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GENDER, GAMES AND SPACE

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ABSTRACT

We report here a study of spatial learning and action videogame play based on Feng et al.'s (2007) finding that 10 hours spent playing an action videogame significantly improved selective attention and mental rotation. Students with above-average scores on measures of spatial abilities, such as mental rotation, prove more successful in Science, Technology, Engineering, and Mathematics (STEM) fields (Lubinski & Benbow 2006), however females demonstrate significantly less ability in mental rotation and spatial navigation than males (Astur et al. 1998) and are, as well, significantly under-represented in STEM subjects and fields (Beede et al. 2011; Hango, 2013). This study aims to better understand the factors that affect abilities to navigate virtual spaces, to identify underlying processes different users bring to bear when navigating virtual environments, and to identify design modifications guiding the development of game-based virtual environments that support improvement in spatial cognition. A Virtual Morris Water Maze is used to assess whether and how playing either FPS (First Person Shooter) or puzzle games appears to impact the navigational performance of male and female participants. Concluding suggestions are (tentatively) offered about specific features of games that appear to support increased success in highly valued STEM subjects and fields and that might assist in re-mediating this persistently gendered disadvantage.

KEYWORDS

Game-based learning, spatial abilities, gender, STEM

1. INTRODUCTION

Playing videogames has become an increasingly popular pastime among both children and adults, and with it has come a growing interest in questions about what and how players learn from videogame play. This study is part of a larger project to identify evidence-based, replicable studies of game-based learning, since much research on that question reports on small-scale, anecdotal and largely qualitative work. Relatively recent research has shown that videogame play could have a positive impact on spatial abilities such as mental rotation and selective attention (De Lisi & Wolford 2002; Green & Bavelier 2003; Feng et al. 2007; Boot et al 2011), but there are still many issues that remain unresolved. This research is of particular interest because we know that students with above-average scores on measures of cognitive ability such as mental rotation tend to be successful in Science, Technology, Engineering, and Mathematical (STEM) fields (Lubinski & Benbow 2006). We also know that females and males use different strategies to solve spatial tasks. We need to know more about how males' and females' spatial perception and cognition are affected by videogame play. This research could lead to identifying ways to maximize skills and abilities that are useful in STEM subjects and fields.

This study of spatial learning and action videogame play builds on the work of Feng et al. (2007), which found that 10 hours spent playing an action videogame significantly improved selective attention and mental rotation. Successful replication will considerably strengthen the evidential basis of investigations into whether and how training with an action video game affects performance in measures of attention, mental rotation, spatial learning and memory. Although not an exact replication, in our study, as in the Feng et al study, participants will be trained in either an action video game or a puzzle game for 10 hours to see how their experience impacts performance on measures of spatial cognition. Both prior to and following 10 hours of action game or puzzle game play, participants complete a test of mental rotation, and a navigation task in a 3D virtual environment.

Spatial cognition encompasses an array of skills and abilities at multiple levels of processing. As Feng et al. (2007) indicate, for instance, "attentional processes are intimately involved in higher-level tasks in spatial cognition." Thus, the ability to deploy attention across space is a "building block" for higher-level cognitive processes such as mental rotation. They found that action video games do improve lower-level attentional processes, and this may be one of the factors that lead to improvement on more complex abilities like mental rotation. As far as we are aware there has been no systematic research into whether video games also lead to improvements in cognitive processes measured at a higher level, and that may depend on mental rotation as a building block. Past research has found a correlation between mental rotation and navigation strategies as measured with maps (Dabbs et al. 1998) and real-world environments (Malinowski 2001). These findings suggest that mental rotation supports more complex tasks such as navigation, which is a form of spatial learning and memory. Discovery of a causal relationship between video game playing and spatial learning and memory, as mediated by mental rotation, would prove important not only at a theoretical but also practical level.

In this study we are using a 3D virtual version of the Morris Water Maze, which has been extensively used to measure spatial learning and memory in non-human subjects (Morris 1984), and more recently, in its virtual versions, to assess spatial cognition in human participants (Astur et al. 1998; Hamilton et al. 2002; and Mueller et al. 2008) as an experimental tool to investigate the extent to which video games lead to improvement not only in mental rotation but also in higher-order spatial learning and memory.

