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Participatory ergonomics simulation of hospital work systems: The influence of simulation media on simulation outcome

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ABSTRACT

Current application of work system simulation in participatory ergonomics (PE) design includes a variety of different simulation media. However, the actual influence of the media attributes on the simulation outcome has received less attention. This study investigates two simulation media: full-scale mock-ups and table-top models. The aim is to compare, how the media attributes of *fidelity* and *affordance* influence the ergonomics identification and evaluation in PE design of hospital work systems. The results illustrate, how the full-scale mock-ups' high fidelity of room layout and affordance of tool operation support ergonomics identification and evaluation related to the work system entities *space* and *technologies & tools*. The table-top models' high fidelity of function relations and affordance of a helicopter view support ergonomics identification and evaluation related to the entity *organization*. Furthermore, the study addresses the form of the identified and evaluated conditions, being either identified challenges or tangible design criteria.

1. Introduction

A recognized problem in work system design is the occurrence of ergonomics problems after implementation of system changes, resulting in resource demanding and costly readjustments to comply with the problems (Hendrick, 2008). One way of preventing the ergonomics problems already during the design process is to include the future workers in participatory ergonomics (PE) (Wilson et al., 2005). PE has been defined as "the involvement of people in planning and controlling a significant amount of their own work activities, with sufficient knowledge and power to influence both processes and outcomes in order to achieve desirable goals" (Wilson, 1995).

Participatory simulation is a PE method that involves the future workers in design of work systems. A work system can be defined as "… a system in which human participants and/or machines perform work using information, technology, and other resources to produce products and/or services for internal or external customers" (Alter, 2006). Simulation has been defined as "an imitation of the operation of a real-world process or system over time" (Banks et al., 2010), and may have two purposes. The first being a method for identifying and evaluating the future work practices and ergonomics conditions (Daniellou, 2007; Daniellou et al., 2014; Nelson et al., 2013) and the second being a social process mediating mutual learning between workers and designers (Béguin, 2014). This study will concentrate on the first purpose.

A key component in participatory simulation is the simulation media (Daniellou, 2007), which represent the work system to be designed. Within the PE field, a variety of different simulation media are applied, all with the purpose of identifying or assessing ergonomics conditions and problems of the work system to be designed. Physical simulation media such as mock-ups and prototypes are applied for assessing work posture (Sundin et al., 2004), muscular discomfort (Paquet and Lin, 2003), physical layout and spatial conditions (Broberg et al., 2011; Steinfeld, 2004; Watkins et al., 2008). Computer based simulation media such as 3D computer animation and mixed reality have been applied for assessing muscular fatigue (Hallbeck et al., 2010; Perez et al., 2014), repetitive work and critical work sequences (Sundin and Medbo, 2003; Sundin et al., 2004).

The variation in ergonomics conditions indicates that different media support identification and assessment of different ergonomics conditions, which is a common reflection point in the literature (Hallbeck et al., 2010; Paquet and Lin, 2003; Steinfeld, 2004; Sundin and Medbo, 2003; Watkins et al., 2008). In addition, some studies indicate that the media have certain attributes,

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but these are not reflected upon in relation to the ergonomics conditions or problems actually possible to identify by applying the media. The media attributes indicated are the ability of the media to represent the reality (Hallbeck et al., 2010; Steinfeld, 2004; Watkins et al., 2008) and the possible actions the media support (Broberg et al., 2011; Steinfeld, 2004). Within the interaction design field, these attributes are recognized as *fidelity* (Hall, 2001; Lim et al., 2008) and *affordance* (Norman, 2002; Turner, 2005). Fidelity may be defined as "the level of detail or sophistication of what is manifested" (Lim et al., 2008). Affordance may be defined as "the perceived and actual properties of the thing… that determine just how the thing could possibly be used" (Norman, 2002). How these two media attributes influence the outcome of simulations, in the form of identified ergonomics conditions, has received little attention in the participatory simulation field.

The Danish healthcare sector is currently a relevant empirical setting for exploring the influence of the simulation media attributes. At the moment, the sector is in a comprehensive design process of new public hospitals, which includes an extensive application of participatory simulation, involving healthcare professionals in PE design. The design activities may be conceptualized as a matter of designing hospital work systems. This study is based on two case studies of participatory simulation events, applying two different simulation media: full-scale mock-ups and table-top models. The aim is to compare, how the fidelity and affordance attributes of these two types of simulation media may influence the ability to identify and evaluate ergonomics conditions during PE design of hospital work systems.

