Fidelity based on the Schema Memory Theory: An Experimental Study

Katerina Mania Andy Robinson
School of Engineering and Information Technology
University of Sussex, UK
k.mania@sussex.ac.uk

Summary

A between groups experiment was carried out to explore the effect of rendering quality on memory recall and its relationship with the sense of presence. The study presented here incorporates a fundamental theory drawn from traditional memory research (schema activation) but adapted to fit computer graphics experimentation. This theory is based on the basic assumption that an individual's prior experience will influence how he or she perceives, comprehends and remembers new information. This fundamental premise is built into an experimental methodology that assesses the fidelity of a VE simulation by linking this assessment with cognitive processes that incorporate newly perceived spatial information with older (semantic) perceptions of space. The computer graphics simulation is displayed on a Head Mounted Display utilising stereo imagery and head tracking. 36 participants across three conditions of varied rendering quality of the same space were exposed to the computer graphics environment and completed a memory task. Schema-based information related to memory for places, or room schema was 'activated' within a VE (triggered by the accurate recall of absent 'inferred' objects) similarly as it is shown to behave in traditional memory research for a real-world environment. Rendering quality did not prove to make substantial difference to the level of recall for various of the objects included in the study.

Keywords: Virtual Environments, Fidelity, Memory.

1 Introduction

Virtual environment (VE) technology is an advancing medium that allows its users to interact with computer-generated three-dimensional worlds. In VE systems, users could receive multi-sensory stimuli (i.e., visual, auditory, haptic, etc.) which respond to users' reactions by simulating a real-world task situation (for instance, using head tracking) and are intended to provide a sensation of natural interaction with the VE. Robust metrics are essential in order to assess the fidelity of VE implementations for simulation and training comprising of computer graphics imagery, display technologies and 3D interaction metaphors across a range of application fields. Technological characteristics such as resolution, field-of-view, latency, etc. as well as task performance measures are significant technological facets related to the fidelity of a VE system.

Transfer of training experimental studies focus on task performance efficiency comparisons but are often limited to a specific application and in many cases on arbitrary selected tasks. Without a formal methodological framework, they could reveal contradictory results. Another common approach is to take a cross-application construct, such as the sense of 'presence' and assess the effectiveness of a VE, or aspects of a VE according to its success in enhancing presence. There is a widespread belief that presence should somehow improve task performance, although this has never been verified or indeed reasons given as to why this should be the case (Stanney et al., 1998).

The research presented here incorporates a fundamental theory drawn from traditional memory research (schema activation theories) but adapted to fit computer graphics experimentation based on the basic assumption that an individual's prior experience will influence how he or she perceives, comprehends and remembers new information. This fundamental premise is built into an experimental methodology that assesses the fidelity of a VE simulation by linking this assessment with cognitive processes that incorporate newly perceived spatial information with older (semantic) perceptions of space.

2 Background

The utility of VEs for any applications for which they are being proposed is predicated upon the accuracy of the spatial representation formed in the VE. Spatial memory tasks, therefore, are often incorporated in benchmarking processes when assessing the usability and fidelity of a VE simulation, since spatial awareness is crucial for human performance efficiency at any task.

A central research issue for VE applications for training is how participants mentally represent an interactive computer graphics world and how their recognition and memory of such worlds correspond to actual conditions. The means of presenting spatial information to trainees range from traditional maps, blueprints, verbal briefings to VE displays. Related research commonly investigates the suitability of VE systems as effective training mediums in comparison to more traditional means of training such as the ones mentioned above (Mania et al, 2001). Experimental post exposure methodologies for spatial recall investigation range from questionnaires to asking participants to draw sketches and maps of a space they experienced. A more direct way of spatial testing requires participants to apply their knowledge of a space, acquired though training across varied technological conditions so as to navigate effectively the real world space represented (Darken, R.P., Peterson, B., 2001)

In spatial awareness/navigation studies, presence assessments are usually not central; presence is assessed via the use of a questionnaire. The proposed research is going to attempt to link the notion of presence with the methodology employed based on schema activation and memory.

3 Role of Schemata in Memory for Places

This research employs well-established theories concerning schema activation and memory. Schema theories, according to memory research, propose that perception, language comprehension and memory are processes that involve the interaction of new (episodic) information with old, schema-based information (preconceptions about what *should* be there, even if it is not). The basic assumption is that an individual's prior experience will influence how he or she perceives, comprehends and remembers new information. Information slots which have not been filled with perceptual information, are filled by default assignments based on stereotypic expectations from past experience (Brewer & Treyens, 1981). Kuipers' (1975) hypothetical example of room perception illustrates default assignments: if a quick visual scan of a room indicates that there is a clock on the wall, hands may be assigned to it at a memory test, even though this particular clock does not have hands. Inferences of absent elements (or objects) of a space are said to occur when memory recall after exposure to a space contains information that was not actually there. This integration model makes no claim about the degree of integration; the integration may be so complete that a human cannot distinguish the episodic info (spatial elements that were actually there) from the schema-based info (spatial elements that could be there and fit into a place, for instance into an office). The two types of information may remain distinct.

