Presence predicts false memories of virtual environment content

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Abstract

False memories can be created by a simple priming manipulation (the Deese-Roediger-McDermott procedure). This phenomenon operates via the strong associative character of declarative memory. If it is true that that content knowledge plays an important role in presence (As some have argued), then a presence experience could prime a subject and create false memories. We tested this notion by repeatedly exposing 47 subjects to a themed VE, and after a 72 hour delay, testing their recall of VE content. As predicted, subjects tended to have higher false memory rates (of VE content) than chance levels for moderately specific false memory items, and lower than chance level rates of false memory for highly specific items. Furthermore, engagement and naturalness (as measured with the ITC-SOPI) predicted false memory rates. These findings support the notion that subjects' semantic knowledge plays a role in the presence experience.

Keywords--- **Presence, Content, Cognition, Memory, Theory.**

1. Introduction

1.1 Presence and memory in virtual environments

The role of human memory in the presence experience is not well understood. While it is common to find extensive reference to attention and perceptual processes in the literature (see for instance [1]), memory receives little attention. Some theoretical work has been done on working memory [2], but declarative memory remains largely unexplored. One interesting empirical study tested episodic and semantic recall under varying immersion conditions, and found that presence was not a predictor of recall [3]. However, no mechanism was proposed for the independence between presence and memory. Indeed, there is an increasing body of work which argues the opposite – that declarative memory (often couched in terms of 'content knowledge') plays a central role in the experience. Wirth *et al*. [4] have argued that a subject's content knowledge can be a factor in directing attention during presence. From an empirical perspective, some interesting evidence exists that the degree of knowledge a subject has about the content of the VE can affect their experiences in complex ways [5]. Nonetheless, no extant model of presence contains an explicit role for declarative memory in the presence experience, and many of the more interesting effects of declarative memory, such as priming and false memories, have not been explored in relation to presence.

1.2 False memories and the Deese-Roediger-McDermott (DRM) procedure

A false memory is the recall of information not experienced by the subject [6], and they are generally indistinguishable from real memories by the subject [7]. Substantial research into this phenomenon indicates that false memories are common, occurring due to the associative nature of semantic memory [7, 8]. The standard method for testing false memory effects is the Deese-Roediger-McDermott (DRM) procedure [8]. In a DRM study, subjects are given word lists to memorize, and after a delay are given a simple recognition test. However, the memorized word lists are constructed such that each has a strong semantic connection to some concept (e.g. hot, snow, warm, winter, ice, wet), and the words in the recognition test are manipulated to create four categories: words which appeared in the original lists, words which did not appear in the original lists and are unrelated to them, words which did not appear in the original lists and are weakly related to them, and finally, words which did not appear in the original lists and are strongly related to them [8]. Numerous studies show an interesting effect for those words which did not appear in the original lists: subjects were unlikely to recognize the unrelated words from appearing in the lists (as one would expect, as they were indeed not in the lists), but were somewhat likely to recognize the weakly related words, and highly likely to recognize the strongly related words (some studies show an average recognition rate for this category as high as 80%) [9].

False memories are thought to operate by the associative retrieval of concepts in declarative memory. Closely related concepts can cue each other for easy retrieval (a phenomenon known as semantic priming [10]). During the word list learning phase of the DRM procedure, the close association of the words in the lists primes other closely related concepts [7]. At recognition time, the unrelated words have not been primed by the learning task, so the probability of false recognition is low, but the related words will have been primed, and therefore have a high probability of being recognized as belonging to the original word lists [8].

1.4 Possible DRM effects in virtual environments

Presence is an interesting variable in considering possible DRM effects in VEs. Presence has been shown to have a semantic information component – it shows some semantic priming effects [5, 11], and also interacts with the degree of knowledge or preference for semantic domains [5, 12]. It is therefore likely that a VE can act to prime particular concepts, and thereby produce a DRM effect on subsequent recognition tasks, particularly if the VE has a strong semantic theme [5]. This is significant, because certain types of VEs are meant to impart information (such as educational systems and virtual museums), and if these systems create false memories, it would significantly reduce information transfer and educational benefits. Similarly, systems which impart information incidentally (such as computer games based on historical content) may also lead to false memories of the content later (an effect could disperse propaganda by means of a VE). Furthermore, McCabe *et al* found that focusing attention on the DRM word lists increased some types of false memory [9]. Thus, VEs which attract more attention (such as computer games) may produce these effects more intensely.

