Psychological Science

http://pss.sagepub.com/

Learned Control Over Distraction Is Disrupted in Amnesia

Joshua D. Cosman and Shaun P. Vecera

Psychological Science 2013 24: 1585 originally published online 12 June 2013
DOI: 10.1177/0956797613475632

Research Report

Psychological Science
24(8) 1585–1590

DOI: 10.1177/0956797613475632
pss.sagepub.com

Learned Control Over Distraction Is Disrupted in Amnesia

Joshua D. Cosman[1,2,3] **and Shaun P. Vecera**[4,5]
[1]Department of Psychology, Vanderbilt University; [2]Vanderbilt Vision Research Center, Vanderbilt University; [3]Center for Integrative and Cognitive Neuroscience, Vanderbilt University; [4]Department of Psychology, University of Iowa; and [5]Department of Neuroscience, University of Iowa

Abstract

Recent studies have demonstrated that brief periods of training facilitate the ability to overcome distraction during future performance of a given task, and researchers have proposed that these effects rely on relational memory systems that enable individuals to link specific attentional states to their learned context. In the current work, we examined whether medial temporal lobe (MTL) structures critical for relational and contextual learning contribute to these effects. A group of amnesic patients with bilateral MTL damage and a group of matched comparison subjects both completed an attentional-capture task in which a brief training session typically leads to decreased distraction in a subsequent testing session. Whereas the comparison subjects showed normal training-related decreases in distractibility, the amnesic patients did not. Thus, our results indicate that MTL-mediated learning plays a critical role in the ability to use past experience to overcome distraction. This suggests a tight linkage between MTL-dependent relational-learning mechanisms and cognitive control.

Keywords
attentional capture, long-term memory, relational memory, medial temporal lobe, distraction

Received 5/6/12; Revision accepted 12/17/12

Theories of attention and cognitive control typically propose that the ability to implement goal-directed control over distraction relies primarily on prefrontal working memory mechanisms responsible for actively maintaining immediate task priorities (Desimone & Duncan, 1995; Miller & Cohen, 2001). However, it has also been proposed that goal-directed control can operate more or less automatically on the basis of learned task representations, which suggests that a complementary control mechanism might attenuate distraction without relying on limited-capacity executive processes, such as working memory (Logan, 1988; Norman & Shallice, 1986; Schneider & Shiffrin, 1977). Consistent with such a view, recent studies have demonstrated that past experience plays a critical role in modulating distraction (e.g., Leber & Egeth, 2006; Vatterott & Vecera, 2012), and it has been shown that these effects reflect relational-learning processes that tie information regarding particular attentional states to their learned context (Cosman & Vecera, 2012; Leber, Kawahara, & Gabari, 2009).

Medial temporal lobe (MTL) structures are critical for general relational encoding (Cohen & Eichenbaum, 1993; Konkel, Warren, Duff, Tranel, & Cohen, 2008), and MTL damage has been shown to disrupt relational influences on gaze and attentional control in particular (Chun & Phelps, 1999; Ryan, Althoff, Whitlow, & Cohen, 2000). These deficits likely arise from an inability to effectively represent the relationships between disparate perceptual elements in the environment, which leads to an inability to effectively use relational information in the service of attentional control. In addition to encoding perceptual relationships, MTL may be important for the experience-dependent linkage of internal attentional states with the context in which they occur. Here, we show that amnesic patients with bilateral MTL damage

Corresponding Author:
Joshua D. Cosman, Vanderbilt University, Department of Psychology, PMB 407817, 2301 Vanderbilt Place, Nashville, TN 37240-7817
E-mail: joshua.d.cosman@vanderbilt.edu

fail to use past experience to overcome distraction during an attentional-capture task, despite their generally normal ability to overcome distraction during a training session. This indicates a novel role for MTL memory structures in goal-directed attentional-control processes typically thought to rely primarily on prefrontal cortex, and suggests that relational memory systems are critical for establishing long-term representations responsible for driving attentional control.

