Virtual Reality Monitoring: Phenomenal Characteristics of Real, Virtual, and False Memories

Article *in* CyberPsychology & Behavior · November 2001

DOI: 10.1089/109493101753235151 · Source: PubMed

Azucena Garcia-Palacios
Universitat Jaume I

Ayanna Thomas
Tufts University

CyberPsychology & Behavior
Volume 4, Number 5, 2001
Mary Ann Liebert, Inc.

Virtual Reality Monitoring: Phenomenal Characteristics of Real, Virtual, and False Memories

HUNTER G. HOFFMAN, Ph.D.,[1,2] AZUCENA GARCIA-PALACIOS, Ph.D.,[3] AYANNA K. THOMAS, Ph.D.,[2] and ANNE SCHMIDT, B.S.[1]

ABSTRACT

This study explored virtual-reality (VR) monitoring, the decision process by which people discriminate memories of real and virtual events. In a study phase, subjects touched 10 real objects with their real finger and touched 10 virtual objects (visual only, no tactile feedback) with their cyberfinger in VR. One week later they took a real versus virtual versus new source identification test. After the source identification test, subjects rated phenomenal qualities associated with each memory, using a Virtual-Real Memory Characteristics Questionnaire (VRMCQ). For old items, results from the VRMCQ are consistent with the idea that VR monitoring draws on differences in qualitative characteristics of memories for perceived and virtual events/objects (consistent with Johnson and Raye[1]). However, subjects also reported similar qualities associated with their false memories for new items, suggesting that they sometimes infer/reconstruct the qualities a memory should have, based on their decision of its source of origin. Furthermore, VR monitoring might prove useful as a sort of Turing test of how convincing the virtual world is, and the VRMCQ can identify which qualities of the virtual experience (e.g., color) require improvement. Examples of applications are discussed.

INTRODUCTION

Source monitoring is the decision process by which memories from different sources (e.g., remembering who said what in a multi-person conversation) and memories from different origins (real, imagined, and dreamed events) are separated/distinguished in memory.[2] Johnson and Raye[1] proposed that differences between real and imagined events as originally experienced are preserved in memory. At the time of retrieval, participants infer where the memory originated, based on these cues associated with the retrieved memory. Johnson and Raye argue that, when making reality monitoring decisions, people take advantage of differences in qualitative characteristics associated with memories to help them infer whether the event really happened or if it was only imagined. For example, memories of real events tend to include more perceptual, spatial and temporal, semantic, and affective (emotional) information, and less information about mental effort than memories of imagined events. Consequently, a memory that comes to mind clearly, vividly, and with rich colors, with

[1] University of Washington, Human Interface Technology Laboratory, Seattle, Washington.
[2] Department of Psychology, University of Washington, Seattle, Washington.
[3] Universidad Jaume I, Castellon, Spain.

little evidence of mental effort associated with it is likely to be attributed to a real source. In contrast, a memory that is unclear, pallid, with dull or no colors, and with mental effort associated with its initial creation is likely to be attributed to an imagined source.[2]

In support of their framework, Johnson and colleagues have shown that increasing the perceptual similarity between memories of real and imagined events can increase reality monitoring confusions.[3,4] For example, if one imagines a banana that has many qualities typically associated with real events (clarity of detail, vividness, rich colors, etc.); these cues could later mislead the person into thinking she/he had actually seen a banana. More generally, memories with qualities atypical of their class are likely to result in reality monitoring confusions.