There are quite a few, fundamentally different ways in which schemata might influence memory performance. Schemata could determine which objects are looked at and encoded into memory or they could provide schema-based information that becomes integrated with episodic information. They could also guide the retrieval process and also determine what information is to be communicated at output (Brewer & Treyens, 1981). It has been generally shown that memory performance is frequently influenced by schema-based expectations. Relevant research has shown that an *activated schema* can aid retrieval of information in a recall task. When and under which circumstances (or which 'minimal cues') schema activation occurs is a challenging research question.

This paper is going to present the methodology and the results of a study that explores memory and schema activation after exposure to a computer graphics environment presented in three varied levels of rendering quality. The task employed is a memory task and the experimental design includes motion sickness and presence assessments.

4 Experimental Methodology

4.1 Experimental Design

The experimental design follows the rationale of the Brewer & Treyens (1981) study. Three groups of 12 participants were recruited to participate in this study, from the University of Sussex postgraduate population. A between-subject design was utilised balancing groups for age and gender. Participants in all conditions were naive as to the purpose of the experiment. Participants had either normal or corrected-to-normal vision. According to the group they were assigned to, participants completed the same memory task in one of the following conditions:

1) Using a high quality, interactive radiosity computer graphics simulation of an office on a stereo head-tracked HMD; referred to as the **HMD high condition** (50,000 polygons).
2) Using a mid quality, interactive radiosity computer graphics simulation of the same office on a stereo head-tracked HMD; referred to as the **HMD mid condition** (30,000 polygons).
3) Using a low quality, interactive flat shaded computer graphics simulation of the same office on a stereo head-tracked HMD; referred to as the **HMD low condition** (24,000 polygons).

Each environment varied considerably with regard to shading (Figure 1). The frame rate was constant across conditions. Since the environment was presented in stereo, the IPD (interpupilary distance) was measured for each participant before exposure and the application presented was subsequently adjusted, accordingly. The exposure time was 45 seconds and was kept the same for every condition.

4.2 Materials and Procedures

4.2.1 Memory Recall Task

The participants completed a memory task, a presence questionnaire and an SSQ questionnaire before and after exposure. Their navigation and idle time were monitored using special software.

The experimental computer graphics space consisted of a graduate student's office. The objects included in the memory recall questionnaire fell on three categories (but in random order in the questionnaire): Room frame objects that were present (walls, floor, ceiling, etc.), high-schema expectancy objects present and absent (books, telephone, pens, etc.) and non-schema objects present and absent (skull, wrench, etc.). The collection of these objects was largely based on a previous study by Brewer & Treyens (1981) on a similar space. Participants were given 45 seconds to explore the space. They were then asked to indicate on