Method

Four densely amnesic patients with bilateral MTL damage, and 4 age- and sex-matched neurologically healthy comparison subjects, performed a visual search task known to show robust influences of past experience on distraction by a salient, task-irrelevant distractor item (Leber & Egeth, 2006). Participants first completed a training session (224 trials, divided into four blocks of 56 trials) in which they were instructed to search for a circle among heterogeneously shaped nontargets (diamonds, squares, and triangles) displayed on a computer monitor and to report the orientation of a line embedded inside the circle by pressing either the "Z" (line tilted left) or "M" (line tilted right) key on the keyboard. This session was directly followed by a testing session (168 trials, divided into three blocks of 56 trials) in which the task was identical, but the search array was composed of homogeneously shaped diamond nontargets. In both sessions, participants were told to ignore a salient red distractor item that appeared unpredictably on half the trials (see Fig. 1 for an illustration of the task in each session; for further details on the patients, stimuli, task, and procedure, see Supplementary Methods in the Supplemental Material available online).

When the homogeneous version of this search task is performed in isolation, the salient distractor interferes strongly with task performance (Kawahara, 2010; Theeuwes, 1992, 2010). Conversely, in the heterogeneous version of this task, interference from the distractor is minimal, owing to the increased strength and specificity with which goal-directed cognitive control processes operate to bias competition in favor of the target under these stimulus conditions (e.g., Bacon & Egeth, 1994). Critically, when neurologically healthy participants first train briefly on the heterogeneous version, as in the current design, distractor effects in the homogeneous version are similarly attenuated (Leber & Egeth, 2006). These effects of learning on attentional control appear to be long term, persisting across delays of up to a week (Leber et al., 2009), and are strongly context dependent (Cosman & Vecera, 2012). Of primary interest in the current work was whether, relative to healthy comparison subjects, amnesic patients would show an impaired ability to use past experience to overcome attentional capture following a brief (~5 min) delay between training in the heterogeneous version of the task and testing in the homogeneous version.

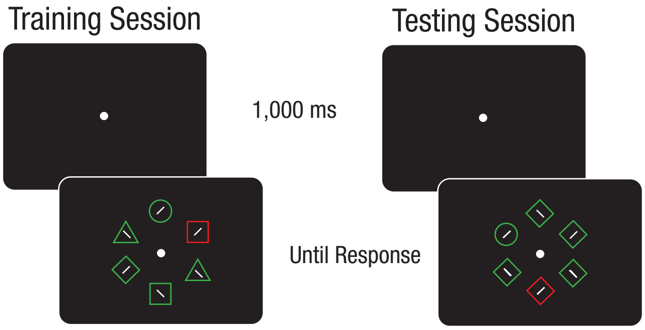

Fig. 1. Example of the displays and timing parameters used during the training and testing sessions. In both sessions, the task was to search for the circle in each array and to report the orientation of the line inside the circle. In the training session, the nontargets were heterogeneously shaped; in the testing session, all nontargets were diamonds. On half the trials, one of the nontargets was red (as shown here).

Results

Reaction times (RTs) on trials responded to correctly were analyzed after removing RTs greater than 3 standard deviations above individual participants' means (loss of 1% of the data in the comparison group and 3% of the data in the patient group). Given our small sample size, mean RTs and error rates for the training and testing sessions (Fig. 2) were analyzed using nonparametric permutation tests (Good, 1994) similar to those used in previous studies involving small-sample neuropsychological methods (see Berryhill & Olson, 2008; Konkel et al., 2008; Olson, Moore, Stark, & Chatterjee, 2006). To perform these tests, we conducted standard parametric mixed-model analyses of variance on RTs and error rates to obtain F statistics (see Supplementary Results in the Supplemental Material). In order to calculate significance values, we randomly permuted the data across each independent variable (group or distractor presence vs. absence) and recomputed a new F statistic on the permuted data. We repeated this process 1,000 times and used the one-tailed proportion of F scores that fell above the initial F score as the level of significance (the p values reported in this section). An analogous procedure was employed for planned comparisons (t tests), and all statistical procedures were carried out in MATLAB (The MathWorks, Natick, MA).