Johnson, Foley, Suengas, and Raye[5] developed the Memory Characteristics Questionnaire. In support of the reality monitoring framework, they showed that real and imagined events do in fact differ in the sorts of qualities/characteristics typically associated with them, and these qualities could potentially be used to help subjects identify which items were real and which were imagined. More recently, the Memory Characteristics Questionnaire has been used to explore qualities associated with false memories.[6]

Advanced visualization technologies such as immersive virtual reality (VR) offer an interesting new source of memories: Memories for events that occur in virtual environments. The essence of immersive VR is the sensation users have that they have gone there into another place, into the three-dimensional (3-D), immersive, computer-generated environment (e.g., Hoffman et al.[7]). The present study explores how accurately people can distinguish reality from VR in memory (i.e., VR monitoring) via a source identification task. Subjects physically touched some real objects with their real finger and with eyes open, and touched other virtual objects with their cyberfinger in immersive virtual reality (visual only, no tactile feedback for virtual objects). One week later, they took a source identification test. Given the name of an object, they had to identify whether it had been real, virtual, or new. They then rated phenomenal qualities associated with each memory, using a Virtual-Real Memory Characteristics Questionnaire introduced in the present study, to compare and contrast the phenomenal characteristics associated with real, virtual, and false memories. Memories for events that occurred in VR are likely different than those from other sources traditionally studied (real events, imagined events, or dreams). If so, people may use a decision process similar to reality monitoring to help them remember whether an object was previously experienced in VR or in the real world.

MATERIALS AND METHODS

Participants

Twenty undergraduate students from the University of Washington participated for extra credit.

Materials and equipment

The study took place in a lab room at the University of Washington with a table in front of the subject. The virtual world consisted of a computer generated 3-D model of the lab room, a virtual model of a table, and the virtual stimuli. Thirty real objects (plate, cucumber, sink stopper, tennis ball, etc.) were modeled in 3-D and texture mapped with digitized photo textures from real objects. During the study, each real object was immobilized by attaching it to a piece of white posterboard and placed on the table in front of the subject. The virtual reality system consisted of an SGI Octane MXE with Octane Channel Option, coupled with a Virtual Research V8 VR helmet (head-mounted display) with the following circular FOV: 60° vertical, 60° horizontal. A Polhemus™ position tracking system was used to track head and hand motions. Thus if subjects looked up, what they saw in the virtual world changed accordingly (e.g., they could look up at the ceiling, or see a wall if they turned their head to their left, etc.).

Design and procedure

Thirty common objects were randomly assigned to one of three stimulus sets of 10 items per set. The sets were rotated through each stimulus condition such that, during the course of the experiment, each item was real, virtual, and new (i.e., not presented) in the study phase equally often. For each participant, 10 real items and 10 virtual items were randomly intermixed (e.g., virtual, real, real, real, virtual, etc.) and presented to participants in the study phase. Each subject was thus presented with 20 study items (the 10 items not presented in the study phase served as new items on a subsequent source identification test).

Individually, participants sat at a conference table, with a position sensor on their right index finger, and put on the head-mounted display. Two experimenters worked together to coordinate the timing and selection of real and virtual stimulus objects, and one of the experimenters placed real objects in front of the subject when appropriate (i.e., only for real stimuli). As a cover task, participants were told that the study was designed to explore similarities and differences between real and virtual objects. They were told they would see some objects in VR (with their helmet down) and that it was very important to control the amount of time they viewed each object, which should always be 7 sec for each object. Prior to stimulus presentation the experimenter said the name of an object. The experimenter said "open your eyes," and 7 sec later the experimenter said "close your eyes." Except for these 7-sec intervals when the subject viewed and touched the object, the subject's eyes were to remain closed throughout the experiment. The interstimulus interval was 15 sec. Subjects were reminded after each item to keep their eyes closed during the interstimulus interval. Experimenters could observe whether subjects were following instructions. Subjects were informed that they were going to view common objects in the real world (i.e., with helmets raised) and view other common objects in the virtual world (with VR helmets lowered). They were to run their index finger back and forth along the middle of the object for the 7 sec they viewed it. Afterwards, they would be asked a few brief questions.