1.5 Predictions for the current study

The current study aimed to apply the DRM procedure to VEs, by using the VE experience as the priming manipulation, and recognition questions about the VE content as the test of false memory. We predict that subjects will have false memories of VE content, particularly for false memory questions which seem plausible and are strongly related to the VE content [7]. Furthermore, we predict that the probability of experiencing a false memory will be higher for subjects which experience more presence, in line with the findings that presence involves a substantial degree of semantic processing discussed in 1.4 above.

2. Procedure

2.1 Sample and design

A total of 47 subjects participated (19 women and 28 men; Age M = 19.93, S = 1.83). The aim of the study was to examine the rate of false memories during presence; however we were also interested in determining if focusing attention on the VE content would affect this rate, as suggested by McCabe *et al.* [9]. We therefore randomly divided our sample into two groups, both of which would experience the same VE three times to ensure they have the opportunity to properly encode the content. The experiment group was given a short set of VE content questions immediately after the experience; the knowledge that they would be tested on VE content after the experience should, we thought, focus their attention on the VE content. The control group was not given any intervention between sessions. The procedure for each of the two groups was:

Control group:

- Day 1: VE experience 1, followed by ITC-SOPI measure; 24 hour delay till next session
- Day 2: VE experience 2, followed by SUS measure [13] (this measure was given only as a filler and not analyzed); 24 hour delay till next session
- Day 3: VE experience 3, followed by ITC-SOPI measure
- 72 hour delay
- Day 4: False memory questionnaire, followed by ITC-SOPI measure of VE experience 3.

Experimental group:

- Day 1: VE experience 1, followed by ITC-SOPI measure, followed by memory questions; 24 hour delay till next session
- Day 2: VE experience 2, followed by SUS measure[13], followed by memory questions; 24 hour delay till next session
- Day 3: VE experience 3, followed by ITC-SOPI measure
- 72 hour delay
- Day 4: False memory questionnaire, followed by ITC-SOPI measure of VE experience 3.

This procedure follows the DRM procedure, but we increased the delay to 72 hours, in order to evaluate longer term effects, as might occur in applied settings. It should be noted that all subjects were kept unaware of the existence of false memory questions during the final session. The final ITC-SOPI measure (after the 72 hour delay) asked subjects to respond with respect to the experience of the third day. The three VE experiences took place in the same VE (see 2.2.1 below), but had three slightly different tasks, the order of which was counterbalanced. Similarly, the two sets of memory questions administered to the experimental group were counterbalanced to avoid ordering effects.

2.2 Apparatus

The study ran on four desktop computers with the same hardware configuration, which produced a measured update rate in the experimental VE ranging between 17Hz and 28Hz at a resolution of 1024x768. The study was run in a dedicated room, which was kept quiet and dark during the duration of the study. The machines were arranged such each subject could only see their own machine during the experiment.

2.2.1 Virtual environment

The VE used simulated an egocentric interactive building walkthrough using the Quake Keys interface [14]. The VE represented a medieval European monastery, containing nineteen rooms spread over three levels of two buildings. Subjects performed an object search and collection task; in each session they searched for a different object (books, candlesticks or small chests) which were placed in different locations in each run.