2. PRIOR RESEARCH

In a previous study of gender and (virtual) spatial navigation, we tested 82 undergraduate students, 50 females and 32 males, at a technology-focused School for Interactive Arts and Technology. Using a Virtual Morris Water Maze (https://youtu.be/v1EPF3YGaHo), we assessed navigational competence by comparing participants' search times to locate a hidden target, and their dwell times in the target area. Results showed videogame experience and spatial ability to be significantly correlated (de Castell et al. 2015). Those results indicated that past 3D video game experience was generally associated with better navigation performance in most, but not all, instances.

We found in that prior study a gender-differentiated uptake of distal and proximal cues, with navigators of high spatial ability being less reliant on salient proximal cues than navigators of low spatial ability --but we were also able to demonstrate how, with the provision of proximal cues, in the form of landmarks on the circumference of a virtual pool, these gender-based differences in navigational performance were significantly diminished. Given that spatial abilities have been correlated with positive educational outcomes in STEM subjects, and that female students have been and remain under-represented in these subject areas despite their centrality to 21st century educational and occupational demands, understanding the underlying processes that different users bring to bear when navigating 3D virtual environments, and knowing what design modifications, support improvements in performance, is of utmost importance in advancing educational access and opportunity.

2.1 Correlation to causation: Strengthening Connections between Claims and Evidence for Game-Based Learning

Participants in this study are 32 undergraduate students, 16 male and 16 female. The data collection procedure has four phases: pre-training, training, post-training, and follow-up. In the pre-training phase, participants complete a mental rotation test (Ganis & Kievit 2015) which involves viewing digital images of abstract three-dimensional objects (Figure 1) and determining if they are the same or different. This task has been used extensively to assess ability to visualize and mentally manipulate 3D figures.

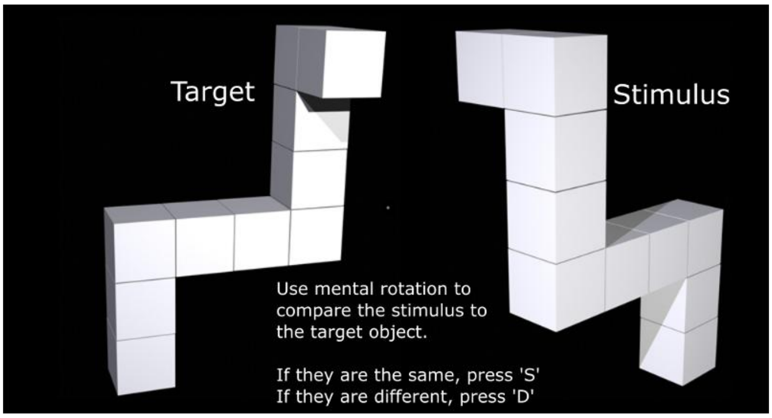

Figure 1. Sample figures used in the mental rotation test (adapted from Ganis & Kievit 2015)

After completing the mental rotation test, the participant's navigation abilities will be assessed with the Virtual Morris Water Maze (VMWM) task. Our VMWM (Figure 2) consists of a virtual environment that contains a pool full of water within a rectangular room. Hidden beneath the water is a platform that is activated whenever a participant swims over it. This task is believed be an accurate measure of spatial learning and memory (D'Hooge & De Deyn 2001). In the present study, all proximal cues have been removed from the pool wall so that successful completion depends upon ability to make use of distal cues to create and manipulate a mental representation of the environment.