After the study phase, participants engaged in a filler task, filling out a brief questionnaire about what it was like to be in VR. Upon their return, exactly 1 week later, participants took an unexpected source identification test. Each subject was given a stack of 30 test words printed on thirty 2" × 3" squares of paper, and an instruction sheet. They were reminded they had seen real and virtual objects the week before. They would now be given a memory test for these old items and were told that new distracter items not encountered in the study phase had been added to the test. For each test word, they were to identify (by circling) whether the object had been real (i.e., seen in the real world with the helmet raised), virtual (i.e., seen in VR with the helmet down over their eyes), or new (i.e., not in the study list), and to indicate how confident they were in the accuracy of their response as a percentage of either 0%, 20%, 40%, 60,%, 80%, or 100% where zero was completely guessing and 100% was completely confident they were right. After the source identification task, subjects filled out the VRMCQ ratings (see Appendix) using 10-cm Visual Analog Scales (i.e., VAS[8,9]). For each object, subjects identified the source again, and made a mark on a 10-cm line to indicate their response for each of the 13 questions about qualities associated with their memories.

Analysis

All p values reported are two-tailed. An alpha level of 0.05 was used for statistical tests on the data in Table 1 (ANOVAs on source identification data). A Bonferroni corrected alpha level of 0.004 was used for statistical tests on the VRMCQ data shown in Figures 1 and 2 (i.e., all t tests reported in this paper). We first calculated the mean proportion of real, virtual, and new responses given by participants as a function of the correct real, virtual, or new

TABLE 1. PROPORTION OF RESPONSES LEADING TO FALSE RECOGNITIONS, HITS, MISSES, AND CORRECT SOURCE IDENTIFICATIONS IN VIRTUAL REALITY MONITORING DECISIONS FOR EXPERIMENT 1

Participant response	*Item origin*		
	Real	*Virtual*	*New*
Real	0.62 (0.05)	0.10 (0.02)	0.08 (0.02)
Virtual	0.26 (0.05)	0.63 (0.05)	0.18 (0.04)
New	0.12 (0.02)	0.27 (0.05)	0.74 (0.04)

Standard error is shown in parentheses.

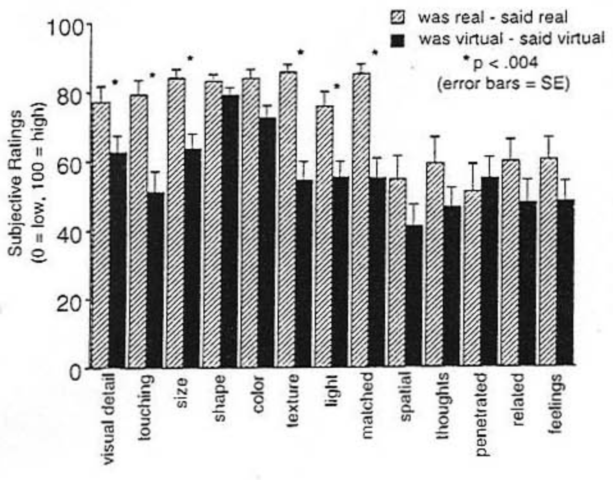

FIG. 1.

origin of the item. These data are shown in Table 1.

RESULTS

Correct source identification of old items

This includes real items to which the participants responded real and virtual items to which the participant responded virtual. A one-factor within-subjects ANOVA showed that source identification accuracy was not significantly different for real items versus virtual items, $F(18) < 1$, NS. There was also no significant difference in the accuracy of correct responses to real versus virtual items, $F(1,18) = 1.57$, $p > 0.10$, NS.

Recognition hits

This includes real and virtual items to which participants responded anything but new. The mean proportion of hits was significantly higher for real items compared to virtual items (0.88 vs. 0.73 respectively), $F(1,18) = 12.38$, $p = 0.002$, $MSE = 0.23$, and participants were significantly more confident when responding to real items than to virtual items, 67% versus 51%, $F(1,12) = 6.76$, $p < 0.05$, $MSE = 236.00$.

