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A meta-analytic review of the role of instructional support in game-based learning

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Computer games can be considered complex learning environments in which players require instructional support to engage in cognitive processes such as selecting and actively organizing/integrating new information. We used meta-analytical techniques to test if instructional support enhances learning in game-based learning ($k = 107$, $N_{adj} = 3675$). We found that instructional support in game-based learning environments improved learning ($d = .34$, $p < .001$). Additional moderator analyses revealed that the learning effect was largest when learning of skills was involved ($d = .62$, $p < .001$) and when the instructional support aimed at the selection of relevant new information ($d = .46$, $p < .001$). Furthermore, we found some evidence for a publication bias since the effect sizes for studies in peer-reviewed journals was significantly higher than for studies in proceedings and unpublished studies (journals: $d = .44$; proceedings: $d = .08$; unpublished: $d = .14$).

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1. Introduction

The last decade shows an increasing attention for the use of computer games in learning and instruction, often referred to as serious games or game-based learning (GBL). In this respect serious games are hypothesized to address both the cognitive and affective dimensions of learning (O'Neil, Wainess, & Baker, 2005), enable learners to adapt learning to their cognitive needs and interest and provide motivation for learning (Malone, 1981). Some recent reviews have indeed shown that GBL can be more effective than conventional instruction such as lectures or classroom instruction (e.g, Sitzmann, 2011; Wouters, Van Nimwegen, van Oostendorp, & van der Spek, submitted for publication).

From a cognitive theory perspective it can be argued that GBL often involves complex learning environments in which players – especially novices – can easily become overwhelmed by all the information that has to be processed and consequently refrain from activities that foster learning (Wouters, van der Spek, & van Oostendorp, 2008). The question can be raised whether learners in GBL environments require support to engage in relevant cognitive activities. Such instructional support may appear in several forms such as providing feedback, scaffolding, giving advice et cetera. However, little is known regarding the effect of instructional support in GBL. Earlier reviews and meta-analyses on GBL did not consider instructional support, but focused on the comparison of GBL with traditional instruction methods (e.g., O'Neil et al., 2005; Sitzmann, 2011; Vogel, Vogel, Cannon-Bowers, Muse, & Wright, 2006; Wouters et al., submitted for publication).

The goal of this study is to systematically investigate the role of instructional support in GBL. Mayer (2011) has divided game research into three categories: a value-added approach with the question how specific game features foster learning and motivation; a cognitive consequences approach which investigates what people learn from serious games and a media comparison approach which investigates whether people learn better from serious games than from conventional media. Our meta-analysis will adopt the value-added approach by comparing studies with and without instructional support. Instructional support includes a broad range of techniques and methods that aim at different cognitive activities. Therefore, we will not only consider the main effect of instructional support, but also investigate the effects of several types of instructional support.

In the following sections we will first define GBL. Next, we will describe the theoretical framework we use to investigate the different types of instructional support. The Method section comprises a description of the literature research, the inclusion criteria, the coding of the

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moderator variables and the calculation of effect sizes. The Results section presents the general characteristics of the analysis, the main effects and the effects of the moderator variables. Finally, we will discuss the findings, draw conclusions and depict some avenues for future research.

2. Definition of GBL

Several scholars have provided definitions or classifications of computer games characteristics (Garris, Ahlers, & Driskell, 2002; Malone, 1981; Prensky, 2001). For the purpose of this meta-analysis we describe computer games in terms of being *interactive* (Prensky, 2001; Vogel et al., 2006), based on a set of *agreed rules and constraints* (Garris et al., 2002), and directed toward a clear *goal* that is often set by a *challenge* (Malone, 1981). In addition, games constantly provide *feedback* either as a score or as changes in the game world to enable players to monitor their progress toward the goal (Prensky, 2001). Some scholars contend that computer games also involve a competitive activity (against the computer, another player, or oneself), but it can be questioned if this is a defining characteristic. Of course there are many games in which the player is in competition with another player or with the computer, but in a game like SimCity players may actually enjoy the creation of a prosperous city that satisfies their beliefs or ideas without having the notion that they engage in a competitive activity. In the same vein a narrative or the development of a story can be very important in a computer game (e.g., in adventure games), but again it is not a prerequisite for being a computer game (e.g., action games do not really require a narrative). This definition of GBL would also comprise 'pure simulations' such as SIMQuest (see also www.simquest.nl) that also include an underlying model in which learners can provide input (either changing variables or perform actions) and observe the consequences of their actions (cf. Leemkuil, de Jong, & Ootes, 2000). However, we concur with Jacobs and Dempsey (1993) who argued that task-irrelevant elements are often removed from simulations whereas other elements such as an engaging context are included or emphasized to define a (simulation) game. In GBL the objective of the computer game is not to entertain the player, which would be an added value, but to use the entertaining quality for training, education, health, public policy, and strategic communication objectives (Zyda, 2005).

