Gender Differences in Spatial Awareness in Immersive Virtual Environments: A Preliminary Investigation

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Abstract

This paper presents an experiment exploring gender differences in spatial navigation, memory performance and spatial awareness through a complex Virtual Environment (VE). The immersive simulation consisted of a radiosity-rendered space divided in four zones including a kitchen area, a dining area, an office area and a lounge area. The space was populated with objects consistent as well as inconsistent with each zone's context. The simulation was then displayed on a stereo head tracked Head Mounted Display. Participants were separated in two groups based on their gender. After being exposed to the VE, they completed an object-based memory recognition task. Participants also reported one of two states of awareness following each recognition response which reflected either the recollection of contextual detail or informed guesses. It was found that reported awareness states interacted with the context consistency of the objects: participants recollected more contextual detail when correctly identifying inconsistent objects compared to consistent objects. Furthermore, a clear gender difference was found with female participants correctly identifying objects in their correct location more often than the male participants.

CR Categories: I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction Techniques J.4 [Computer Applications]:Social and Behavioral Sciences—Psychology

Keywords: Perceptual Fidelity, Spatial Navigation, Spatial Awareness

1. Introduction

The effect of gender on spatial abilities and spatial performance inspired numerous studies carried out in real and Virtual Environments (VE). VEs are now becoming an increasingly popular alternative approach for research exploration of gender differences in spatial navigation. Investigation of gender differences in a variety of navigational tasks showed that spatial performance in a VE exploited "real life's" abilities [Moffat and Resnick 2002]. Robust gender differences in training effectiveness of VEs were also found [Ross et al. 2006]. Males showcase performance superiority while conducting spatial tasks such as navigating in virtual mazes and way finding [Lovden et al. 2007] in a novel environment using different types of cues or maps. Such superiority is reduced or follows dissimilar patterns according to the task requirements. For example, female participants responded faster in a 2D matrix navigation task than males when landmark instructions were provided; however, when the same participants participated in a recognition task, male participants recognized key elements involved in a previously viewed video of a real-world driving scene more accurately than female participants. [Bia et al. 2007]. Previous research has also revealed that there are no gender differences in the use of different spatial strategies based on either geometric or landmark information when navigating through virtual mazes such as water or radial arm mazes [Levy et al. 2005]. In spite of the premise that men have more experience with video games than women, thus, a male advantage may be possible in virtual spatial navigation, it seems that video game experience does not predict the success of spatial tasks [Chai and Jacobs 2009]. On the other hand interesting findings from earlier research [Desney et al. 2003] present specific benefits for females in spatial navigation with wider fields of view (FOV) on large displays.

A recent study proposed a cognitive map model integrated by two parallel map components that are constructed from two distinct classes of cues: directional cues and positional cues respectively [Jacobs and Schenk 2003]. In a target location experiment men were overall more accurate in estimating the target location. It was then concluded that gender differences influence navigation performance in humans. In addition, similar research investigated the effect of directional cues such as sky and slant but also positional such as trees on a hidden target memory test with cue removal. Men and women performance was impaired when directional and positional cues were removed respectively [Chai and Jacobs 2009]. Those findings supported previous reports that gender differences in spatial memory arise from the dissociation between a preferential reliance on directional cues in males and on position cues in females [Sandstrom et al. 1998].

Another study examined eye movements and physiological measures of the pupil in order to compare visual scanning of spatial orientation. The eye movement data provided novel insight into differences in navigational strategies between the genders [Mueller et al. 2008]. It was concluded that while women employ a strategy based on memory, males seem to use spatial relations in order to navigate.

The experimental methodology presented in this paper focuses upon exploring the effect of gender (male vs female) on object-location recognition memory and its associated awareness states while immersed in a radiosity-rendered synthetic simulation of a complex scene. The space was populated by objects consistent as well as inconsistent with each zone's context, displayed on a head-tracked, stereo-capable HMD. The main premise of this work is that memory performance is an imperfect reflection of the cognitive activity that underlies performance on memory tasks. A secondary goal was to investigate the effect of varied scene context on object recognition tasks post-VE exposure in relation to eye tracking data.