Our basic assumption was that the two simulation media would have different capabilities in supporting *identification and evaluation of ergonomics conditions* because of difference in the attributes. By adapting the International Ergonomics Association's definition, *ergonomics conditions* are defined as: (1) conditions influencing the healthcare professionals' well-being in the future work system, e.g. work posture, psychosocial work load, indoor climate, safety and division of labor; and (2) conditions influencing the work system's overall performance, e.g. efficiency, consumption of resources, quality of system output and risk of errors. We refer to *identification* as the process of simulation participants being able to articulate or visually show possible ergonomics challenges of the future work system. We refer to *evaluation* as the process of participants being able to formulate tangible design criteria based on discussions of the identified ergonomics conditions.

In the following, we first define the key work system concept, followed by the methodological approach, including the introduction of the two cases. We present the results from the analysis in the form of the identified and evaluated ergonomics conditions of the two cases and the influence of fidelity and affordance. In the discussion, the results of each case are compared and related to existing studies on full-scale mock-ups and table-top based models. We end with concluding remarks, including implications for practitioners.

2. The work system concept

In order to analyze the participatory simulation phenomenon, we introduce the work system concept. A work system has been defined as consisting of different interconnected entities (Alter, 2006; Carayon, 2009; Horgen et al., 1999; Kleiner, 2006). We operate with six entities: *work practice*, *participants*, *information*, *technologies & tools*, *space* and *organization*. The *work practice* is the work activities within the work system (Alter, 2006). The *participants* are the people who perform the work (Alter, 2006) and have psychosocial, cognitive and physical characteristics (Carayon, 2009). The *information* is explicit and tacit knowledge, which is exchanged as participants perform their work (Alter, 2006). The *technologies & tools* are the tools that help participants work efficiently (Alter, 2006; Carayon, 2009). The *space* is the physical environment and workspace design (Carayon, 2009; Horgen et al., 1999). The *organization* is the organizational design, the organization of work, coordination of work (Kleiner, 2006), work scheduling and culture (Carayon, 2009). The six entities of the work system concept are applied as an analytical frame to help identify, to what extent the entities are addressed in the two simulation cases.

3. Methodology

The Danish healthcare sector is designing and building new public hospitals, with the purpose of increasing the quality and efficiency of the healthcare service. The design process includes redesign of the current hospital work systems. To facilitate user participation in the work systems design, the Danish Regional Councils have established innovation centers spread around the country. A significant part of the centers' activities is based on participatory simulation, involving healthcare professionals from the existing hospitals. We had the opportunity to study participatory simulation in two innovation centers, each related to a hospital design project. The first center applied full-scale mock-ups as simulation media, and the second center applied table-top models as simulation media. We considered the simulation activities of the centers as naturally occurring data, described as "real interactions happening naturally out in the world" (Potter, 2004), contrasting controlled laboratory experiments. These naturally occurring simulation activities provided a unique opportunity for studying, how the fidelity and affordance of these two types of simulation media may influence the ability to identify and evaluate ergonomics conditions. We approached the simulation activities of the two hospital design projects as two case studies, each constituting of four simulation events viewed as nested units of analysis (Thomas, 2011). The simulation activities in both cases had the purpose of providing input to the engineers and architects, who designed the new hospital buildings during complex design processes. However, in this study we focus exclusively on the actual ergonomics outcomes of the simulations. The two cases are described in the following Sections 3.1 and 3.2.

3.1. Full-scale mock-ups

The innovation center of the first case study was part of the building process of a new hospital, which replaced two current hospitals. The center was located in a hall at the construction site, containing mock-ups facilities. The facilities were managed by two center employees: one with a clinical background and one with an occupational health and safety background. The purpose of the center was to test standard room proposals for the somatic hospital and thereby contribute to the architectural design process.

The four simulation events, constituting the case as presented in Table 1, were based on blueprints of room proposals provided by the consulting architects. The room proposals were key rooms in the sense that the rooms would be extensively repeated throughout the hospital. The proposals were transformed into full-scale mock-ups based on movable chipboard walls, big foam bricks and standard hospital interior, see Fig. 1. The mock-ups were constructed by the two center employees prior to the simulation events.

The participants of the four simulation events were healthcare professionals with various professions; project employees from the project owner organization; engineers and architects from the consulting companies; and the two center employees. The center employees selected the participating healthcare professionals on the criteria of having work experience in the room to be tested.