3. Theoretical framework

From a cognitive perspective instructional support can be implemented in order to overcome the limitations of the human cognitive architecture (Mayer, 2001, 2008; Paas, Renkl, & Sweller, 2003; van Oostendorp, Beijersbergen, & Solaimani, 2008). Two structures are regarded crucial for the processing of information. The first, working memory, has a limited capacity to process information and is often not adequate for learning material when it is complex, multimodal and/or dynamical. Especially for novices the complexity and the dynamic character of instructional material may lead to problems: they do not know what is relevant and therefore focus on the wrong information. The second structure, long term memory, has a virtually unlimited capacity which can serve as added processing capacity by means of schemas, i.e., cognitive structures that can be processed in working memory as a single entity (Kintsch, 1998; Paas et al., 2003).

Based on this cognitive architecture, theories have emphasized several important cognitive processes that are involved in learning. Mayer's cognitive theory of multimedia learning, for example, discerns three types of cognitive processing: the *selection* of relevant information by paying attention to the presented material, mentally *organizing* the new information in a coherent structure and the *integration* of this structure with prior knowledge (Mayer, 2001).

Although the organization and integration of information reflect different cognitive processes, they are closely related and difficult to separate (cf. Moreno & Mayer, 2005). Therefore, we propose that, from a cognitive perspective, instructional support should enable learners to engage in two types of learning processes: (1) the selection of relevant information from the learning material and (2) the active organization of that information and the integration with prior knowledge in long term memory (Mayer & Moreno, 2003).

GBL involves complex learning environments in which it is not obvious that players automatically engage in these basic learning processes. To start with, players can be easily overwhelmed by the plentitude of information, the multimodal presentation of information (sometimes simultaneously on different locations of the screen), the choices players potentially can make, the dynamics of the game and the complexity of the task that has to be performed. This implies that instructional guidance to support players to adequately *select* relevant information and ignore irrelevant information is important, certainly given working memory constraints. Secondly, in computer games players act and see the outcome of their actions reflected in changes in the game world. This may lead to a kind of intuitive learning: players know how to apply knowledge, but they cannot explicate it (Leemkuil & de Jong, 2011). Yet, it is important that learners articulate and explain their knowledge, because it urges them to *organize* new information and *integrate* it with their prior knowledge. Ultimately, this will yield a knowledge base with higher accessibility, better recall and higher transfer of learning (Wouters, Paas, & van Merriënboer, 2008).

4. Method

4.1. Sample and literature search

We started with computer-based searches via GoogleScholar. The search terms we used were: 'Game-based learning', 'serious games', 'educational games', 'simulation games', 'virtual environments', and 'muve'. When necessary these search terms were combined with 'learning', 'instruction', and 'training'. In addition, we investigated the references of previous meta-analyses and reviews on the effectiveness of serious games (Fletcher & Tobias, 2006; Ke, 2009; O'Neil et al., 2005; Sitzmann, 2011; Vogel et al., 2006; Wouters et al., submitted for publication). In order to find unpublished, but relevant studies we also asked researchers and educators within our network of scholars whether they were aware of relevant studies for the meta-analysis. Our meta-analysis covered the period from 1990 to 2012. For the selection process we considered only studies in which GBL complied with our definition. In addition, studies were only selected when GBL with instructional support was compared with GBL without instructional support in a controlled experimental design. Furthermore, the study had to report data or indications that allowed us to calculate or estimate effect sizes (group means and standard deviations, *t*-test, *F* test et cetera). Third, the focus of the study comprised nondisabled participants. Our research located 197 studies of which 29 studies met these inclusion criteria.

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