For training RTs, there was no main effect of distractor presence, $F(1, 6) < 1$, $p = .77$, but a marginally significant effect of participant group was observed, $F(1, 6) = 91.8$, $p < .07$ (amnesic group: $\bar{x} = 1{,}575$ ms, $\sigma = 462$; comparison group: $\bar{x} = 1{,}073$ ms, $\sigma = 298$). The individual-level data in Table 1 reveal that, with the exception of 1

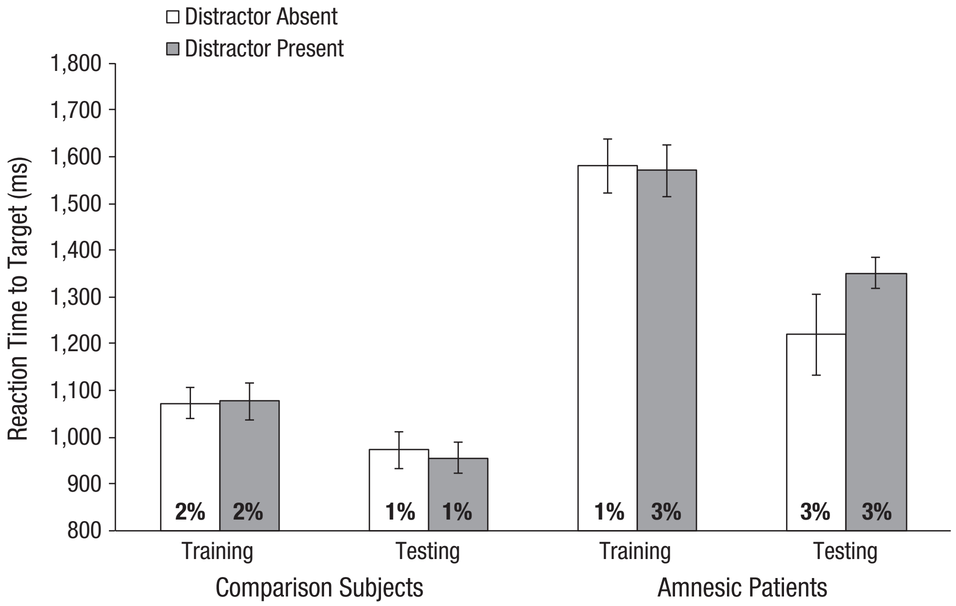

Fig. 2. Overall reaction time and error rate (percentages in the data bars) as a function of participant group (comparison, patient), session (training, testing), and distractor presence (present, absent). Error bars represent 95% confidence intervals calculated for the within-subjects factor (distractor presence vs. absence), separately for the training and testing sessions (Cousineau, 2005; Morey, 2008).

particularly slow amnesic patient and 1 particularly fast comparison subject, training RTs were generally similar across individuals in each group. There was no interaction between group and distractor presence, which indicates that the amnesic patients were not generally more distractible than the comparison subjects, $F(1, 6) < 1$, $p = .63$. Further, this lack of an interaction was not due to a simple ceiling effect in the amnesic patients; even in the fastest quartile of RTs, there was no significant difference in RT between distractor-present and distractor-absent trials, $t(3) < 0.47$, $p = .33$, and there was no evidence of distraction in even the amnesic patients who responded the fastest.

For testing RTs (see Table 1 for individual-level data and Fig. 2 for group-level data), we observed a significant effect of group, $F(1, 6) = 129.4$, $p < .05$ (patient group: $\bar{x} = 1{,}285$ ms, $\sigma = 327$; comparison group: $\bar{x} = 965$ ms, $\sigma = 186$), but not distractor presence, $F(1, 6) = 3.8$, $p = .10$. However, during testing, we also observed a significant interaction between group and distractor presence, $F(1, 6) = 6.2$, $p < .05$; there was a significant capture effect in the amnesic patients (131 ms), $t(3) = 2.28$, $p = .05$, but not in the comparison subjects (−15 ms), $t(3) = 1.6$, $p = .18$. (Fig. 3 presents the effect of the distractor in each session for each participant group.) These results indicate that the amnesic patients failed to use past experience to