2. Memory Awareness States and Schemata

In the process of acquiring a new knowledge domain, visual or non-visual, information retained is open to a number of different states. Accurate recognition memory can be supported by: a specific recollection of a mental image or prior experience (Type A); reliance on a general sense of knowing with little or no recollection of the source of this sense (Type B) [McCabe and Geraci 2009]. Tulving 1992 provided the first demonstration that these responses can be made in a memory test, item by item out of a set of memory recall questions, to report awareness states as well. Object recognition studies in VE simulations have demonstrated that low interaction fidelity interfaces, such as the use of a mouse compared to head tracking, as well as low visual fidelity, such as flat-shaded rendering compared to radiosity rendering, resulted in a higher proportion of correct memories that are associated with those vivid visual experiences of a 'remember' awareness state [Mania et al. 2003; Mania et al. 2006; Mania et al. 2010]. As a result of these studies, a tentative claim was made that those immersive environments that are distinctive because of their variation from 'real' representing low interaction or visual fidelity recruit more attentional resources. This additional attentional processing may bring about a change in participants' subjective experiences of 'remembering' when they later recall the environment, leading to more vivid mental experiences. The present research builds upon this pattern of results and its possible explanations.

Moreover, it has been shown that memory performance is frequently influenced by context-based expectations (or 'schemas') which aid retrieval of information in a memory task [Minsky 1975]. A schema can be defined as a model of the world based on past experience which can be used as a basis of remembering events and provides a framework for retrieving specific facts. In terms of real world scenes, schemas represent the general context of a scene such as 'office', 'theatre' etc. and facilitates memory for the objects in a given context according to their general association with that schema in place.

The experimental study presented here investigates the effect of gender on both the accuracy and the phenomenological aspects of object memories acquired in a VE.

3. Materials and Methods

3.1 Participants and Apparatus

The participants of the experiment were recruited from the postgraduate population of the Technical University of Crete. Two groups were balanced for gender and age and were naive as to the purpose of the experiment. 40 males and 29 females participated to the experiment. All participants had normal or corrected to normal vision and no one reported neuro-motor or stereovision impairment. The test VE was set up in a studio on campus, which was darkened to remove any periphery disturbance during the exposure.

The VE was presented in stereo at SXGA resolution on an NVIS nVisor SX111 Head Mounted Display with a Field-of-View comprising 102 degrees horizontal and 64 degrees vertical. An InterSense InertiaCube3, three degrees of freedom head tracker was utilized for rotation. The viewpoint was set in the middle of the virtual room and navigation was restricted to 360 degrees circle around that viewpoint (yaw) and vertically (pitch) into -20^0 downwards and $+33^0$ upwards from eye's height of the pawn. Participants sat on a swivel chair during exposure.

3.2 Visual Content

The displayed scene was implemented with the Unreal Development Kit. The VE represented a six by six meters square room as shown in Figure 1. The radiosity-rendered space was divided in four zones including a dining area, a kitchen, an office area and a lounge area located on northeast, northwest, southwest and southeast side of the house, respectively. The space was populated by objects consistent as well as inconsistent with each zone's context. Three consistent objects and three inconsistent objects populated each zone resulting in twenty-four objects located in the scene overall, six in each zone.

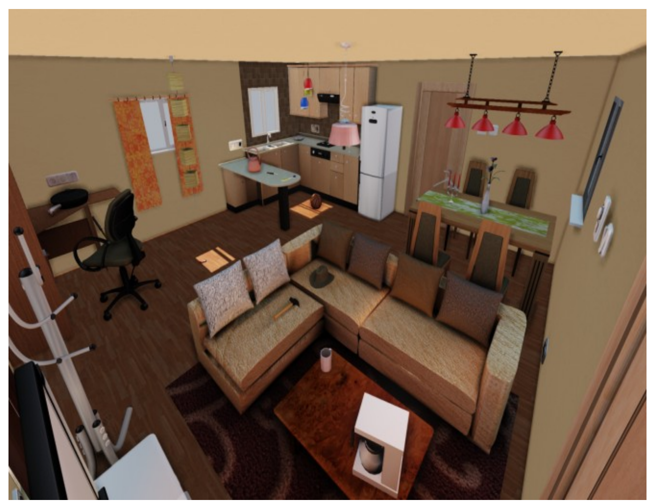

Figure 1: The experimental scene (side-view).

The between-subjects factor was 'Male' vs 'Female'. The within-subjects factor was 'object type' comprised of two levels: 'consistent' and 'inconsistent'. According to the group that they were assigned to, participants completed a memory recognition task including self-report of spatial awareness states and confidence rating for each recognition. The list of objects was assembled based on an initial pilot study which explored which objects were expected to be found in each area and which were not [Zotos et al. 2009].

3.3 Experimental Procedure

Participants were instructed to observe and navigate around the VE for 120seconds. The exposure time was defined after a series of pilot studies which aimed to identify an exposure time where no floor or ceiling effects were observed, e.g. the task being too easy or too difficult. After the exposure each participant was given a four-paged leaflet; each page contained one of the four zones of the house respectively with items removed. The on-line questionnaire was also divided in four pages, each one representing the four areas. Participants were required to select which object they think they saw during the exposure in each position as well as one out of five levels of confidence (no confidence to certainty), and also two choices of awareness states: Type A and Type B. A recognition list was devised including a list of objects per scene zone. Each zone included in random order the six present objects as well as six absent. The four lists included a total of 48 objects. Prior to the memory recognition task, awareness states were explained to the participants in the following terms:

"TYPE A means that you can recall specific details. For example, you can visualize clearly the object in the room in your head, in that particular location."

