Computers in Human Behavior 64 (2016) 264–273

Contents lists available at ScienceDirect

Computers in Human Behavior

journal homepage: www.elsevier.com/locate/comphumbeh

Full length article

Impacts of behavioral engagement and self-monitoring on the development of mental models through serious games: Inferences from in-game measures

Valentin Riemer*, Claudia Schrader

Ulm University, Institute of Psychology and Education, 89069 Ulm, Germany

ARTICLE INFO

Article history:
Received 19 January 2016
Received in revised form
23 June 2016
Accepted 29 June 2016

Keywords:
Serious games
Mental model assessment
Knowledge structures
Complex skill acquisition
Gameplay engagement
Self-monitoring

ABSTRACT

The present study investigated the potential of serious games for the acquisition of complex cognitive skills by assessing learners' mental model development, operationalized as an increase in Mental Model Accuracy (MMA). Furthermore, we assessed behavioral engagement and self-monitoring as two specific engagement types within the gameplay process and analyzed their impact on mental model development. German undergraduate students ($N = 97$) played a serious game developed to foster practical money skills. We obtained pre- and post-gaming measures of MMA to analyze the development of mental models by applying a structural assessment method. Unobtrusive measures of behavioral engagement and self-monitoring were obtained by computerized collection of participants' in-game activities. Although we did not find a significant increase in overall MMA through playing, the degree of self-monitoring had a significant and positive effect on post-gaming MMA, even beyond the effect of initial MMA. Behavioral engagement had no impact on mental model development; however, it was positively related to self-monitoring behavior. The results are discussed in light of findings from research on self-regulated learning and controversial notions regarding the effect of behavioral engagement in serious games. In addition to insights into gameplay processes that affect mental model development through serious games, the present study also has practical implications in stressing the importance for game designers to provide learners with the opportunity to engage in self-monitoring behavior while playing a serious game.

1. Introduction

The potential of serious games, defined as computer-based games developed for a purpose other than entertainment (Michael & Chen, 2006; Ritterfeld, Cody, & Vorderer, 2009), is seen in their ability to model complex realities and to provide interactive experiences that enables learners to immediately experience the consequences of their actions. This has made serious games increasingly popular for the acquisition and training of *complex cognitive skills*. Also called high-performance skills (e.g., Schneider, 1985), complex cognitive skills are defined as a set of multiple and highly interrelated constituent skills in the cognitive domain, which involve continuous processing and exhibit goal-directed behaviors (van Merriënboer, 1997). Complex cognitive skills come into operation in situations or systems where a variety of problem states needs to be transformed into goal states. In order to accomplish these goal states, the constituent skills are required to conduct specific behaviors pertaining to problem detection, diagnosis, and solution (van Merriënboer, 1997). Recent examples of complex cognitive skills addressed in serious games research are skills for conducting emergency procedures (e.g., Toups, Kerne, & Hamilton, 2011; Wouters, Van der Spek, & van Oostendorp, 2011), military strategy skills (e.g., Orvis, Horn, & Belanich, 2009; Serge, Priest, Durlach, & Johnson, 2013), or financial skills such as practical money management (Barzilai & Blau, 2014).

While many researchers (e.g., Wouters, Van der Spek, & van Oostendorp, 2009; Wouters, van Nimwegen, van Oostendorp, & Van der Spek, 2013) argue that serious games have the potential to support the acquisition of complex cognitive skills, the empirical findings reveal a more inconsistent picture. Brennan and Vos (2013), for example, reported a positive effect on financial skills

* Corresponding author.
E-mail addresses: valentin.riemer@uni-ulm.de (V. Riemer), claudia.schrader@uni-ulm.de (C. Schrader).

http://dx.doi.org/10.1016/j.chb.2016.06.057
0747-5632/

by using a business game. In contrast, Barzilai and Blau (2014) could not find a general effect on participants' financial skills through playing a serious game. Besides the mixed findings for different games within the same subject domain, in a study investigating the impact of serious gaming on inquiry skills, Dede, Ketelhut, Clarke, Nelson, and Bowman (2005) reported inconsistent effects due to methodological problems. In their study, a gaming group only outperformed the control group when learning performance was assessed via a written essay, but not when it was tested with open-ended questions. Therefore, these results highlight the need for more research including the application of more appropriate methods of assessment for complex cognitive skill acquisition (Wouters et al., 2009).

To overcome the issue of assessment, in the current study we investigate the effectiveness of a platform game on practical money skills by measuring learners' *mental model* development. Mental model development is seen as one of the most important prerequisites to and, thus, indicator of cognitive skill acquisition (e.g., Kraiger, Salas, & Cannon-Bowers, 1995). However, only a few studies in the field of game research investigate cognitive skill acquisition by assessing learners' existing mental models and their development (e.g., Van der Spek, van Oostendorp, Wouters, & Aarnoudse, 2010; Van der Spek, Wouters, & van Oostendorp, 2011; Wouters et al., 2011).