Table 1. Average Reaction Time (in Milliseconds) by Condition and Group

	Training session		Testing session	
Participant group	Distractor absent	Distractor present	Distractor absent	Distractor present
Amnesic patients				
1	2,298	2,278	1,577	1,868
2	1,490	1,487	1,165	1,286
3	1,126	1,127	885	903
4	1,407	1,388	1,251	1,345
Comparison subjects				
1	1,493	1,500	1,162	1,137
2	1,012	999	912	875
3	1,323	1,380	1,090	1,112
4	790	790	726	701

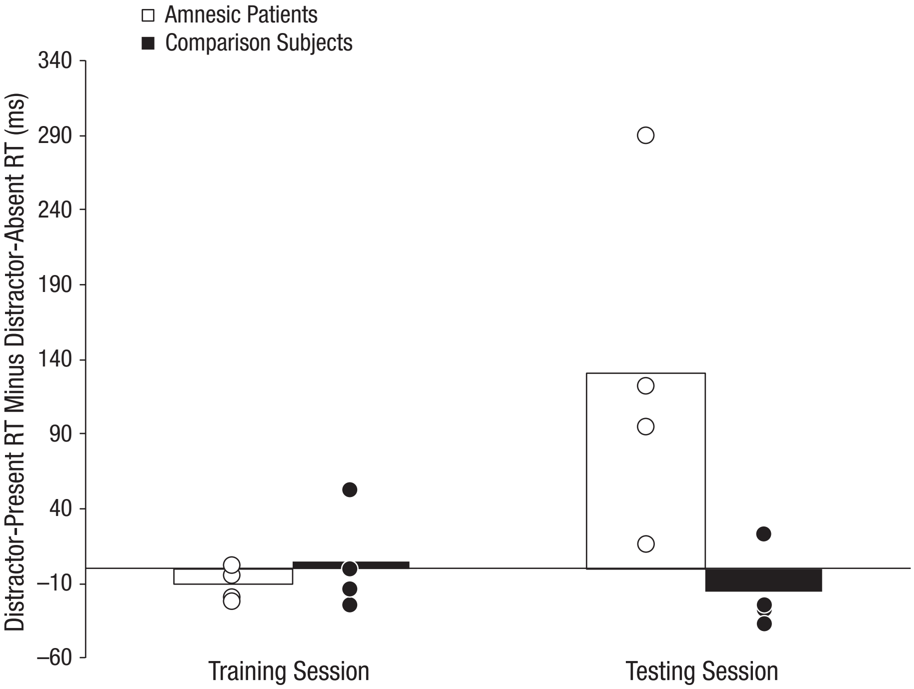

Fig. 3. Mean magnitude of distractor-related slowing for each group (comparison, patient) and session (training, testing). Distractor-related slowing was calculated by subtracting reaction time (RT) on distractor-absent trials from RT on distractor-present trials. The circles indicate effects for individual participants.

overcome attentional capture. Error rates showed no significant effects in either session (see Fig. 2).

Finally, to rule out the possibility that the comparison subjects did not exhibit attentional capture during testing because our testing stimuli were unable to generate capture effects typical of the homogeneous search task (Theeuwes, 1992), we asked a separate group of healthy subjects ($N = 10$) to complete only the testing portion of the experiment, without the training. We observed robust attentional capture, with slower RTs on trials in which the salient distractor was present (803 ms), compared with trials in which it was absent (775 ms), $t(9) = 3.8$, $p = .004$. Thus, in the main experiment, comparison subjects' lack of attentional capture during the testing session was due to a learning process and not an idiosyncrasy in our task.