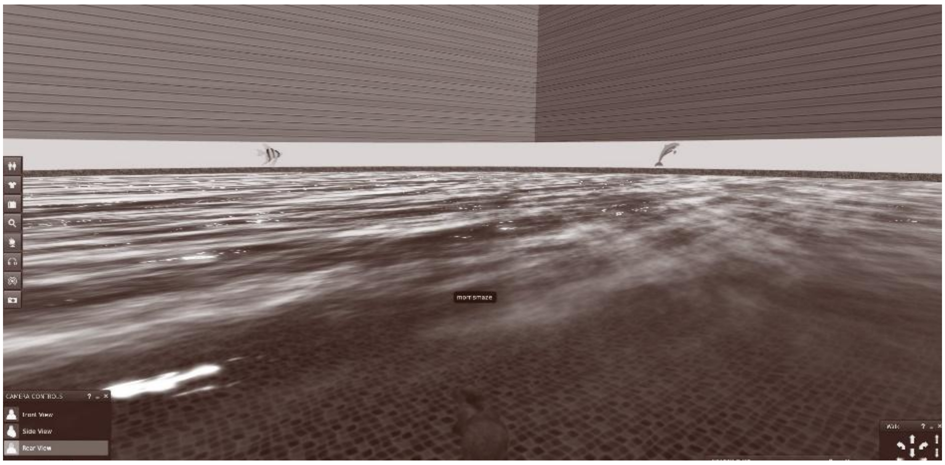

Figure 2. The Virtual Morris Water Maze. The figure shows the room walls and the pool, with proximal cues along the pool wall

Participants use the keyboard to move an avatar, in the form of a lab rat, to learn the location of the hidden platform. There are 15 trials in total, all of which are video-recorded. After participants complete these tasks, they are asked to fill out a video game and demographics questionnaire. The video game training phase randomly assigns participants to play either an action game (Call of Duty 2) or a puzzle game (Puzzle Ball) for a total of 10 hours. In the post-training phase, the participants will again complete both a mental rotation test and 15 trials in the virtual maze. In a follow-up phase designed to evaluate retention of learning, participants will again to complete the mental rotation test and the VMWM task, as well as a short questionnaire to assess their video game habits over the six months since the completion of training.

This study's results will help us understand the factors that affect abilities to navigate virtual spaces, identify the underlying processes different users bring to bear when navigating 3D virtual environments, and identify design modifications to guide the development of game-based virtual environments that support improvements in performance.

3. CONCLUSION

The advantages of this approach are both theoretical and practical: virtual environments, paradoxically enough, can enable more naturalistic assessments of the complex and diverse abilities involved in spatial navigation, than could previous assessments reliant on narrow psychometric tests, paradigmatically pen and paper mental rotation tests. As they become increasingly ubiquitous, virtual environments afford wide availability of computationally powerful technologies for experimentation. Unlike 'real world' experimental conditions, they enable greater control, and support complex and realistic scenarios that can be easily modified to test specific variables, for instance proximal cues can be inserted or removed, trial times can be lengthened or reduced, performance can be easily tracked in a variety of different ways (e.g. latency, path length, movement patterns, goal completion, etc.), and data capture storage and retrieval, as well as some forms of analysis can be automated. The 'portability' of virtual environments such as the VMWM mean experimentation is no longer restricted to the lab, the range of potential ethical concerns is greatly reduced and accessibility for differently-abled participants made possible. Such on-line experimental environments also allow for dissemination and knowledge-sharing and comparative analysis across locations on an unprecedented scale. Moreover, most of the research on sex differences in spatial abilities, and specifically research using the Morris Water Maze, has been conducted with animals, but the VMWM allows us to test a wide range of questions using human participants, thus enabling cross-species comparisons.

Limitations of our experimental approach are that directional cues are not fully 3-D---however this limitation will in time be circumvented by new developments in virtual reality technologies. Other limitations include possible gender differences in the ways males and females interact with virtual stimuli, (Viaud-Delmon et al.,1998; Wooley et al., 2010), specifically gender-differentiated responses to expanding both field of view and shape of the visual display, the fact that the VMWM has not yet been extensively studied and there are several design and protocol differences in the research which has been reported---and that it remains possible that differences in virtual maze performance may have less to do with spatial abilities than with the typical and often-reported 'hesitation' phenomena displayed by female subjects, both animal and human, interestingly enough (Shore et al, 2001,Wooley et al, 2010).

Implications for future work relate to the potential uses of the VMWM to easily, affordably and accurately assess spatial abilities, and to inform the design of game-based training instruments to remediate those abilities. As Feng et al. point out, given the evidence that quite specific cognitive abilities are associated with success in specific educational and vocational fields, and the evidence that these abilities can, indeed, be ameliorated through specific kinds of digital gameplay, "training with appropriately designed action video games could play a significant role as part of a larger strategy designed to interest women in science and engineering careers". (Feng et al, 2007, p.854).

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