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Factors related to sex differences in navigating a computerized maze

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ABSTRACT

The aim of this study was to compare computerized maze navigation performance and strategy by sex, and to investigate the relationships between navigation variables and self-reported experiential or personality dimensions. Participants used a joystick to explore a maze and were told to learn the layout of the maze as well as the locations of six objects within the maze. Men outperformed women, but some of the sex differences decreased in magnitude when we accounted for video game experience. Men were more likely than women to report strategies consistent with using an allocentric perspective to solve the maze, whereas women were more likely than men to report strategies consistent with an egocentric approach. We report several factors associated with successful navigation in a computerized maze, some of which relate to real life navigation and may contribute to the sex differences often reported for measures of spatial cognition.

1. Introduction

Contributions to the variability in human spatial behavior are manifold. Evolutionary (e.g. for review, see Silverman & Choi, 2005; Silverman, Choi, & Peters, 2007), developmental (e.g., for reviews, see Bohbot et al., 2012; Moffat, 2009; Voyer, Voyer, & Bryden, 1995), physiologic (e.g., for review of hormonal effects, see Hampson, 2008), and experiential/social (e.g., for review, see Hyde, 2014) influences on spatial behavior have all been demonstrated. Here we present a comprehensive investigation of sex differences in computerized maze navigation performance, self-reported maze navigation strategy, and real-life navigation-related experiential factors, which have all been previously investigated in their own right but to the best of our knowledge not in the same study. Considering these factors within the same study will allow us to address the ongoing yet unresolved investigation into the factors contributing to the male advantage in spatial performance. Specifically, the present study will allow us to better understand the relationships between performance in a controlled, laboratory spatial task and compare it to how people report to think or behave in large-scale environments in their daily lives.

Men reliably outperform women on tests of navigation, whether in real-world or computerized environments (Coluccia & Louse, 2004). In a review of sex differences in wayfinding abilities that spanned 20 years of literature, Coluccia and Louse (2004) reported a male advantage in at least 57% of the published reports. Navigation tasks based on maps (e.g., map drawing, verbal description of a route, recall of landmarks or streets) produced a male advantage in 42% and a female advantage in 18%of the studies. A male advantage was observed in approximately 59% of studies requiring men and women to navigate real environments such as woods, buildings, and university campuses. Of the simulated navigation studies, which required participants to actively traverse computerized environments, a significant male advantage was reported in nearly 86% of the studies.

Common simulated environments include computerized analogs of mazes traditionally used in non-human research, such as the Morris water task (MWT; Morris, 1984) which requires rodents to swim to a platform submerged in an opaque pool of water based on the configuration of external cues, or the multiple T-maze (e.g., Tolman, 1948) which requires rodents to find their way from a start to a goal position using either a place or response strategy. Humans view a virtual MWT (vMWT) on a computer screen and use various cues in the maze to locate the hidden platform by maneuvering through the pool with a joystick or keyboard. Time and distance to locate the hidden platform across learning trials, time and distance spent in the platform quadrant during the probe trial, and platform area crossings during the probe trial have all been used to describe performance. A sex difference favoring men is often present in hidden platform and probe trials (Astur, Ortiz, & Sutherland, 1998; Burkitt, Widman, & Saucier, 2007; Driscoll, Hamilton, Yeo, Brooks,

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& Sutherland, 2005; Mueller, Jackson, & Skelton, 2008; Nowak & Moffat, 2011; Nowak, Diamond, Land, & Moffat, 2014; Sandstrom, Kaufman, & Huettel, 1998). Men typically locate the hidden platform across trials using less distance and time than women, spend more time and travel a greater distance within the goal quadrant during the probe trial than women, and cross the platform area during the probe trial more frequently than women.

Virtual corridor mazes generally include a start location, interconnecting corridors with multiple decision points, and a goal area (e.g., Moffat, Hampson, & Hatzipantelis, 1998). Errors, time to navigate from start to goal, and number of trials to criterion are commonly use to assess performance. Similarly to performance on vMWT, men commit fewer errors and complete the corridor mazes faster than women (e.g., Grön, Wunderlich, Spitzer, Tomczak, & Riepe, 2000; Moffat et al., 1998; Moffat, Zonderman, & Resnick, 2001).