"TYPE B means that you just 'know' the correct answer and the alternative you have selected just 'stood out' from the choices available."

4. Results of Pilot Studies

The accuracy of memory was measured by counting the number of correct positions of objects (out of a possible 24). Prior probabilities were obtained by calculating the proportions of correct answers falling in each of the three memory awareness categories for each participant.

Total Correct

The total number of objects that were identified in the correct location was counted for each participant (Table 1).

	Males (n=40)		Females (n=29)	
	Consistent	**Inconsistent**	**Consistent**	**Inconsistent**
Total correct (out of 24)	5.15 (1.75)	7.10 (2.35)	6.97 (1.68)	8.41 (1.66)

Table 1: Number of correct responses and standard deviations

Correct recognition scores were analyzed using a 2x2 mixed analysis of variance (ANOVA) with gender (male, female) entered as a between subjects variable and the context consistency of the objects (consistent, inconsistent) entered as a within subjects variable. A large main effect of gender was identified (F(1,67)=16.65, p<0.001, partial eta-squared=0.20). Female participants correctly recognised more objects in their locations (Mean = 7.69) compared to the male participants (Mean = 6.13). A large main effect of context consistency was also identified (F(1,67)=40.77,p<0.001, partial eta-squared=0.38). More inconsistent objects were correctly recognised in their locations (Mean = 7.76) than consistent objects (Mean = 6.05). No interaction between gender and context consistency was revealed (F(1,67)=0.89, p>.05).

Awareness states

The proportion of correct responses assigned to each awareness state are displayed in Table 2.

	Males (n=40)		Females (n=29)	
	Consistent	**Inconsistent**	**Consistent**	**Inconsistent**
Type A (remember)	.25 (.11)	.43 (.15)	.23 (.11)	.39 (.12)
Type B (know)	.17 (.13)	.14 (.15)	.22 (.10)	.16 (.13)

Table 2: Proportion of correct responses and standard deviations

The proportion of correct responses (displayed in Table 2) was analyzed with separate 2x2 mixed ANOVAs for each awareness state. Gender (male, female) was entered as a between subjects variable, with the context consistency of the objects (consistent, inconsistent) entered as a within subjects variable. A minimum alpha level of .05 was used throughout the analyses to judge a reliable difference.

No reliable main effects of gender were found for either Memory A awareness states (F(1,67)=1.81, p>.05) or Memory B awareness states (F(1,67)=1.49, p>.05). Similarly, no interactions were found between gender and the context consistency of the objects for either Memory A awareness states (F(1,67)=0.22, p>.05) or Memory B awareness states (F(1,67)=0.52, p>.05). However, there was a large main effect of context consistency on Memory A awareness states (F(1,67)=66.30, p<.001, partial eta-squared = 0.50) and a small main effect of context consistency on Memory B awareness states (F(1,67)=4.81, p<.05, partial eta-squared = 0.067). When objects were correctly recognized in the correct location, a higher proportion of correct responses were reported as Memory A awareness state (remember) with inconsistent objects (Mean = .41) compared to consistent objects (Mean = .24). Conversely, participants reported a higher proportion of correct responses were reported as Memory B awareness states with consistent objects (Mean = .19) compared to inconsistent objects (Mean = .15).

Consideration was given to the unequal number of males and females within the analyses. The analyses were therefore repeated following the removal of the last 11 male participants tested, to create equal group sizes. The exact same pattern of results was (N=29).

5. Discussion

The analyses highlighted two important effects. The first was a clear influence of the context consistency of objects on the type of memorial experience that participants had. Vivid and contextually detailed memorial experiences were reported more often for objects that were inconsistent with the context of the scene (e.g. a toothbrush in the kitchen area). Conversely less contextually detailed feelings of knowing were reported more often for objects that were consistent with the context of the scene (e.g. a book in the office area). This indicates that context consistency has an important influence on the memorial experiences of users in such environments. Secondly, there was a clear influence of gender on the number of objects correctly recognised in their correct location. Female participants outperformed male participants through correctly recognising more of the objects in the correct locations. The gender of users is therefore an important consideration in terms of memory for objects and their locations within such environments. Future work will include the analysis of eye tracking data acquired.

Acknowledgements

This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Heracleitus II. Investing in knowledge society through the European Social Fund. Project code: 80641

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