2.3 Measures

2.3.1 Memory questionnaire

A set of 21 statements about the VE were created to test the subjects' recall of VE content. These were shown to the participants who had to indicate whether the statement was true or false. 10 of the items were in fact true, while 11 were false. The 21 items were created to reflect three categories of specificity or detail: low, medium and high (see Table 1 below for samples of the items used in these categories). These 21 items were randomly divided into three sets: Two sets of four questions to be administered immediately after the first and third VE experiences to measure if the VE content had been encoded by the subject (these were administered only to the experimental condition), and one set of 13 questions which would act as the measure of false memory. These false memory items were administered to both conditions after a 72 hour delay during which the subjects did not have access to the VE. Eight of the thirteen items (2 in the low condition, 2 in the medium condition, and 4 in the high condition) made reference to objects of situations which did not exist in the environment. In line with the procedure described in [8], when subjects responded to these statements as true, we took it to mean that they experienced a false memory.

2.3.3 Presence measure

Presence was measured using the ITC Sense of Presence Inventory (ITC-SOPI) [15]. This questionnaire measures four factors: Spatial presence (a sense of being in the space), engagement (psychological engagements with the content and enjoyment of the experience), naturalness (congruency with real-world experience or a sense of realism) and negative effects (eyestrain, fatigue, simulator sickness, etc.). The ITC-SOPI was chosen as its factorial structure allows the measurement not only of spatial presence [as emphasized by 16], but also more strongly semantic factors such as a subject's connection with the content, and their evaluation of the realism (factors which have been implicated in the presence experience by [5]). This allows for great flexibility and range in the interpretation of the subject's experience.

Category (Specificity)	*Sample items*
Low	There is a rug on one of the hallway floors There is a bedroom with no books in it.
Medium	There are lit candles in the tables in the dining room There are candles on the tables inside the dining hall
High	There are exactly two books on the table in the church The bed in the bedroom with the most light had a pillow on it.

Table 1: Sample memory items in each specificity category

3. Results

3.1 Validation of false memory items

To validate the false memory items, we correlated them with the memory items presented to the experimental group immediately following the VE experience. We reasoned that if the VE was well encoded during the experience, there would be less post-delay ambiguity, and therefore a reduced probability of having a false memory. We therefore expected to see a strong negative correlation between post-experience memory scores, and post-delay memory scores. The correlation analysis supports, this, for all categories of memory question (see Table 2 below). It should be noted that for all memory question categories, the corresponding false memory questions give the strongest correlation, in the predicted direction. This indicates that the false memory items were sufficiently valid for further analysis.

		False memory categories			
		Low	Medium	High	Total
Memory categories	Low	***-0.87***	-0.20	0.31	-0.42
	Medium	-0.06	***-0.78***	0.06	-0.47
	High	0.34	0.13	***-0.83***	-0.34
	TOTAL	-0.25	-0.51	-0.34	***-0.78***

Table 2: Correlations between memory item categories and false memory item categories. Corresponding categories have been marked in italics.

3.2 Rates of false memories

We examined the rates of false memories for VE content (as defined in 2.3.1 above) in the three specificity categories, and for the total across all categories. Figure 1 below shows the box-and-whisker plots of the distribution of false memory rates. We conducted one-sample t-tests (against the baseline chance rate of 0.5) for each category to determine if any of the categories showed a false memory rate higher or lower than simple random guessing. The medium specificity category showed a higher than expected rate ($t(47) = 2.699$, $p < 0.009$), while high specificity category showed a lower than expected rate ($t(47) = -2.00$, $p < 0.05$).

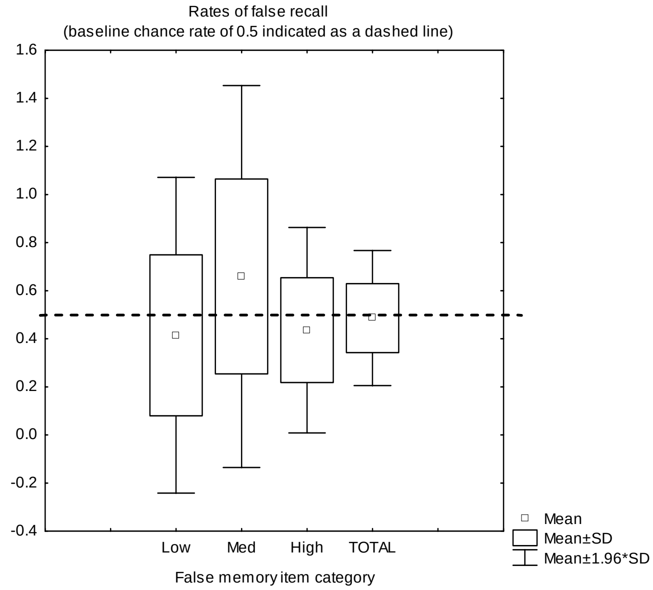

Figure 1: False memory rates. The dashed line indicates the baseline chance response rate of 0.5