False recognitions

This includes new items to which participants responded real or virtual. The mean proportion of false recognitions, or false alarms (FAs), are shown in Table 1. When making FAs, participants were significantly more likely to respond virtual than real, $F(1,18) = 4.55$, $p < 0.05$, $MSE = 0.02$. Although confidence was higher when participants responded virtual versus real on false recognition (61% vs. 47%, respectively), the difference was not significant, $F(1,8) = 2.59$, $p = 0.15$, NS. (If subjects didn't respond real in one or both of the FA cells, than those FA cell(s) received a zero for proportion of responses and could be included in analyses, but received a missing data point for confidence; hence, the low n for the confidence comparison. The proportion of old/new recognition hits was higher for real items, and subjects were more confident on old real items. The pattern of results on false recognitions is the opposite of the pattern of old/new recognition hits. On false recognitions, subjects showed a significant bias to respond virtual rather than real, an it-had-to-be-virtual effect. This pattern of results is consistent with the notion that memory source identifications can sometimes be influenced by memory strength.[14,27])

Qualitative characteristics of correctly identified real and virtual memories: the VRMCQ test

For items whose sources were correctly identified, the most salient overall pattern in Figure 1 is that both real and virtual items were given higher ratings on perceptual characteristics than for cognitive operations (thoughts, feel-

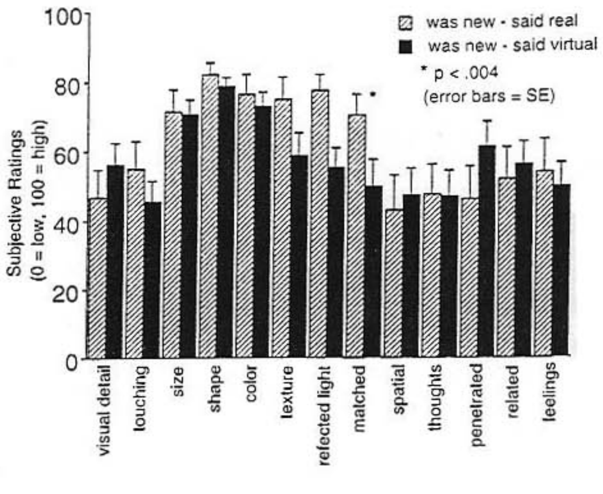

FIG. 2.

ings, related memories). And qualities associated with real objects were consistently rated higher than qualities associated with virtual objects. As indicated in Figure 1, real items were given statistically higher VRMCQ ratings than virtual items on the following characteristics: visual detail, touching, size, physical texture, light reflectivity, and whether what they saw matched what they touched. Virtual items were not given statistically higher VRMCQ ratings than real items on any memory characteristic.

Qualitative characteristics of false memories

Subjects gave high ratings to qualities associated with their false memories. For example, on a scale from 0 to 100 mm, new items falsely identified as real received ratings of 70 mm or higher on six questions about perceptual characteristics (but no questions about cognitive operations reached 70 mm). New items falsely identified as real generally received higher ratings than false memories attributed to a virtual source, but only one qualitative difference (a perceptual characteristic) was statistically significant. (Figure 2 shows all the data, whereas the t tests were performed on a subset of the subjects who said real when it was new, and also sometimes said virtual when the correct response was new.)

