

Simulation in full-scale mock-ups: an ergonomics evaluation method?

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Abstract. This paper presents an exploratory study of four simulation sessions in full-scale mock-ups of future hospital facilities. The aim was to explore full-scale mock-ups' potential of not only being a method for testing and evaluating design concepts but also being an ergonomics evaluation method of specific work conditions at future hospital facilities. The results show that the simulation in the full-scale mock-ups revealed work conditions of Room Layout, Musculoskeletal Conditions, Organizational Interconnections, Indoor Climate, Safety and Psychosocial Conditions. However, the full-scale mock-ups were primarily supporting ergonomics evaluation of Room Layout and Musculoskeletal Conditions.

Keywords. Full-scale Mock-ups, Hospitals, Simulation, Participatory Ergonomics.

1. Introduction

Direct participation of workers in participatory ergonomics design process is considered to be a success factor for increasing comfort and productivity of the workers (Vink, Koningsveld, & Molenbroek, 2006). Within the design process of hospital buildings participatory ergonomics is utilized to increase the performance of healthcare teams and hospital facilities (Villeneuve, Lu, Hignett, & Duffy, 2007). The Danish healthcare sector is currently applying a participatory approach in a comprehensive renewal process of its hospital buildings and facilities. A key method in the renewal process is simulation in full-scale mock-ups, which is facilitated by regional innovation centers and involving healthcare professionals, architects and engineers.

Simulation in full-scale mock-ups is a recognized participatory ergonomics method in design of buildings and facilities. The method is used for testing layout, exploring design challenges and evaluating design concepts (Villeneuve et al., 2007; Watkins, Myers, & Villasante, 2008; Wilson, Haines, & Morris, 2005). This paper aims at exploring how full-scale mock-ups simulation not only is a method for testing and evaluating design concepts but also an ergonomic evaluation method for evaluating specific work conditions in hospital facilities.

The paper presents an exploratory study of four simulation sessions in full-scale mock-ups in the building design process of a major Danish hospital. The immediate purpose of the sessions was to test and evaluate architectural design concepts. An additionally ergonomics evaluation potential was explored through the research questions: 1) What is the potential of simulation in full-scale mock-ups in revealing and evaluating the work conditions of future hospital facilities, and 2) which specific work conditions are revealed and evaluated?

1.1 The four full-scale mock-ups sessions

The four full-scale mock-ups sessions were managed by a major Danish hospital and

situated in the local regional innovation center. The innovation center's aim is to test and develop concepts for room size, layout, working procedures and logistics. The purpose being strengthening the planning process of future hospital facilities and thereby improving continuity in patient care and work environment of the healthcare professionals (DNV-Gødstrup, 2012). The mock-up sessions were organized and facilitated by two innovation center employees, one with an ergonomic background and one with a clinical background.

The innovation center has facilities, such as movable walls, simple foam bricks and standard hospital furniture, to construct full-scale mock-ups of hospital rooms and corridors, see figure 1. These facilities have so far allowed mock-up sessions testing the architectural drawings of layout concepts of future hospital rooms. Having a participatory approach the sessions involve healthcare professionals from current regional hospitals, representative from the project owner, consulting architects and engineers in testing the architectural layout concepts.



Figure 1, mock-ups of movable walls, foam bricks and standard hospital furniture.

A typical mock-up session in the innovation center is constituted by two parts, an introductory part and a testing part. In the introductory part, the participants and the facilitators discuss work procedures and possible challenges of proposed room layouts, with foundation in the healthcare professionals' experiences from their own work. In the testing part, the participants enact and discuss scenarios of future work practices, enabling discussions on the room layouts' implications on work practices and identification of possible layout improvements. The healthcare professionals are developing the scenarios continually during the testing with foundation in own experiences and the discussions from the introductory part of the sessions.

The enactment of the scenarios during the testing part of a session relates to experimental simulation (Daniellou, 2007) because the participants are physically testing the scenarios. The discussions of the scenarios relate to narrative simulation (Daniellou, 2007) because the participants articulate feasible ways to carry out future work tasks in the room. Both types of simulations lead to reflections, which often result in mock-ups adjustments, leading to new experimental or narrative simulations. The simulations are supported by the full-scale mock-ups functioning as simulation models (Gupta, 2013). The facilitators' role is making sure that all discussed aspects from the introductory part are covered during the tests. The four sessions constituting the foundation for this paper, are presented in table 1.

Table 1, the four full-scale mock-ups sessions.

