



Full length article

Computer games that exercise cognitive skills: What makes them engaging for children?

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ARTICLE INFO

Article history:

Received 12 October 2015

Received in revised form

12 January 2016

Accepted 15 February 2016

Available online xxx

Keywords:

Computer games

Engagement

Cognitive skills

Schoolchildren

ABSTRACT

This paper stems from a mixed-methods study in which we scientifically tested 15 computer games to investigate their suitability for cognitive training. After determining which cognitive functions are utilized while playing these games, we were able to relate schoolchildren's game performance to their cognitive abilities (e.g., executive functioning, perception, memory). As a continuation, we sought to identify the factors that lead to greater engagement in games, such as children's age, gender, and cognitive skills, as well as game genres and features. Forty-one children played 15 computer games, each three times, under the scrutiny of two raters who completed an observational scale for each game. This scale was constructed as a reliable measure of engagement, comprising factors such as enjoyment, frustration, and effort. The data were analyzed using correlations and content analyses. The results indicated that game performance increased with greater levels of engagement and that games involving planning and problem solving tended to be too difficult for younger children. The findings of this study are informative for psychologists, educators, as well as game designers, and can be used to recommend engaging and beneficial games for children.

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1. Introduction

Video and computer games have become an increasingly popular form of entertainment over the past decades. In fact, electronic games are now considered a routine part of children's and adolescents' lives (Olson, 2010). There are many reasons for which people play computer games, such as relaxing (Reinecke, 2009), competing with an opponent (Olson, 2010), becoming immersed in the story, developing skills and learning, and experiencing pleasure and/or challenge (Martinovic et al., 2014). Not surprisingly, there has recently been great interest in the field regarding the potential of games to improve learning and cognition among all age groups. This interest is based on the assumption that these leisure activities engage players in a variety of ways, which are yet to be fully understood (Boyle, Connolly, Hainey, & Boyle, 2012), and that education and work experiences could be enriched by using similar techniques to those that make games appealing to their players.

For video game developers, creating enjoyable games is a primary goal (Hamlen, 2010; Sweetser & Wyeth, 2005). In order to be successful, a game must have features that encourage players to return to gameplay. According to Garris, Ahlers, and Driskell (2002), if the instructional content of educational games is successfully paired with suitable game features, the player is more likely to find the game engaging and become motivated to achieve the desired learning outcomes.

Ideally, a well-designed instructional game “provides the player with immediate feedback [and] clear goals and challenges that are matched to his/her skill level” (Kiili, 2005, p. 1). The difficulty of a particular game should be within the realm of an individual's competence, as this contributes to more effective learning (Gee, 2003) and greater immersion and flow in the game (Cowley, Charles, Black, & Hickey, 2008). A game's ability to produce high levels of engagement is important, especially for educational games (Brockmyer et al., 2009), as greater immersion may lead to greater performance in games and learning (Cheng, She, & Annetta, 2015). In Cheng et al.'s (2015) study, seventh graders who were more immersed in *Virtual Age*, a game designed to help students understand evolution, increased their knowledge of the topic and had

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higher game scores. Similarly, in a qualitative study by [Squire and Barab \(2004\)](#), the learners who played the computer simulation game, *Civilization III*, achieved favourable results in their history course. [Squire and Barab \(2004\)](#) agree that games may serve as powerful tools for engaging learners, but that engagement is a complex phenomenon that includes an interplay of personality, goals, socio-cultural practice, and the game's required actions.

According to [O'Brien and Toms \(2008\)](#), engagement in gaming integrates the game's attributes with the emotional tendencies of the player. The player's engagement is an experience that is influenced by "challenge, positive affect, endurance, aesthetic and sensory appeal, attention, feedback, variety/novelty, interactivity, and perceived user control" (p. 938). Engagement in gaming may depend on various personal traits, but of interest to this study are players' gender and age. What is considered engaging may be different for boys versus girls and for younger versus older children. It has long been determined that boys enjoy and spend more time playing video games than do girls, and that most games are designed for boys ([Kinzie & Joseph, 2008](#); [Lucas & Sherry, 2004](#)). Boys and girls also differ in their genre preferences; boys tend to enjoy active games with physical enactment, while girls enjoy strategy, creative, exploratory, and traditional games (e.g., card, trivia, puzzle, and board games; [Kinzie & Joseph, 2008](#); [Sherry, Lucas, Greenberg, & Holmstrom, 2013](#); [Lucas & Sherry, 2004](#)). Neurologically, boys and girls have different cognitive abilities; boys are more apt for mental rotation and navigation, whereas girls are more apt for landmark memory and processing speed, which may partially explain the difference in preferences ([Reilly & Neumann, 2013](#)). However, the majority of the research has focused on differences in preferences between these two groups, but not on their specific, observable aspects of engagement, such as attention, frustration, and understanding.