Sex differences in spatial performance may be partially attributable to differential use of navigation strategies. Research commonly distinguishes two navigation strategies: egocentric, in which the self is the reference point for navigating based on self-landmark relationships (e.g., left and right turns); and allocentric, a viewer-independent conceptualization of the environment which affords knowledge of the relationships between multiple distal landmarks (for reviews of navigation strategies, see, e.g., Burgess, 2008; Klatzky, 1998; O'Keefe & Nadel, 1978). A number of investigations have supported the argument that men prefer allocentric strategies while women prefer egocentric strategies (e.g., Choi & Silverman, 1997; Coluccia & Louse, 2004; Dabbs, Chang, Strong, & Milun, 1997; Galea & Kimura, 1993; Lawton, 1994; Levy, Astur, & Frick, 2005; MacFadden, Elias, & Saucier, 2003; Malinowski & Gillespie, 2001; Sandstrom et al., 1998; Saucier et al., 2002; Ward, Newcombe, & Overton, 1986), while others have presented evidence against this claim (Andersen, Dahmani, Konishi, & Bohbot, 2012; Bohbot et al., 2012; van Gerven, Schneider, Wuitchik, & Skelton, 2012; Goeke, König, & Gramann, 2013; Hund & Nazarczuk, 2009; Iaria, Petrides, Dagher, Pike, & Bohbot, 2003; Rodgers, Sindone, & Moffat, 2012). There is evidence that women perform best when using an egocentric strategy, whereas men are adept at using both strategies. For example, men used distal geometric cues to locate the hidden platform in a vMWT whereas women performed better when stable landmarks were available to aid relocation of the hidden platform (Sandstrom et al., 1998). Likewise, women given Euclidean-based instructions to navigate a university campus made more errors than men, and more errors than women who were given landmark-based navigation instructions (Saucier et al., 2002). Although a sex difference in strategy preference was not observed in a study by van Gerven et al. (2012), their findings support the notion that even when women choose an allocentric strategy they may not be as successful as men at using that strategy.

In addition to a reliable effect of sex on laboratory tests of spatial performance, sex differences also exist in everyday spatial behavior and cognition. Men report a preference for orientation-based (e.g., cardinal directions), whereas women report a preference for route-based (e.g., left-right turns) wayfinding strategies (e.g., Lawton, 1994). Men score lower than women on measures of environmental navigation-related anxiety (Bryant, 1982; Castelli, Corazzini, & Giuliano, 2008; Gabriel, Hong, Chandra, Lonborg, & Barkley, 2011; Lawton, 1994; Lawton & Kallai, 2002; Malinowski & Gillespie, 2001; and Schmitz, 1997). Higher scores by men indicate they have a greater self-reported environmental spatial ability (e.g., sense of direction) than women (e.g., Turano et al., 2009). Men also tend to have more video game experience than women (e.g., Astur et al., 1998; Lawton & Morrin, 1999; Moffat et al., 1998; Richardson & Collear, 2011; Schmitzer-Torbert, 2007; Terlecki et al., 2011; van Gerven et al., 2012; cf. Daugherty et al., 2014; Driscoll et al., 2005; Levy et al., 2005.

2. Present study

The general aim of this study was to compare navigation performance and self-reported navigation strategy by sex in a novel environment. Specifically, we hypothesized that better performance in our computerized maze would require allocentric encoding. Further, we predicted that men would outperform women and be more likely to report using strategies that could be classified as allocentric.

The secondary aim was to investigate the associations between virtual navigation and self-reported experiential (video game experience, spatial anxiety, wayfinding strategy, and sense of direction) or personality (competitiveness) dimensions. We hypothesized that navigation-related experiential variables, spatial anxiety, and competitiveness would differ by sex and relate to maze navigation outcomes. Specifically, we predicted that men would be more competitive and less anxious than women, and that men would score higher on measures of environmental spatial ability. We predicted that higher self-reported environmental spatial ability and competitiveness, and lower spatial anxiety, would correlate with better maze performance.

3. Method

3.1. Participants

Participants were 50 undergraduate college students (21 men; 29 women) who were compensated with extra credit for a course. The mean age of the sample was 22.06 (SD = 3.99) years. The average college educational attainment was commensurate with a junior level standing. 62.8% of the sample identified as White or Caucasian; 14% as Black or African American; 11.6% as Asian; 7% as Hispanic; and 4.7% as Native American.

3.2. Navigation tasks

All virtual environments were designed using Unreal Tournament 2003 and Unreal Editor software (Epic Games Inc., Rockville, MD, USA). Participants viewed all virtual assessments on a 27.5″ flat panel LCD monitor, and controlled their movement through the virtual environments with a joystick. Software automatically collected (x,y) path coordinates every 10 ms, which it used to calculate distance and create a diagram of the participants' movement paths.

The maze used in this study is similar but not identical to the one developed and used by Moffat, Elkins, and Resnick (2006) in a study of the functional neuroanatomical correlates of allocentric spatial navigation. Like the Moffat et al. (2006) study, our participants were instructed to actively explore a virtual maze and learn the location of six objects, the interconnections of the hallways, and the general layout of the maze such that they could draw a map of the environment if asked to do so. The recall test used in the present study is also similar to the recall test of Moffat et al. (2006). The present study added assessments of free-hand map drawing, object location memory, heading direction, and self-reported strategy.

Participants received training in a general practice environment to familiarize them with the interface and use of a joystick. During practice, participants were instructed to move from object to object in a large square room containing five objects, and to follow a long winding hallway until they reached a flag at the end.

The testing maze was a combination of interconnected hallways and small rooms, where there were six common objects placed