	Session 1	Session 2	Session 3	Session 4
Architectural room concepts	Standard reception and back-office for bed wards.	Standard examination room of outpatient department.	Standard depot for bed wards.	Standard bed paternoster lift.
Participants	<ul style="list-style-type: none"> - Three medical secretaries. - One executive medical secretary. - Two executive nurses. - Three hospital managers. - Two IT consultants. 	<ul style="list-style-type: none"> - Three medical secretaries. - One executive medical secretary. - Two executive nurses. - Three from the hospital management. - Two IT consultants. 	<ul style="list-style-type: none"> - Three executive nurses. - One from the hospital management. - One from the project division focusing on logistics. 	<ul style="list-style-type: none"> - One hospital porter. - One technical employee. - Two from the project division. - One architect. - One project engineer. - Two technical consultants.
Facilitators	<ul style="list-style-type: none"> - The facilitator with clinical background. - The facilitator with ergonomic background. 	<ul style="list-style-type: none"> - The facilitator with clinical background. - The facilitator with ergonomic background. 	<ul style="list-style-type: none"> - The facilitator with clinical background. 	<ul style="list-style-type: none"> - The facilitator with clinical background. - The facilitator with ergonomic background.
Purpose	Making the reception appealing to the patients. Test whether large touch screens could fit into the back-office.	Redesigning the layout of the examination room to optimize patient experience and work conditions.	Optimizing the layout of the depot to obtain the necessary storage without compromising the work conditions.	Find the minimum dimensions for the paternoster lift without compromising work conditions of the porter.
Duration	1 hour	1 hour	1,5 hours	2 hours

2. Methods

The data was collected through observations of the introductory parts and observations and video recording of the test parts of the four full-scale mock-ups sessions. The video recordings constituted the primary data foundation. However, the observations of the introductory parts helped understand the rationale behind participants' actions and discussions during the testing parts of the sessions.

We analyzed the video recordings by coding each recording to identify mock-ups adjustments and topics addressed by the participants, both relating to and influencing the future work conditions of the healthcare professionals. The coded mock-ups adjustments and topics were noted on paper. We analyzed the large amount of notes by applying an inductive affinity diagram approach (Beyer & Holtzblatt, 1998). The observations of the introductory parts of the mock-ups sessions helped in understanding the underlying meanings of the notes. In the development of the affinity diagram, the data formed 14 topics and 6 overlaying categories. Each topic was quantified by counting the number of notes per topic in relation to each of the four sessions. The quantification showed the distribution of the different topics between the four mock-ups sessions.

3. Results

Table 2 presents the results of the analysis of the four mock-ups sessions. The first column presents two types of categories, firstly, factors influencing work conditions (referred to as influencing factors in the following sections), secondly, direct work conditions. The columns three to six present the number of times each topic was revealed during each session. Column seven presents the number in total in relation to each topic.

Furthermore, column eight presents the number of mock-ups adjustments in relation to each overlaying category.

Table 2, analysis results of the four full-scale mock-ups sessions.

Overlaying categories	Topics	Session 1	Session 2	Session 3	Session 4	Total	Mock-ups adjustments
Room Layout	Room size and dimensions	2	0	3	16	21	11
	Type of furniture in the room	1	11	12	4	28	
	Dimensions and space needed for furniture	8	4	25	14	51	
	Layout of furniture in the room	1	5	11	0	17	
	Working procedures in rooms in relation to layout of furniture	0	2	4	12	18	
Musculo-skeletal Conditions	Design of permanent workstations	8	1	0	0	9	6
	Work posture in relation to rooms and furniture	0	0	13	14	27	
Organizational Interconnections	The rooms' connections to other rooms	2	3	0	3	8	0
	Logistics in relation to the rooms	0	2	2	5	9	
Indoor Climate	Noise in relation to workspaces	1	0	0	4	5	1
	Draught in workspaces	1	0	0	0	1	
	Inflow of light from windows to workstations	3	1	3	0	4	
Safety	Safety of the work space	0	0	1	8	9	0
Psychosocial Conditions	Rooms' influence on employees' psychosocial conditions	6	0	0	0	6	0

4. Discussion and Conclusion

The full-scale mock-ups sessions revealed following categories of work conditions, Musculoskeletal Conditions, Indoor Climate, Safety and Psychosocial Conditions. Additionally, the sessions revealed following categories of influencing factors, Room Layout and Organizational Interconnections. However, not all categories led to mock-up adjustments and ergonomics evaluations by the participants. The full-scale mock-ups primarily supported evaluation of Room Layout and Musculoskeletal Conditions.