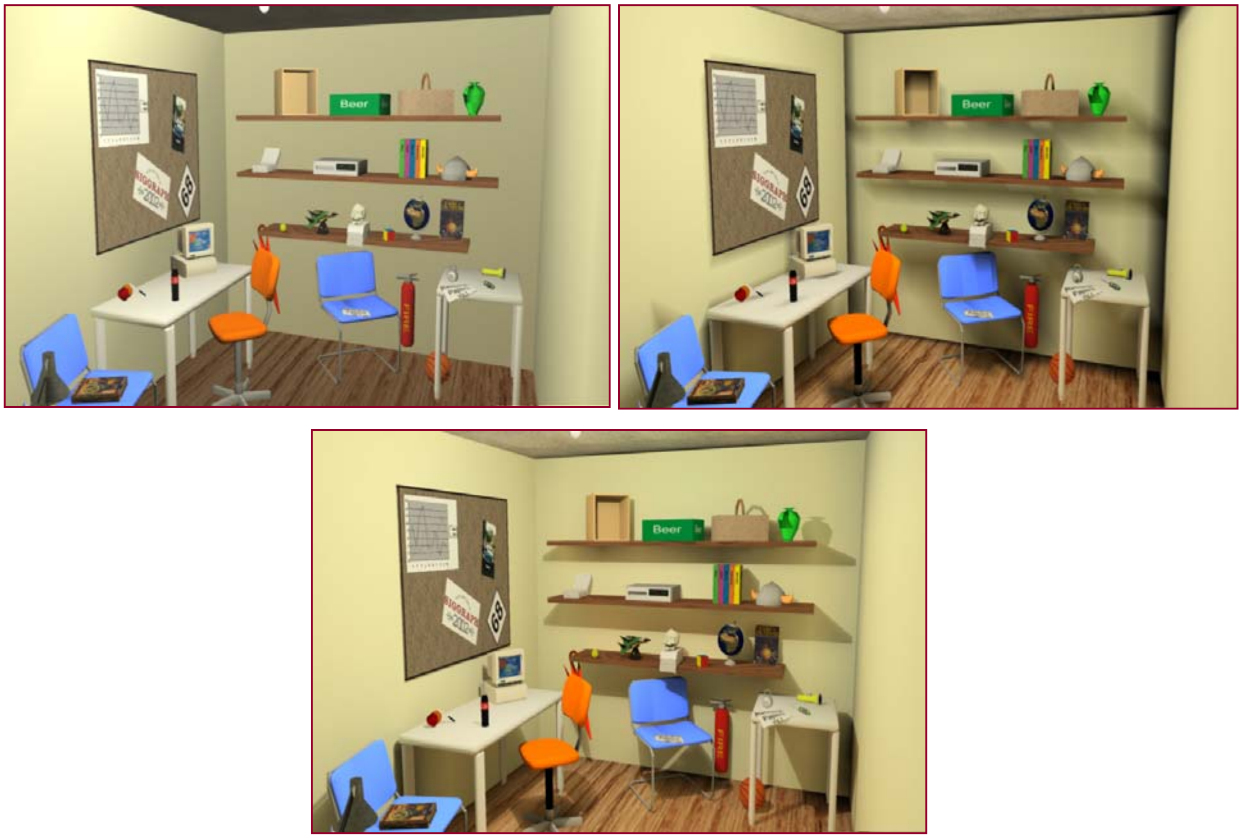

Figure 1: Flat-shaded (left), radiosity mid-quality environment (right) and high-quality environment (centre).

a scale of 1 to 5 how strongly they believed each object mentioned in the questionnaire was present in the environment to which they had been exposed, with 1 being positively not present and 5 being positively present. There were a total of 90 objects in the questionnaire.

The room where the experiment was taking place was kept dark during exposure. The amount of time between exposure and memory recall was the same across conditions. Participants were led to believe that this was just a test phase of the main experiment.

5 Results and Conclusions

Results are going to be summarised here. The significance of inter-group variation between recalled items was calculated. The results are preliminary analysed using ANOVA (Analysis of Variance). Taking into consideration the nature of the data involved (ordinal data), more detailed analysis will follow. The variation in recall for each of the three object types was examined across conditions.

Employing a similar method to that used by Brewer & Treyens (1981), the average recall score was obtained for each object. ANOVA did not show any significant difference across conditions for the schema-based objects that were present. It could be, therefore, assumed that increasing the level of rendering quality has no impact on accurate recall of objects that are expected to be 'found' in such an environment and which were indeed present. ANOVA did reveal a significant difference with regard to certain of the objects that had high-schema expectancy but were absent, for instance, for books between the high quality and the low quality environment and scissors between the mid and the low quality environment. ANOVA did not also show any significant difference across conditions for the absent non-schema based objects.

Most importantly, it is important to analyse the overall schema activation within the VE and compare results acquired in a synthetic environment with relevant conclusions regarding schema in memory research. The results indicate that, in a similar way to the results by Brewer & Treyens (1981) within a real-world environment, schema activation is also triggered within a VE. Certain objects, for instance, with high schema expectancy but which were not present in the room received higher average recall scores than certain objects with similar schema expectancy that were present. As observed by Brewer, books received the highest recall frequency of the non-present but schema relevant objects with a combined average of 3.9 compared to 2.8 for the table with a kettle which were two of the schema objects present. Also, objects such as the telephone and pens that were absent received high recall scores. The recall of schema objects which were absent from the room (such as books) can only be accounted to schema-based knowledge about offices in general becoming integrated with episodic information. The much lower recall frequency of non-schema objects that were absent must be due to the lack of a schema frame supporting accurate recall. The conclusion that could maybe drawn from this is that schema-based information related to memory for places, or room schema is 'activated' within a VE (triggered by the accurate recall of absent 'inferred' objects) similarly as it is shown to behave in the study by Brewer & Treyens (1981) for a real-world environment. Rendering quality did not prove to make substantial difference to the level of recall for most of the objects, therefore, the mininal 'cue' or requirement for schema activation in the context of the present study, could be just plain visibility of these objects.

Presence, assessed by using the SUS questionnaire (Slater, Usoh & Steed, 1995) did not prove to be significantly different across conditions. Prof. Mel Slater in a recent keynote argued that 'if we act as if we are there, it seems that our brain cannot distinguish between really 'being' there and being there' (Slater, 2002). He concluded saying that very simple cues are required to trigger presence and our brain together with our perceptual mechanisms fill in the gaps. If the 'scientific study of presence is the exploration of the minimal cues necessary to act as if we are there' (Slater, 2002) which could be extended to 'perceive information as if we are there', then the study presented in this paper tried to identify the minimal cues necessary for schema activation in a VE, employing a validated methodology. For this study, the minimal cue necessary for memory recall of various objects was just visibility. Further studies will introduce the use of an eye tracker.

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