DISCUSSION

For correctly identified old items, clear differences in the qualities associated with memories of real and virtual objects were found that could have been used to infer the source of their memories at time of retrieval, consistent with the Johnson and Raye[1] framework. Namely, in the present study, memories of real objects were more likely than memories of virtual objects to be associated with perceptual cues. Interestingly, qualities associated with their false memories for new items showed this same pattern and surprisingly high ratings. Subjects sometimes mistakenly reported seeing a real object in the study phase that actually was not in the study phase. They gave false memories the same pattern of qualities they gave memories for real objects that were in the study phase. Similarly, subjects sometimes mistakenly reported seeing a virtual object in the study phase that actually was not in the study phase. They gave these false memories the same pattern of VRMCQ qualities they gave memories for old virtual objects that were in the study phase. Although not conclusive from the present study, one interpretation of these results is that subjects sometimes infer the qualities a memory was likely to have, based on their decision of its source of origin. That is, they may sometimes decide whether a memory was real or virtual, and then reconstruct the qualities it was likely to have *after* they have made their source identification. Bartlett[10] promoted the influential concept that memory is a reconstructive process. According to Bartlett, memory involves combining elements from new material with existing knowledge participants possessed before: memories, schemata, and expectations acquired from previous experience shape what is perceived/remembered. The process of recollection involves gathering bits and pieces of memories from different sources of experience, and actively reconstructing a memory of what happened.[11–13] We are suggesting here that qualities associated with memories may similarly be reconstructed. (e.g., I remember the orange was virtual, . . . and I think I remember the color was off, not quite the right color). Source attribution biases on false recognitions have also been used as evidence that memory strength[14] and social influence[15] can play an important role in reality monitoring decisions.

Unlike imagined events, virtual events can be programmed/manipulated by the experimenter in great detail. It is probably not possible to pin down permanent qualities associated with memories of virtual events, and permanent differences between memories of real and virtual objects/events. The qualities associated with virtual events will depend on the virtual world program and the VR system, and will likely change drastically in the near future (e.g., 10 years) as VR technology quickly improves.

VR monitoring can be used to quantify the quality of the human–computer interface. Most VR systems currently exhibit a number of performance limitations (e.g., field of view,[16] update rate, resolution, lack of physical tactile feedback, and taste[17]) that reduce the quality of the virtual experience. These technological shortcomings and artifacts may be stored in the user's memory and later help them identify the source of these memories as virtual. In future studies, these limitations of VR (e.g., field of view) can be manipulated to explore how each factor contributes to performance on the source identification test, and how each factor affects qualitative characteristics of the virtual experience, as reflected by ratings of memory qualities on the VRMCQ. As VR technology improves and the artifacts are reduced, the cues to source will also diminish, reducing the participants ability to remember what was real, and what was virtual. VR monitoring can serve as a way of measuring how closely virtual events simulate real events, a sort of Turing test for quantifying the realism of virtual environments. Qualitative characteristic ratings on the VRMCQ can help identify specific areas of the virtual experience that could use improvement (e.g., colors are unrealistic, etc.). Such qualitative characteristics could also be rated during the VR experience (e.g., study phase)—qualities of perception rather than qualities of memory.

One popular application of VR technology is for medical training (e.g., training surgeons[18]). The more accurately the virtual world simulates the real world, the more likely it is that training will transfer to the real world. For some medical training purposes, the ideal (but perhaps unattainable) goal is for the virtual world to be made indistinguishable from the real world. VR monitoring can serve as a metric for quantifying the fidelity of virtual worlds to real worlds. Similarly, the VRMCQ can help identify which qualities of a particular virtual world (e.g., color) needs improvement to make the world more difficult to distinguish from the real world being modelled.

Also, VR monitoring could be used to reduce transfer effects in situations where transfer is undesirable. Violent entertainment may contribute to violent behavior in the real world.[19,20] For example, a teenaged boy named Lionel Tate is presently serving a life sentence without parole for crushing and killing a 6-year-old friend when he was 12. He claims he was imitating moves he had seen on All Star Wrestling on television. Such problems may become more pronounced for violent games played in immersive VR. Undesirable transfer of training from the virtual world to the real world could perhaps be reduced by making the qualities of the experience in the virtual world distinctively unreal (e.g., vertical flight enablement, permeable walls, etc.). Such telltale cues to a virtual source could help players compartmentalize these entertainment experiences and keep them separate from their pool of knowledge about the real world.[2,21,22]

The present results indicate that VR monitoring can be studied using the Johnson-Raye reality monitoring paradigm, and vice versa. Identifying the source of our memories is a central cognitive ability implicated in such memory phenomena as the reliability of eyewitness testimony,[13,23] amnesia,[24,25] age-related memory deficits,[26] and the distinction between controlled and automatic memory processes.[27,28] Additional research using VR to study source monitoring and related attributional processes (and vice versa) is warranted.

