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Can participatory ergonomics process tactics improve simulator fidelity and give rise to transdisciplinarity in stakeholders? A before–after case study

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ABSTRACT

Production of high fidelity simulators requires stakeholders to remain engaged throughout the process, and development of research-oriented simulators requires the sharing of knowledge beyond individual disciplines. Failings in simulator design that compromise the goals of the End-user evidence a participatory problem associated with how actors are coordinated during its development. Participatory ergonomics has been shown to improve collaboration between eclectic groups in a variety of psychosocial settings and may help people transcend disciplinary boundaries, enabling them to anticipate problems, create solutions and produce innovation. A before–after approach involving design evaluations and Design Decision Group sessions with three stakeholder groups was used to evaluate and re-design a high fidelity rail simulator. Prior to re-design, the evaluation identified issues with functional design, task design, visual ergonomics, and tractability for the End-user, which meant that the simulator was unfit for purpose. Following the participatory ergonomics process, the second evaluation identified significant improvements in all these areas and solutions, providing compelling evidence that transdisciplinarity had occurred. Based on the pattern of continued engagement, the process produced further innovation and opportunity for collaboration in the long term. This study supports the utility of collaborative initiatives that energise iterative design processes, find common ground, and ensure that knowledge and methods are utilised in ways that transcend the boundaries of conventional disciplines. The study reveals a unique perspective and research scope on the design of a simulator facility, with insights about research-industry partnerships that highlight the value and necessity of participatory processes. This work contributes to the literature on participatory methods calling for more research on team function, and a corresponding framework incorporating participatory ergonomics and collective function is proposed for further study.

Relevance to Industry: The approach and lessons from this study are broadly generalisable to a variety of industry contexts, particularly those that would benefit from conditions where people with disparate views must work together with end-users to achieve a common goal and where exchange of knowledge is a crucial predictor for success.

1. Introduction

1.1. Simulators as tools for human factors and ergonomics research in rail safety

Simulators are an established tool for researching human factors and ergonomics research in transportation (e.g., Guo et al., 2015; Kim et al., 2007; Llaneras et al., 1998). Along with the validity of a simulator, its faithfulness to the real world or "fidelity" is an important aspect of simulator design (Riener, 2010). As equipment, training and research needs continually change, the ability to improve or update simulators becomes critical for them to remain realistic, relevant, and continue to provide return on investment. In particular, simulator types that are classed as 'high fidelity' are very complex (Gray, 2002). Fidelity is the degree of similarity between

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the simulator and the system being simulated thus in the context of high fidelity, they must balance a variety of physical (how it looks), functional (how it acts) and psychological (how it transfers) requirements in order to faithfully replicate the task and make it plausible to the end-user (Stanton, 1996). Simulators offer authentic learning situations (Naweed and Ambrosetti, 2015), but as a high-fidelity simulation of a real-world task, simulators must also incorporate good usability design principles to make them simple to manage and easy to work with (Neilsen, 1989; Nielsen, 1993). In practice, the input of individuals from different disciplines with specialised knowledge is needed.

Regardless of the industry context, high-fidelity simulator production requires a number of stakeholders to remain engaged throughout the developmental phases (e.g., Jahangirian et al., 2012; Seropian et al., 2004; Yates et al., 2007). These stages may include the initial tender, as well as the early specification phase and subsequent design stages leading through to implementation and commissioning. In the context of research (i.e. using a simulator to investigate a problem or undertake a process of systematic scientific enquiry), these stakeholders comprise three core groups: the individual or persons responsible for building the simulator (i.e. manufacturers); the individual or persons responsible for acquiring the simulator and any services that enable it to operate (i.e. procurers); and finally the scientists or researchers that will work with the simulator on a regular basis, as well as their research subjects (i.e. end-users). For research applications, most procurers have a tendency to rely on the faith validity of their simulator; that is they assume it is an accurate duplication of the real world and overlook the need to perform their own validation work (Stanton, 1996). Once deployed however, options for improvement can be limited, costly, and highly constrained (Naweed et al., 2014).