3.3 Presence effects on memory items

To determine if presence affected encoding of the VE content, we ran a set of general linear models to predict each of the four categories of memory item using the four ITC-SOPI factors and experimental condition as predictors. None of the models were significant, indicating that presence did not affect encoding of VE content.

3.4 Presence effects on false memory items

As in 3.3 above, we used general linear models to predict rates of false memories on each of the four categories of false memory items using the ITC-SOPI factors and experimental condition as predictors. We found the high specificity items were predicted by the degree of engagement during the first VE exposure, regardless of experimental condition (model: $F(6,40) = 2.713$; $p < 0.026$; $R^2 = 0.29$; engagement partial $r = 0.330$). Also, the rate of false memories across all categories was significantly predicted by naturalness during the third exposure (model: $F(6, 40) = 2.19$; $p < 0.047$; $R^2 = 0.24$; naturalness partial $r = 0.321$).

3.5 Delayed presence effects on false memory items

As with 3.3 and 3.3 above, we used general linear models to determine if the presence measured after the 72 hour delay was a predictor of false memory rates (this was done to separate out encoding and retrieval effects; see the discussion in 4 below). We ran general linear models to predict each of the four categories of false memory question using the experimental condition and the four ITC-SOPI (post delay) factors as predictors. The models showed no significant predictors.

4. Discussion

The negative relationship between the memory items and the false memory items shows that the basic procedure and memory measure was successful. As predicted, the procedure did manage to produce false memories, although in an unexpected pattern – the medium specificity items behaved as predicted, producing a higher than base chance rate of recognition; however the high specificity items produced a lower than base chance rate of false memories. This is contrary to the classic DRM finding (for instance, [8]) which does not find performance at lower than base rates. We can therefore easily explain the higher than base rate performance for the medium specificity items – exploration of the VE primed particular memory clusters, which then interacted with the cue provided by the false memory items to produce the false memories (following the explanation provided by [7]). The lower than expected performance for the high specificity items could be explained from an information processing perspective. A false memory is associated with a match between the priming of memory clusters due to VE exploration, and the activation of clusters brought about by the false memory items [7]. The medium specificity items (such as “There are lit candles on the tables inside the dining hall.”), by their general nature activate a broad range of possibilities, which are then more likely to match with the traces of activity left by priming in the environment, thereby increasing the probability of a match between the priming trace and the clusters activated by the false memory item. The high specificity items however (such as “There are exactly two books on the table in the church.”), activate a narrower range of possibilities, which have a proportionately lower chance of matching the primed memory clusters, and therefore a lower chance of forming a false memory.

A surprising finding was the lack of effect of the attention manipulation on the rate of false memories. We expected that subjects in the attention condition would have more effectively encoded the semantic content of the VE, as predicted by [17]. However, the attention manipulation did not appear as a predictor of false memory rate for any of the models tested. This suggests one of two plausible explanations: First, that amount of attention required to completely encode the semantic content of the environment is present in the control condition; and second, that focusing attention does not reduce the false memory phenomenon (although this is contrary to the finding in [9]).