APPENDIX

"Think back now to your memory for the bowl you saw last week: Please try to remember whether it was real, virtual or new. Circle one: real, virtual, or new." How confident are you that the answer you just circled is accurate? Endpoints on the Visual Analog rating scale = not at all confident, completely confident. "Regarding your memory for the bowl from last week. We are interested in the qualities associated with your memory of the bowl. 1. How much visual detail does your memory for the bowl have? Endpoints: None, A lot. 2. How much does "touching the bowl" come to mind when you remember the bowl? None, A lot. 3. The object (the bowl) was the SIZE I was expecting. Not at all, Absolutely. 4. The object (the bowl) was the *shape* I was expecting. Not at all, Absolutely. 5. The object (the bowl) was the *color* I was expecting. Not at all, Absolutely. 6. The object (the bowl) had the *physical texture* I was expecting. Not at all, Absolutely. 7. The object (the bowl) *reflected light* the way I was expecting. Not at all, Absolutely. 8. What I was seeing with my eyes matched what I was touching with my finger. Not at all, Absolutely. 9. When I think of the bowl, I also think of the spatial locations of other objects in the room/virtual room: Not at all, Clearly. 10. I remember what I thought when the object (the bowl) was presented to me. Not at all, Clearly. 11. I remember my hand/fingers penetrating the object (the bowl). Not at all, Clearly. 12. I remember events related to the object (the bowl) regarding my own previous experience: Not at all, Clearly. 13. I remember feelings associated with the object (the bowl). Not at all, Clearly."

ACKNOWLEDGMENTS

This project was funded by the Pla de Promocio de la Investigacio, Fundacio Caixa Castello-Bancaixa 1998. Thanks to Ari Hollander (www.imprintit.com), Duff Hendrickson (www.hitl.washington.edu.edu/people/duff/), and Scott Rousseau for help programming and modelling.