Discussion

The fact that amnesic patients showed a normal ability to overcome distraction during the training session indicates that the attentional capture they exhibited during the testing session was not due to nonspecific attentional impairments or impaired on-line representation of task priorities. Instead, our results indicate a novel role for the MTL in the acquisition of learned control over distraction. With respect to the mechanisms of this effect, we propose that sufficient experience with a given task leads to the formation of a memory trace that links the internal state of the attentional system to contextual attributes of the task, influencing control when the same task is performed in the future (Cosman & Vecera, 2012). Such a view is broadly consistent with theories of automaticity and attentional control proposing that task experience leads to the rapid acquisition of episodic traces that can be used in the service of goal-directed control (Logan, 1988, 2002).

Furthermore, recent studies have demonstrated extensive overlap in the brain systems responsible for the goal-directed control of attention to perceptual inputs and for episodic memory representations (see Cabeza, Ciaramelli, Olson, & Moscovitch, 2008). The current results suggest a bidirectional relationship between the mechanisms subserving goal-directed attentional control and those subserving episodic memory processes, raising the possibility that "attentional episodes" linked to performance of a particular task may directly influence cognitive control processes responsible for overcoming distraction by task-irrelevant information when the same task or similar tasks are performed in the future. However, using a nearly identical task, we have recently shown that learned control effects such as these arise regardless of awareness (Cosman & Vecera, 2012). Therefore, we hesitate to call these episodic memory effects per se, because explicit awareness is often considered to be requisite for episodic memory proper (e.g., Squire, 1992). Instead, we argue that MTL-dependent relational memory mechanisms important for encoding relationships between stimuli in the environment may also participate in linking internal attentional states with the context in which they arise, even when these relationships occur implicitly (see Cosman & Vecera, 2012; Olsen, Moses, Riggs, & Ryan, 2012). In this way, MTL structures may enable the rapid acquisition and storage of distributed relational representations of a task that may then be used to supplement more discrete working memory representations typically thought to drive attentional control processes (e.g., "target templates"—Desimone & Duncan, 1995).

Although an explanation of our results in terms of relational learning fits well with the proposed functions of the MTL, a possible alternative exists. Specifically, it may be the case that the MTL, rather than being necessary for attentional learning in our task, is instead involved more broadly in overriding attentional capture during homogeneous visual search tasks. In this view, it is possible that training on the heterogeneous version of our search task actually did decrease attentional capture (relative to baseline) in the amnesic patients, but that this decrease was insufficient to entirely override capture during the homogeneous visual search trials. Thus, it may be the case that the MTL is involved in attenuating capture in homogeneous search displays regardless of past experience, and that damage to the MTL influenced on-line attentional control during the testing session rather than influencing control through impaired learning.

Given the large magnitude of the capture effects observed in the amnesic group during the testing session, as well as the intact ability of these patients to overcome distraction during the training session, it seems unlikely that the training session had more than a minimal influence on attentional capture during testing. Nevertheless, it is impossible to rule out this alternative interpretation with the current data set, and it would thus be beneficial for future work to probe non-mnemonic accounts of MTL involvement in attentional control. Regardless of the precise mechanism, the current work provides strong evidence that the MTL memory system can directly participate in the goal-directed control of visual attention, and offers one means through which past experience may influence control over distraction by salient, task-irrelevant visual information.

Author Contributions

J. D. Cosman developed the study concept, and J. D. Cosman and S. P. Vecera designed the study. Testing and data collection were carried out by J. D. Cosman. J. D. Cosman wrote a draft of the manuscript, and S. P. Vecera provided revisions. Both authors approved the final version of the manuscript for submission.

Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Supplemental Material

Additional supporting information may be found at http://pss.sagepub.com/content/by/supplemental-data

References

Bacon, W. F., & Egeth, H. E. (1994). Overriding stimulus-driven attentional capture. *Perception & Psychophysics*, *55*, 485–496.

Berryhill, M. E., & Olson, I. R. (2008). Is the posterior parietal lobe involved in working memory retrieval? Evidence from patients with bilateral parietal lobe damage. *Neuropsychologia*, *46*, 1775–1786.

Cabeza, R., Ciaramelli, E., Olson, I., & Moscovitch, M. (2008). The parietal cortex and episodic memory: An attentional account. *Nature Reviews Neuroscience*, *9*, 613–625.