Besides the issue of assessment in recent studies, little is known about the factors that determine mental model development within the process of serious game playing. Thus, we examine the role of learners' engagement during gameplay on mental model development as engagement is widely seen as a primary rationale for the application of serious games in educational settings (e.g., Garris, Ahlers, & Driskell, 2002; Rieber, 1996). Specifically, we focus on *behavioral engagement*, defined as the amount of effort and persistence invested in a task (Fredricks, Blumenfeld, & Paris, 2004; Pekrun & Linnenbrink-Garcia, 2012) and on *self-monitoring* as an aspect of cognitive-behavioral engagement (Pekrun & Linnenbrink-Garcia, 2012). In order to gain objective and unobtrusive assessments of these two types of engagement and investigate their impact on mental model development, the computerized registration of learners' in-game activities serves as real-time indicator of engagement in our study.

Both, the investigation of mental model development and the role of the two types of engagement aim to gain a deeper understanding of the mechanisms underlying complex cognitive skill acquisition in serious games. Moreover, using in-game activities as indicators of behavioral and cognitive-behavioral engagement, the results can substantially enhance game developers' and educators' understanding about learner behaviors that might foster or hinder mental model development while playing a serious game.

1.1. Mental model development as an indicator of complex cognitive skill acquisition in serious games

Mental models are generally identified as higher-order learning objectives that are meaningfully structured in individuals' minds (Johnson-Laird, 2001; Jonassen, 1995; Kraiger, Ford, & Salas, 1993; van Merriënboer, van Jelsma, & Paas, 1992). Greene and Azevedo (2009) define mental models more specifically as "representations that include the declarative, procedural, and inferential knowledge necessary to understand how a complex system functions" (p. 19). Mental models reflect the in-depth understanding, organization, and relation of knowledge containing concepts relevant to the skill acquisition (Kraiger et al., 1993; van Merriënboer et al., 1992). As such, mental models can be seen as knowledge structures that comprise the representations of concepts as well as the structural relation between these concepts (Jonassen, 1995; Messick, 1984).

Mental models are typically associated with the ability to identify meaningful functions, forms, and requirements of tasks (Rouse & Morris, 1985) and to interpret objects and events within a context (Messick, 1984). These organizational and functional aspects of mental models specifically account for their capacity to integrate the detection and the diagnosis of problem states together with the identification of appropriate solution strategies (Glaser, 1989; van Merriënboer et al., 1992). Thus, mental models are assumed to provide the basis for complex cognitive skill acquisition (van Merriënboer, 1997). To test the presumed implications of mental models for the acquisition of complex cognitive skills, there has been a concentrated effort mostly in the field of training evaluation (e.g., Acton, Johnson, & Goldsmith, 1994; F. D.; Davis & Yi, 2004; M. A.; Davis, Curtis, & Tschetter, 2003; Day, Arthur, & Gettman, 2001; Dorsey, Campbell, Foster, & Miles, 1999). Findings of empirical studies comparing domain experts and novices confirm that an increase in mental model accuracy (i.e., the similarity to an expert referent model), is a valid predictor of training performance, skill retention, and skill transfer (e.g., F. Davis & Yi, 2004; Day et al., 2001; Kraiger et al., 1995).

In game research, the assessment of complex cognitive skill acquisition has predominantly been done by assessing declarative knowledge (e.g., Boeker, Andel, Vach, & Frankenschmidt, 2013; Hou & Li, 2014). However, Kraiger et al. (1993) argued that measuring declarative knowledge is only appropriate for the initial stages in acquiring a novel skill and less capable to find differences in skill performance. This inappropriateness of applied measures might be one reason for the inconsistent findings on skill acquisition in games (e.g., Barzilai & Blau, 2014; Brennan & Vos, 2013; Dede et al., 2005) as outlined by Wouters et al. (2009). Only few studies in the field of game research investigated the assessment of mental model development as a mean of evaluating complex cognitive skill acquisition (e.g., Wouters et al., 2011; Van der Spek et al., 2011, 2010). Van der Spek et al. (2010), for example, analyzed participants' mental models before and after learning with a game to train medical triage using a method called structural assessment (Kraiger et al., 1995). The results of this study demonstrated that learners' mental models were more similar to an expert referent model after gameplay. Using the same method of mental model assessment, Wouters et al. (2011) reported similar effects to those of Van der Spek et al. (2010). However, the effectiveness of serious games regarding mental model development as an indicator of complex cognitive skills was not straightforward when learner characteristics, such as learners' levels of expertise, are taken into account. Wouters et al. (2011) showed that playing a serious game only had a positive impact on the mental models of novice learners, while advanced learners' mental models became even less similar to the referent model after playing.

So far, however, to our knowledge no studies investigated factors within the gameplay process that might affect mental model development in serious games. Thus, in the following sections, we introduce two types of engagement as possible determinants for mental model development within the process of serious game playing.

1.2. The role of engagement in mental model development

Engagement is seen as a primary rationale for the application of serious games in educational settings (e.g., Rieber, 1996) and widely discussed with regard to its impact on learning achievement through serious gaming (e.g., Conati, 2002; Garris et al., 2002; Graesser, Chipman, Leeming, & Biedenbach, 2009). Overall, engagement can be defined as a multifaceted construct composed of components that comprise "active, energetic, and approach-