REFERENCES

1. Johnson, M.K., & Raye, C.L. (1981). Reality monitoring. *Psychological Review*, 88:67–85.
2. Johnson, M.K., Hashtroudi, S., & Lindsay, D.S. (1993). Source monitoring. *Psychological Bulletin*, 114:3–28.
3. Johnson, M.K., Foley, M.A., & Leach, K. (1988). The consequences for memory of imagining in another person's voice. *Memory and Cognition*, 16:337–342.
4. Johnson, M.K., Raye, C.L., Wang, A.Y., & Taylor, T.H. (1979). Fact and fantasy: the roles of accuracy and variability in confusing imaginations with perceptual experiences. *Journal of Experimental Psychology: Human Learning and Memory*, 5:229–240.
5. Johnson, M.K., Foley, M.A., Suengas, A.G., & Raye, C.L. (1988). Phenomenal characteristics of memories for perceived and imagined autobiographical events. *Journal of Experimental Psychology: General*, 117:371–376.
6. Mather, M., Henkel, L.A., & Johnson, M.K. (1997). Evaluating characteristics of false memories: remember/know judgments and memory characteristics questionnaire compared. *Memory and Cognition*, 25:826–837.
7. Hoffman, H.G., Doctor, J.N., Patterson, D.R., Carrougher, G.J., & Furness, T.A., III. (2000). Use of virtual reality for adjunctive treatment of adolescent burn pain during wound care: A case report. *Pain*, 85:305–309.
8. Gift, A.G. (1989). Visual analogue scales: measurement of subjective phenomena. *Nursing Research*, 38:286–288.
9. Huskisson, D.C. (1974). Measurement of pain. *Lancet*, 2:1127–1131.
10. Bartlett, E.C. (1932). *Remembering: a study in experimental and social psychology*. Cambridge, U.K.: Cambridge University Press.
11. Loftus, E.F., Hoffman, H.G., & Wagenaar, W.A. (1992). The misinformation effect: transformations in memory induced by postevent information. In: Howe, M.L., Brainerd, C.J., and Reyna, V.F. (Eds.), *Development of long-term retention*. New York: Springer-Verlag, pp. 159–183.
12. Neisser, U. (1967). *Cognitive psychology*. Englewood Cliffs, NJ: Prentice Hall.
13. Loftus, E.F., & Hoffman, H.G. (1989). Misinformation and memory: the creation of new memories. *Journal of Experimental Psychology: General*, 118:100–104.
14. Hoffman, H.G. (1997). The role of memory strength in reality monitoring decisions: evidence from source attribution biases. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 23:371–383.
15. Hoffman, H.G., Granhag, P.A., Kwong See, S.T., & Loftus, E.F. (2001). Social influences on reality monitoring decisions. *Memory and Cognition*, 29:394–404.
16. Prothero, J.D., & Hoffman, H.G. (1995). Widening the field-of-view increases the sense of presence in immersive virtual environments [Online]. Human Interface Technology Laboratory Technical Report TR-95-2. Available: http:/s/www.hitl.washington.edu/publications/r-95-5/.
17. Hoffman, H.G., Holander, A., Schroder, K., Rousseau, S., & Furness, T.A., III. (1998). Physically touching and tasting virtual objects enhances the realism of virtual experiences. *Virtual Reality: Research, Development and Application*, 3:226–234.
18. Machado, L.S., de Mello, A.N., Lopes, R.D., Odone Filho, V., & Zuffo, M.K. (2001). A virtual reality simulator for bone marrow harvest for pediatric transplant. *Studies in Health Technology and Informatics*, 81:293–297.
19. Comstock, G., & Scharrer, E. (1999). *Television: what's on, who's watching, and what it means*. San Diego: Academic Press.
20. Lazar, B.A. (1994). Why social work should care: television violence and children. *Child Adolescent Social Work Journal*, 11(1):3–19.
21. Potts, G.R., & Peterson, S.B. (1985). Incorporation versus compartmentalization in memory for discourse. *Journal of Memory and Language*, 24:107–118.
22. Potts, G.R., St. John, M.F., & Kirson, D. (1989). Incorporating new information into existing world knowledge. *Cognitive Psychology*, 21:303–333.
23. Lindsay, D.S. (1990). Misleading suggestions can impair eyewitnesses' ability to remember event details. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 16:1077–1083.

24. Hirst, W. (1982). The amnesic syndrome: descriptions and explanations. *Psychological Bulletin,* 91:435–460.
25. Schacter, D.L., Harbluck, J.L., & McLachlan, D.R. (1984). Retrieval without recollection: an experimental analysis of source amnesia. *Journal of Verbal Learning and Verbal Behavior,* 23:593–611.
26. Hashtroudi, S., Johnson, M.K., & Chrosniak, L.D. (1990). Aging and qualitative characteristics of memories for perceived and imagined complex events. *Psychology and Aging,* 5:119–126.
27. Jacoby, L.L. (1991). A process dissociation framework: separating automatic from intentional uses of memory. *Journal of Memory and Language,* 30:513–541.
28. Yonelinas, A.P. (1999). The contribution of recollection and familiarity to recognition and source-memory judgments: a formal dual-process model and an analysis of receiver operating characteristics. *Journal of Experimental Psychology: Learning, Memory, and Cognition,* 25:1415–1434.

Address reprint requests to:
Hunter Hoffman, Ph.D.
215 Fluke Hall
Box 352142
University of Washington
Seattle, WA 98195

E-mail: hunter@hitL.washington.edu