Chun, M. M., & Phelps, E. A. (1999). Memory deficits for implicit contextual information in amnesic patients with hippocampal damage. *Nature Neuroscience*, *2*, 844–847.

Cohen, N. J., & Eichenbaum, H. (1993). *Memory, amnesia, and the hippocampal system*. Cambridge, MA: MIT Press.

Cosman, J. D., & Vecera, S. P. (2012). Context-dependent control over attentional capture. *Journal of Experimental Psychology: Human Perception and Performance*. Advance online publication. doi:10.1037/a0030027

Cousineau, D. (2005). Confidence intervals in within-subject designs: A simpler solution to Loftus and Masson's method. *Tutorials in Quantitative Methods for Psychology*, *1*, 75–78.

Desimone, R., & Duncan, J. (1995). Neural mechanisms of selective visual attention. *Annual Review of Neuroscience*, *18*, 193–222.

Good, P. I. (1994). *Permutations tests for testing hypotheses*. New York, NY: Springer-Verlag.

Kawahara, J. (2010). Identifying a "default" visual search mode with operant conditioning. *Acta Psychologica*, *135*, 38–49.

Konkel, A., Warren, D. E., Duff, M. C., Tranel, D., & Cohen, N. J. (2008). Hippocampal amnesia impairs all manner of relational memory. *Frontiers in Human Neuroscience, 2*, Article 15. Retrieved from http://www.frontiersin.org/Human_Neuroscience/10.3389/neuro.09.015.2008/full

Leber, A. B., & Egeth, H. E. (2006). It's under control: Top-down search strategies can override attentional capture. *Psychonomic Bulletin & Review*, *13*, 132–138.

Leber, A. B., Kawahara, J.-I., & Gabari, Y. (2009). Long-term abstract learning of attentional set. *Journal of Experimental Psychology: Human Perception and Performance*, *35*, 1385–1397.

Logan, G. D. (1988). Toward an instance theory of automatization. *Psychological Review*, *95*, 492–527.

Logan, G. D. (2002). An instance theory of attention and memory. *Psychological Review*, *109*, 376–400.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience*, *24*, 167–202.

Morey, R. D. (2008). Confidence intervals from normalized data: A correction to Cousineau (2005). *Tutorials in Quantitative Methods for Psychology*, *4*, 61–64.

Norman, W., & Shallice, T. (1986). Attention to action. In R. J. Davidson, G. E. Schwartz, & D. Shapiro (Eds.), *Consciousness and self-regulation: Advances in research and theory* (pp. 1–18). New York, NY: Plenum Press.

Olsen, R. K., Moses, S. N., Riggs, L., & Ryan, J. D. (2012). The hippocampus supports multiple cognitive processes through relational binding and comparison. *Frontiers in Human Neuroscience*, *6*, Article 146. Retrieved from http://www.frontiersin.org/Human_Neuroscience/10.3389/fnhum.2012.00146/full

Olson, I. R., Moore, K. S., Stark, M., & Chatterjee, A. (2006). Visual working memory is impaired when the medial temporal lobe is damaged. *Journal of Cognitive Neuroscience*, *18*, 1–11.

Ryan, J., Althoff, R., Whitlow, S., & Cohen, N. (2000). Amnesia is a deficit in relational memory. *Psychological Science*, *11*, 454–461.

Schneider, W., & Shiffrin, R. M. (1977). Controlled and automatic human information processing: 1. Detection, search, and attention. *Psychological Review*, *84*, 1–66.

Squire, L. R. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review*, *99*, 195–231.

Theeuwes, J. (1992). Perceptual selectivity for color and form. *Perception & Psychophysics*, *51*, 599–606.

Theeuwes, J. (2010). Top-down and bottom-up control of visual selection. *Acta Psychologica*, *123*, 77–79.

Vatterott, D. B., & Vecera, S. P. (2012). Experience-dependent attentional tuning of distractor rejection. *Psychonomic Bulletin & Review*, *19*, 871–878.