Preferences for game genres may also differ across children's age groups. For example, it has been found that children enjoy strategy games more as they grow older and that simulation games are quite popular among elementary school children ([Sherry et al., 2013](#)). In addition, children of different ages play games for different reasons; children under the age of 10 play games to achieve success while adolescents play games to seek sensation ([Boyle et al., 2012](#)). Overall, children are more likely to be engaged in games that they prefer and that utilize the cognitive skills that they currently possess; however, to support the further development of games for educational and cognitive purposes, more research is needed to identify differences among additional factors of engagement.

1.1. Engagement in cognitive games

In this study, we aimed to offer a broader perspective of gaming experience and determine how player characteristics (e.g., age and gender) and game features relate to players' engagement and success in a game. Following [Squire and Barab \(2004\)](#), we considered engagement as a complex construct that must be exhibited by players' responses to the gaming experience. As [Cheng et al. \(2015\)](#) stated, to be engaged, the players must like the characteristics of the game, which will lead to the devotion of time and effort into gameplay, which will then lead to greater focus of attention.

The current study was an extension of previous research by [Martinovic, Burgess, Pomerleau, and Marin \(2015\)](#), which gave insight into the cognitive skills required to play 15 'cognitively responsible' computer games. These games demonstrated convergent and divergent validity with presumed, pre-assigned cognitive categories, derived from a reliable rating system, thereby evidencing the specific cognitive skills required when playing the games ([Martinovic et al., 2015](#)). However, further research was necessary to understand which game characteristics elicit

engagement and encourage children to continue playing such games. Our goal was to measure schoolchildren's engagement while playing these 15 games by concentrating on observable feelings (e.g., enjoyment, frustration) via emotional behaviours (e.g., vocalizations, facial expressions, gestures, body language, and intonation; [Burgess, 2011](#)). In doing so, we could better understand how the children interacted with the games, which games and which game features they preferred, and how their level of engagement related to their gaming scores.

Based on the literature, the following research questions were of interest:

RQ1. Do children's engagement scores correlate with their performance scores on computer games?

RQ2. What qualities make games more engaging for younger vs. older children and for girls vs. boys?

RQ3. Do certain game qualities relate to certain aspects of engagement, such as the games being enjoyed, eliciting frustration, etc.?

Studies on engagement in gaming have used a variety of data collection methods, such as player questionnaires, observations (e.g., [Brockmyer et al., 2009](#); [Dempsey, Haynes, Lucassen, & Casey, 2002](#); [Ke, 2008](#); [Kinzie & Joseph, 2008](#); [Olson, 2010](#); [Papastergiou, 2009](#)), or physiological response tracking (see [Boyle et al., 2012](#) for a review). In this study the observational method seemed fitting for investigating our research questions. By looking into the games' design characteristics and the cognitive skills they involve, alongside the players' demographics, game scores, and observed feelings and behaviours during game play, we could triangulate our findings and identify connections between player engagement and computer game features.

2. Methods

For this study we used a mixed methods research approach in the form of an explanatory sequential design where the quantitative gaming data were explained through the qualitative observation data. The content analysis of observations was deemed appropriate since we intended to interpret children's genuine interactions with the computer games ([Denzin & Lincoln, 2005](#)). While the conditions under which the children played games were not natural (e.g., playing each game three times in a fixed order inside a research lab), all children were familiar with playing computer games, resulting in conditions that encouraged authentic behaviour. We conducted a highly structured observation of children during game play ([Neuman, 2011](#)). This approach enabled the unobtrusive recording of observers' perceptions about children's engagement in gaming, revealing aspects of gameplay that children may not have been able to articulate or that may have escaped their conscious awareness. In order to avoid misinterpretation, we also asked children about the meanings of some of their non-verbal behaviours and/or their opinions about the games.

2.1. Sample and recruitment

A sample of 45 schoolchildren was selected for this study, although four participants were excluded as one did not complete the study and three of them were observed by different raters because of scheduling conflicts; thus, their engagement may not have been scored consistently with that of other participants'. The resulting sample was composed of 21 boys and 20 girls between the ages of 7 and 12. The children attended grades 1 to 7 in Windsor/Essex, Ontario schools. They came from diverse ethnic

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