Rendering Quality and User Cognition: An Experimental Study

Summary

A between groups experiment was carried out to explore the effect of rendering quality on object-based memory recall, memory awareness states and presence. The experimental space, consisting of two interconnected rooms which included primitive objects (boxes, sphere, pyramids) was rendered either flat-shaded or using radiosity. The computer graphics simulations were displayed on a Head Mounted Display utilising stereo imagery and head tracking. 18 participants across two conditions of varied rendering quality of the same space were exposed to each computer graphics environment and completed a memory task. After exposure, participants described how they completed spatial recollections by selecting one of four choices of awareness states after retrieval. These reflected the level of visual mental imagery involved during retrieval, the familiarity of the recollection and also included guesses, even if informed. Experimental results revealed variations in the distribution of participants' awareness states across conditions while, task performance failed to reveal any. The general premise of this research focuses on *'how'* tasks are achieved, rather than only on *'what'* is achieved. Interestingly, results revealed a higher proportion of 'remember' correct responses associated with visual mental imagery associated to the flat-shaded condition while presence responses were not significantly different across conditions. This finding follows similar findings in two previous studies when the less 'naturalistic' interaction interface was associated with a higher proportion of visually-induced recollections, while presence responses measured via a standard questionnaire were not affected by the quality of the computer graphics rendering.

1 Introduction

The utility of Virtual Environments (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 of 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. (Mania, Troscianko, Hawkes & Chalmers, 2003).

This investigation focuses on the effect of different viewing conditions (perception of objects in a flat-shaded computer graphics rendering setting versus perception of the same space rendered using a photorealistic rendering algorithm such as radiosity) on observers' attributions regarding object-location memory. Accuracy of performance per se is an imperfect reflection of the cognitive activity that underlies performance in memory tasks (Conway et al., 1997). Accurate memory can be supported by either a recollection of prior specific experience (remembering) or reliance on a general sense of knowing with little or no recollection of the source of this sense (knowing) including familiarity and guesses even if informed. Presence assessments are not central to this investigation; presence is assessed via

the use of a standard questionnaire (Slater et al., 1998). However, the results reported here follow the same pattern as in two previous large studies focusing on interaction interfaces (Mania & Chalmers, 2001, Mania et al., 2003) and could have implications on the study of presence.

2 Experimental Methodology

Two groups of 9 participants were recruited to participate in this study. A between-subject design was utilised balancing groups for age and gender. 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 a space on a stereo head-tracked HMD; referred to as the **HMD radiosity condition.**
2) 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 flat-shaded condition.**

Each environment varied considerably with regard to shadows. The flat-shaded environment did not include any, however, the radiosity environment was rendered photorealistically. 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 2.2 minutes. Idle time and direction of idle time as well as navigation was monitored via software during exposure.

The two groups of participants were asked to fill in the same set of questionnaires. This set included the Simulator Sickness Questionnaire (Kennedy, Lane, Berbaum & Lilienthal, 1993) before and after exposure, the memory task and memory awareness states questionnaire and the presence questionnaire (Slater, Steed, McCarthy & Maringelli, 1998).

The memory recall questionnaire was designed to test the participants' memory recall of the positions and geometric shape of the 20 objects scattered the experimental space. Stylistic spatial diagrams were administered together with the task questionnaire which consisted of 20 multiple-choice questions representing the 20 objects in the scene. Every question included three possible answers (box, sphere or pyramid) and a confidence scale with five possible states: No confidence to Certain. Every question also included an awareness states report for every recollection, based on the memory awareness methodology offering four choices: Remember, Know, Familiar or Guess. Prior to filling out the core of the task questionnaire, participants were given instructions designed to explain what the memory awareness states depicted summarised here:
- REMEMBER means that you can visualise clearly the object in the room in your head, in that particular location.
- KNOW means that you just 'know' the correct answer (it stood out) without visualising the specific image or information in your mind.
- FAMILIAR means that it may seem or feel more familiar than any of the other alternatives.
- GUESS means that you may not remember, know, or feel that the choice was familiar.

The computer graphics application was displayed on a head tracked Kaiser Pro-View 30 HMD. Navigation was restricted based on collision detection. Translational movement was allowed via the use of a wireless navigation device. The display resolution was 640*480 (HMD maximum resolution) across technological conditions.

