. We consider the results as providing some initial insights into the challenges of transferring ergonomics knowledge into such a huge design project. These insights might be valuable in similar projects within other industries. However, it is a limitation that the results is based solely on knowledge transfer in a large-scale design project. Knowledge transfer mechanisms may be different in smaller design projects, e.g. there is a more direct contact between designers and the simulation events. We suggest further research in the transfer of ergonomics knowledge from simulation

events into design projects, especially in other design domains and in smaller design projects.

6.6. Concluding remarks

This study investigated the ergonomics knowledge transfer from PS events and integration into hospital design. We identified actors and objects with abilities of transferring ergonomics knowledge from the PS events to the hospital design project. The producers of the objects functioned as a filter, meaning that not all ergonomics knowledge was transferred from the PS events. The integration of the transferred knowledge seemed not to be affected by the form of the knowledge represented in the objects. Instead, the main influencing factors on the integration were: predetermined building dimensions and room interdependency. Based on the learnings from this explorative study we proposed four recommendations for ergonomists and safety professionals when planning PS events.

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Table 1 The six participatory simulation events

Table 2 Data materials

Table 3 Interviews with key actors of the design project.

Table 4 Created ergonomics knowledge and actors and objects possibly transferring the knowledge.

Table 5 Ergonomics knowledge integration and non-integration

Table 1

	PS Event 1 1.5 hours	PS Event 2 1 hour	PS Event 3 1.5 hours	PS Event 4 1 hour	PS Event 5 1 hour	PS Event 6 1 hour
Area of design	New ward corridor, including a bed paternoster lift	New ward reception area	New depot for ward	New outpatient examination room	New, small, cancer day-treatment room	New, large, cancer day-treatment room
Participants	1 orderly, 1 technical employee, 2 project employees, 2 technical consultants, 1 architect, 1 engineer, 2 center employees	4 secretaries, 2 charge nurses, 1 hospital management staff member, 2 IT consultants, 1 project employee, 2 center employees	1 nurse, 2 head nurses, 2 project employees, 1 center employee	4 secretaries, 2 charge nurses, 1 hospital management staff member, 2 IT consultants, 1 project employee, 2 center employees	2 charge nurses, 1 nurse, 2 center employees	2 charge nurses, 1 nurse, 2 center employees
PS process	Participants acted out scenarios by maneuvering a standard bed through the mock-up, leading to mock-up adjustments.	Participants stood in the mock-up discussing future work scenarios, leading to adjustments of the mock-up.	Participants acted out scenarios of work practices and at the same time furnished the room according to the work.	Participants stood in the mock-up discussing future work scenarios, leading to adjustments of the mock-ups.	Participants stood in the mock-ups and acted out scenarios of work practices, leading to adjustments of interior design.	Participants stood in the mock-ups and acted out scenarios of work practices, leading to adjustments of interior design.

Table 2

	PS Event 1 Bed ward corridor	PS Event 2 Reception area	PS Event 3 Depot	PS Event 4 Examination room	PS Event 5 Small treatment room	PS Event 6 Large treatment room
Observations	Observations of all the PS events					
Interviewees	1 hospital orderly from surgery hall 1 architect from the design office 1 technical consultant 1 engineer from project management	1 charge medical secretary from the medical department 1 IT consultant	1 head nurse from oncology 1 project employee focusing on logistics 1 project employee focusing on space documentation	1 staff member of the hospital management board 2 charge nurses from the medical department	1 head nurse from hematology	1 nurse from oncology
Documents collected	Design notes taken by the architect	Redesign description	Sketch of redesigned room	Sketch of redesigned room	Redesign description	Redesign description

Table 3

	Project owner representatives	Actors receiving and applying knowledge from PS events	Representatives from the consortium
Interviewees	<p>1 project manager</p> <p>2 center employees</p>	<p>1 architect participating in PS Event 1 and integration of knowledge from PS Event 1</p> <p>1 architect involved in integration of knowledge from PS Events 2 and 3</p>	<p>1 architect involved in the management of the received intermediary objects</p> <p>1 managing architect</p> <p>1 engineer managing construction</p> <p>1 project managing engineer</p> <p>1 OHS consultant responsible for compliance with ergonomics legislation</p>

Table 4

		PS Event 1, Ward corridor	PS Event 2, Reception area	PS Event 3, Depot	PS Event 4, Examination room	PS Event 5, Small treatment room	PS Event 6, Large treatment room
Created ergonomics knowledge	Ergonomics challenges	Work posture of the orderly Safety for technical staff	Work posture when applying screens Space in back office Pressure of handling patient info discreetly	Work posture when collecting assistive devices Inefficient work procedure in the room Stock management of utensils	Space behind workstation Sufficient computer screens Handling of separation wall Having the needed tools	Work posture around beds Work posture at fixed cabinets Handling of beds in emergencies Oxygen access Pressure of hand-ling patient info.	Limited view of the beds from the nurses workstation Handling of beds in emergencies Pressure of handling patient info. discreetly Work posture around beds

	Mock-up adjustments	Adjustment of the corridor dimensions for improving work posture	Reducing number of workstations to improve work posture when applying screens Increasing back office area	Cabinets for storage space Larger assistive devices under shelves for improving work posture Excluding separation wall, including printer in depot for work procedures Reducing number of workstations	New position of the workstation Introduction of a third screen Changed position of separation wall Portable cabinets for external tool collection	Chair instead of a bed increases space for work posture and emergencies Portable cabinet instead of fixed improves work posture Position of screen for discretion	New position of workstation to increase overview Position of screen for discretion Replacing chair with bed to increase area for work and improve work posture and emergency procedures
Actors		Architect Project engineer	No actors identified				
Objects	Document	Personal notes	Descriptive document	Hand-drawn 2D sketch	Hand-drawn 2D sketch	Descriptive document	Descriptive document

	Represented knowledge	Minimum dimensions of corridor	New dimensions of back office New number of workstations Point of attention on patient data discretion	Introduction of cabinets Introduction of assistive devices under shelves New placement of printer within the depot, excluding the wall	New position of workstation Introduction of a third screen New position of separation wall Introduction of portable cabinets	Introduction of chair Introduction of cabinet Point of attention on access to oxygen	New position of workstation Introduction of chairs replacing bed Point of attention on access to oxygen
	Non-represented	Safety issues for the technical staff	Position of the workstation	Explanation of the position of printer	Explanation of the new workstation position	New position of the screen	New position of the screen

Table 5

	PS Event 1, Bed ward corridor	PS Event 2, Reception area	PS Event 3, Depot	PS Event 4, Examination room	PS Event 5, Small treatment room	PS Event 6, Large treatment room
Integration	Indication of minimum dimensions of the corridor Wall is moved 1 meter	New dimensions of the back office area Reduction of workstations from two to one	Space under shelves for larger assistive devices is added	New position of separation wall Two portable cabinets are added Third screen is added	Replacement of bed with chair One portable cabinet is added Possibility for oxygen access	Replacement of bed with chair
Non-integration		Considerations on discretion of patient information in reception area	New position of printer Removing wall of printer niche Reduction of number of workstations Addition of cabinets	New position of workstation		New position of workstation

Figure 1 A full-scale mock-up applied in the PS session in the innovation center.

Figure 2 Overall design of the study

Figure 3 Hand-drawn 2D sketch representing the final stage of the examination room from PS event 4

Figure 4 The depth of the back office and the front office.

Figure 5 Relocation of the corridor wall.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5