The data also matched our predictions with respect to the role of presence in false memories. We predicted that presence would aid in the false memory effect by enhancing the conceptual priming effect of the VE, and the data suggests that this has indeed occurred. It should be noted that only the engagement and naturalness factors of the ITC-SOPI (and not the spatial presence factor) operated in this way. This finding is in line with the findings in [5], which found that conceptual effects were strongest for these two ITC-SOPI factors. The argument posed in that paper was that naturalness and engagement rely more on semantic than spatial processing; the findings of this study support that notion, as the formation of false memories of this type are almost exclusively due to semantic processing. It is worth noting the difference in effect between the presence measures taken immediately after the VE sessions, and the presence measure taken after the 72 hour delay. The immediate measures produced significant predictors of false memory, while the delayed measure did not. This could be taken as an indication of two phenomena: the first is that there is a reduction in the reliability of the ITC-SOPI over a 72 hour delay, and the other is that the presence effect on false memory occurs at encoding time and not retrieval time (following our prediction). Further study will be required to disentangle these two explanations.

The lack of a predictive effect on spatial presence could also exist as an artifact of the experimental procedure. The measure of false memory used is inherently semantic rather than spatial. If it is true that spatial presence uses a different form of processing to engagement and naturalness, then it should come as no surprise that this chosen measure shows no effect. If one selected a measure of spatial false memory, then one might expect to see an effect on spatial presence also.

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References

[1] Slater, M. and A. Steed, *A virtual presence counter.* Presence: Teleoperators and Virtual Environments., 2000. **9**: p. 413-434.

[2] Nunez, D. *Working memory and presence: Reconsidering the role of attention in presence.* in *7th International workshop on presence (PRESENCE 2004).* 2004. Valencia, Spain.

[3] Mania, K. and A. Chalmers, *The effects of levels of immersion on memory and presence in virtual environments.* Cyberpsychology & Behaviour, 2001. **4**(2): p. 247-263.

[4] Wirth, W., et al., *A Process Model of the Formation of Spatial Presence Experiences.* Media Psychology, 2007. **9**(4).

[5] Nunez, D. and E.H. Blake. *Content knowledge and thematic inertia predict virtual presence*. in *The ninth international workshop on presence (PRESENCE2006).* 2006. Cleveland, OH.

[6] Loftus, E. and J.E. Pickrell, *The formation of false memories.* Psychiatric Annals, 1995. **25**: p. 720-725.

[7] Robinson, K.J. and H.L. Roediger, *Associative processes in false recall and false recognition.* Psychological Science, 1997. **8**: p. 231-237.

[8] Roediger, H.L. and K.B. McDermott, *Creating false memories: Remembering words not presented in lists.* Journal of Experimental Psychology: Learning, Memory, and Cognition, 1995. **21**: p. 803-814.

[9] McCabe, D.P., et al., *Item-specific processing reduces false memories.* Psychonomic Bulletin & Review, 2004. **11**(6): p. 1074-1079.

[10] Tulving, E. and D.L. Schachter, *Priming and human memory systems.* Science, 1990. **247**: p. 301-306.

[11] Nunez, D. and E.H. Blake. *Conceptual priming as a determinant of presence in virtual environments.* in *2nd International Conference on Computer Graphics, Virtual Reality, Visualisation and Interaction in Africa (AFRIGRAPH 2003),*. 2003. Cape Town, South Africa.

[12] Ladeira, I., D. Nunez, and E.H. Blake. *The role of content preference on thematic priming in virtual presence.* . in *The 8th Annual International Workshop on Presence (PRESENCE2005)*. 2005. London, UK.

[13] Slater, M., M.K.A. Usoh, and A. Steed, *Depth of presence invirtual environments.* . Presence: Teleoperators and Virtual Environments, 1994. **3**: p. 130-144.

[14] Dalgarno, B. and J. Scott, *Motion control in virtual environments: A comparative study.*, in *Workshop on Usability Centred Design and Evaluation of Virtual 3D Environments*, V. Paelke and S. Volbracht, Editors. 2000, University of Padeborn: Padeborn, Germany.

[15] Lessiter, J., et al., *A cross-media presence questionnaire: The ITC-Sense of Presence Inventory.* Presence: Teleoperators and Virtual Environments., 2001. **10**(3): p. 282-297.

[16] Slater, M., *A note on presence terminology.* Presence Connect, 2003. **3**.

[17] Baddeley, A.D., *Working Memory*. 1986: Claredon Press.