Developing high-fidelity simulators can be challenging if there are deficiencies with the methodology used to manage the project and coordinate those involved. In particular, the inability to understand or appreciate the perspectives of other disciplines can create barriers for collaboration and reduce the efficacy of the process (Jahangirian et al., 2012). Collaboration between stakeholders has been conceptualised as a process of collective action where individual goals are pursued autonomously within the background of a common social structure. Ossowski (1999) referred to this as a society of agents and coordination within a multi-agent system. While social interaction processes influence the characteristics and achievements of individual goals, they can also modify them, essentially so that actions lead to collective action. Deficiencies in the way that the manufacturer, procurer and end-user collaborate in the early stages of design have been suggested to impact the efficacy of collective action, and reduce the usability of the end-product (Rail Safety & Standards Board, 2007).

This paper takes the view that poorly designed simulators are a participatory problem associated with how the actors and stakeholder input are coordinated during its development. It also views the development of high-fidelity research-oriented simulators as activity that requires the sharing of knowledge beyond individual disciplines.

1.2. Participatory approaches and high-fidelity simulator development

Very little has been published within peer-reviewed literature about the way simulator development is holistically coordinated to satisfy research aims. While some functional specifications have been given for rail research simulators (e.g., Young, 2003), the literature for the end-user is heavily concerned with modelling and simulation (e.g., Ho et al., 2002; Martin, 1999) or the plausibility of the person immersed inside the simulation (e.g., Dahlstrom et al., 2009; Naweed, 2013). Relevant information is available from the grey literature about industrial applications (e.g., Rail Safety & Standards Board, 2007) though this adopts the procurer perspective and focuses on high-level issues, like organizational and business plans for continuity. Virtually no information is available on simulator manufacturing, largely because of the commercially competitive nature of the work. The paucity of literature here presents a clear knowledge gap, particularly as the majority of the coordination among stakeholders is stage-managed by the manufacturer. Whilst various approaches are used to coordinate the design and development of high-fidelity simulator projects, a common approach used by rail simulator manufacturers (e.g., Sydac Pty Ltd, 2015) is the *Agile* methodology (Beck et al., 2015).

Originally developed for software design, the Agile approach is intended to promote planning, evolutionary development, and continuous improvement in the dynamic of cross-functional teams (Martin, 2003). Some of its principles include: close and daily cooperation between business people and developers; face-to-face conversation as the best form of communication; continuous attention to technical excellence and good design; welcoming changing requirements even if they are late in development, and regular adaptation to changing circumstances (Beck et al., 2015). Cockburn and Highsmith (2001) indicate that the Agile approach focuses on the “talents and skills of individuals, moulding the process to specific people and teams” (p. 131) and is “designed to capitalise on each individual and each team's unique strength” (p. 132). Whilst the approach is reported to have clear benefits, numerous shortcomings in the way it is implemented have also been identified (e.g., Abrahamsson et al., 2009; Kajko-Mattsson, 2008; Lindvall et al., 2002; Pisoni, 2015). Amongst these, scalability, coordination with other teams, and losing sight of the big picture rank among the top-ten concerns (Begel and Nagappan, 2007).

One approach that has not been used to manage team coordination in simulator development is *participatory ergonomics*. As a concept, participatory ergonomics first came about in the early 1980s, where it was described as a macroergonomic approach for developing and implementing technology in organizational systems with end-users (Imada, 1991). While macroergonomics is focused on the design of organizational structures and work systems, participatory ergonomics focuses on designing jobs, work environments, hardware and software to fit individuals (Hendrick, 2005). Participatory ergonomics has since been described as a philosophy or strategy and formally 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 et al., 2005, p. 1071). As a set of tools, or techniques, participatory ergonomics is designed to expand the capacity for active stakeholders to implement knowledge, procedures and changes. The intent is to create improvement in the working environment in terms of its safety and quality, as well as the levels of productivity, comfort, and morale in workers. While participatory ergonomics has received some criticism for limited evidence of positive impact (Cole et al., 2005), the approach has been shown to improve engagement and enhance collaboration in a variety of psychosocial work settings, including libraries (Yuan, 2015), furniture companies (Guimarães et al., 2015), hospitals and healthcare (Andersen and Broberg, 2015; Glina et al., 2011; Rasmussen et al., 2017; Xie et al., 2015), glaziers (de Jong and Vink, 2000), construction (Jaegers et al., 2014), engineering plants (Cervai and Polo, 2017; Laitinen et al., 1998) and train driving (Lynas and Burgess-Limerick, 2013; Naweed and Balakrishnan, 2014; Naweed et al., 2012). In the context of simulator-based research, the end-users include actual researchers, and participatory ergonomics amounts to them being able to provide input into the design of their own

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