4.1 Revealed work conditions

The most frequently addressed categories, Room Layout and Musculoskeletal Conditions, were revealed during the experimental and narrative simulations. The high frequency indicates the mock-ups ability to enable the participants envision, how future room layouts would influence work practices and work postures, in a simply and straight

forward manner. This ability was shown during the participants' enactments, which instantly directed the participants' discussions towards the physical work conditions of future hospital facilities. Even though the facilitators varied in the third session, the four sessions showed all the same tendency of frequent addressed Room Layout and Musculoskeletal Conditions. This tendency indicates that the high focus on the physical work conditions was in some degree independent from the background of the facilitators.

The categories, Organizational Connections, Indoor Climate, Safety and Psychosocial Conditions, were mainly revealed during the narrative simulations. The category of Organizational Connections stands out because it includes the tested rooms' connection to other rooms and functions, while the categories Indoor Climate, Safety and Psychosocial Conditions focus on the tested rooms independently from external functions. The revealing of these four categories showed to be influenced by the participants' professional background in the form of their current workplaces and work practices. The participants' professional background was the starting point for many of the narrative simulations. This was especially the case in the category of Psychosocial Conditions, where the current work pressure of the participants encouraged discussions on how future room layouts could affect the work pressure. The four sessions were to a great extent driven by the participants and influenced by their respectively professional backgrounds, while the facilitators had a more supporting role.

4.2 Ergonomics evaluation potential

The results show that the simulation in the mock-ups revealed categories of different work conditions and influencing factors. However, the participants were not able to evaluate all the revealed conditions because the mock-ups showed to be more supportive in evaluating some work conditions than others.

The mock-ups' ability to show the room layouts' impacts on work practice and work posture highly supported the revealing of the categories Room Layout and Musculoskeletal Conditions. The participants' discussions of the impacts had ergonomics evaluation characteristics since participant conversations included assessments of the identified impacts. The evaluations led to 'local problem solving' in the form of mock-up adjustments, which resulted in redesigns of the architectural proposals on the spot. The categories Room Layout and Musculoskeletal Conditions had a high degree of mock-ups adjustments, indicating an ergonomics evaluation potential of the mock-ups in relation to these two categories.

The categories Organizational Connections, Indoor Climate, Safety and Psychosocial Conditions were not in the same degree supported by the full-scale mock-ups as the categories of Room Layout and Musculoskeletal Conditions. In the revealing of the Organizational Connections, the participants identified problems in the connections between the tested rooms and other rooms of the future hospital. However, it was difficult for the participants to evaluate these problems because the mock-ups solely represented few rooms or corridors and not the external rooms or functions. Thereby, the mock-ups supported intensive focus on specific rooms or corridors having a tendency to isolate rooms and only showing the work practices taking place within these specific rooms. The ergonomics evaluation potential of Organizational Connections was thereby weaker than the evaluation potential of Room Layout and Musculoskeletal Conditions.

The mock-ups as simulation models were abstractions of complex future realities (Gupta, 2013) and were thereby only reflecting the future reality to a certain degree. The difference between a future reality and the present mock-ups prevented participants in making accurate evaluations of the category Indoor Climate because work conditions such as natural inflow of light and acoustics were not reflected by the full-scale mock-ups. The

mock-ups were situated in a workshop at the innovation center, which did not allow the natural inflow of light in the mock-ups. Furthermore, the mock-ups were built with primitive materials, which did not reflect the acoustic abilities of the intended materials. Nevertheless, the mock-ups sessions resulted in an evaluation leading to one mock-up adjustment. The adjustment was in relation to the position of fixed furniture to hypothetically obtain as much natural light inflow as possible in the room. The abstraction level of the mock-ups showed thereby evaluation potential of Indoor Climate work conditions to a limited extend.

To sum up, the full-scale mock-ups supported ergonomics evaluations of Room Layout and Musculoskeletal Conditions. The categories of Organizational Connections, Indoor Climate, Safety and Psychosocial Conditions were revealed by the mock-ups but the evaluation potential was weaker.

4.3 Improving ergonomics evaluation potential

The study of the four mock-up sessions indicated that the facilitation of the sessions were open, thereby these sessions ended up being primarily defined by the participants and their professional backgrounds. The participants were not actively focusing the sessions towards ergonomics evaluations, instead their focus was on testing the physical layout of the rooms. The analysis of the sessions indicated a latent potential for improving the ergonomics evaluation abilities of the mock-ups in relation to the categories Room Layout and Musculoskeletal Conditions. Therefore, we suggest to strengthen the facilitators role towards initiating and guiding the sessions (Haines, Wilson, Vink, & Koningsveld, 2002), thereby increasing the facilitators ability to control the direction of the sessions. The facilitators could accomplish this by asking questions directly related to the work conditions under evaluation, although it is important to note that the process should still remain participant driven through their inputs and initiatives.

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