3 Results and Discussion

Awareness state data were initially represented as prior probabilities. Although this notation does not follow the Bayesian probability theory principles for 'prior' probabilities, it is adopted as such following the Koriat & Goldsmith, 1994 as well as Conway, Gardiner, Perfect, Anderson & Cohen, 1997. Prior probabilities are obtained by calculating the proportions of correct answers falling in each of the four memory awareness categories for each participant. Generally, prior probabilities reflect on the following: Given that the response of a participant is correct, what is the probability that the participant has chosen a particular state on that question? The participants completed the memory task including confidence and awareness responses across the two conditions (flat-shaded and radiosity). The memory recall scores for the initial task and retest, the confidence scores as well as the prior probabilities derived from the memory awareness states dataset were analysed using **AN**alysis of **VA**riance (ANOVA). Significance decisions involve rejecting or retaining the null hypothesis (which claims that groups are identical). The null hypothesis is rejected when the probability that a result occurring under it is less than .05 (Coolican, 1999).

The total number of objects that were correctly located and identified was counted for each participant. The memory performance measures were subjected to an ANOVA analysis that did not reveal a significant effect of viewing condition. ANOVA analysis conducted on the prior probabilities revealed a significant higher proportion of correct 'remember' responses associated with the HMD flat-shaded condition. 'Remember' responses reflect recollections linked with visual mental imagery. However, correlation analysis revealed a significant positive correlation between confidence scores and correct 'know' responses for the flat shaded condition as well as a significant negative correlation between confidence scores and correct 'guess' responses for this condition. Additionally, correlation analysis revealed a significant positive correlation between memory performance scores as well as confidence scores and correct 'remember' responses for the radiosity condition. The flat-shaded environment provoked more correct 'visually-induced' recollections, although interestingly, the highest confidence scores were associated with correct 'know' responses. Moreover, confidence scores and task performance scores were positively correlated with the 'remember' awareness state for the photorealistic, radiosity condition.

There was no effect of condition related to the presence dataset as measured by the SUS questionnaire (Slater et al., 1998). The measuring device (questionnaire) either failed to pick up the difference across conditions or there was not any difference across conditions as assessed by the questionnaire. In previous studies (Mania & Chalmers, 2001, Mania et al. 2003), the utilisation of a viewing method such as the HMD together with an 'unreal' motor response such as the mouse, appeared to have prevented participants employing non-visually induced recollections and resulted in a larger distribution of correct responses assigned to the 'remember' awareness state. A similar results was identified in the study presented here, applied to rendering quality rather than to the actual interaction interface. Therefore, by

decreasing the degree of 'reality' of the motor response or the rendering, participants - paradoxically- adopted visually induced recollections. Achieving high fidelity could incorporate the need for similar awareness states between a real-world task situation and its computer graphics simulation. Something less 'real', therefore, less computationally expensive but more demanding because of its novelty or difference with reality may restore a more 'naturalistic' or desirable awareness state. How the degree of 'reality' of the motor response or rendering algorithm relate to presence assessments (if at all) remains an open research question.

References

Conway, M.A., Gardiner, J.M., Perfect, T.J., Anderson, S.J., Cohen, G.M. Changes in memory Awareness during Learning: The Acquisition of Knowledge by Psychology Undergraduates. *Journal of Experimental Psychology, Vol. 126, No4*, 393-413, 1997.

Coolican, H. (1999). *Research Methods and Statistics in Psychology*, 3rd edition. Hodder & Stoughton.

Koriat, A., Goldsmith, M. (1994). Memory in Naturalistic and Laboratory Contexts: Distinguishing the accuracy oriented and quantity oriented approaches to memory assessment. *Journal of Experimental Psychology: General*, 123, 297-315.

Kennedy, R.S., Lane, N.E., Berbaum, K.S., Lilienthal, M.G. (1993). Simulator Sickness Questionnaire: An Enhanced method for Quantifying Simulator Sickness. *The International Journal of Aviation Psychology*, 3(3), 203-220.

Mania, K., Chalmers, A. (2001). The Effects of Levels of Immersion on Presence and Memory in Virtual Environments: A Reality Centred Approach. *Cyberpsychology & Behavior*, 4(2), 247-264.

Mania, K., Troscianko, T., Hawkes, R., Chalmers, A. (2003). Fidelity Metrics for Virtual Environment Simulations based on Human Judgments of Spatial Memory Awareness States. *Presence, Teleoperators and Virtual Environments*, 12(3), 296-310. MIT Press.

Slater, M., Steed, A., McCarthy, J., Maringelli, F. (1998). The Influence of Body Movement on Subjective Presence in Virtual Environments. *Human Factors: Journal of the Human Factors Society,* 40(3), 469-477.

Stanney, K.M., Salvendy, G. et al. (1998). Aftereffects and Sense of Presence in Virtual Environments: Formulation of a research and development agenda. Report sponsored by the Life Sciences Division at NASA Headquarters. *International Journal of Human-Computer Interaction*, 10(2), 135-187.