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IMPLICIT MEMORY FOR NOVEL CONCEPTUAL ASSOCIATIONS IN AMNESIA

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Abstract

In two experiments, we evaluated the status of implicit memory for novel associations in amnesia. Experiment 1 assessed priming in a category exemplar generation task in which contextual information associated with a target could increase the likelihood of target generation. Control participants, but not amnesic patients, showed associative priming. Amnesics' impairment was not due to the use of explicit memory by control subjects, but reflected a genuine impairment in implicit memory for novel conceptual associations. Experiment 2 assessed priming in a relatedness judgment task, in which associative priming was manifest as slower latencies for old than for recombined pairs of unrelated words. Amnesic patients showed intact associative priming in this task. We discuss differences in the status of implicit memory for novel conceptual associations in amnesia with reference to the nature of the representation that supports priming in the two tasks and the type of processing that is required at test.

An influential view of hippocampal functioning is that the hippocampus subserves relational (Eichenbaum, 1999) or configural (O'Reilly & Rudy, 2001) learning mechanisms that are critical for binding together the disparate pieces of information that make up an event into an integrated memory trace. Substantial evidence in support of this view is now available from lesion and neuroimaging studies. For instance, amnesic patients with medial temporal lobe lesions perform disproportionately worse on explicit memory tasks requiring memory for the association between items than on tasks requiring memory for individual items (Giovanello et al., 2003; Turriziani et al., 2004). Similarly, neuroimaging studies have reported greater hippocampal activation during associative compared to item-based encoding (Davachi & Wagner, 2002; Henke et al., 1997; Henke et al., 1999), and during associative compared to item-based retrieval (Giovanello et al., 2004; Yonelinas et al., 2001).

Much of the research evaluating the role of the hippocampus in relational memory has focused on explicit memory for newly acquired associations. Therefore, while it is apparent

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that the hippocampus is critical for the formation of representations that support explicit memory for novel associations, it is less clear whether and under what conditions the hippocampus is also critical for the formation of representations that support implicit memory for novel associations. A potentially important line of evidence pertaining to this question comes from studies evaluating implicit memory for newly formed associations in amnesia. In such studies, priming for novel associations is evaluated by comparing performance in a test phase for word (or picture) pairs that had been presented as pairs in the study phase (old pairs), and for pairs for which both elements had been presented in the study phase, but not as part of the same pair (recombined pairs).

To date, studies evaluating new associative priming in amnesia have yielded mixed results. On the one hand, several studies have found intact priming for novel word pairs in amnesic patients, using tasks that require identification of briefly presented word pairs (Gabrieli et al., 1997; see also Musen & Squire, 1993) or speeded identification in the form of reading or lexical decision (Goshen-Gottstein et al., 2000; Moscovitch et al., 1986). On the other hand, several stem-completion studies have found impaired priming for new verbal associations in amnesia (Cermak et al., 1988; Mayes & Gooding, 1989; Schacter & Graf, 1986b; Shimamura & Squire, 1989).

In an attempt to accommodate these contradictory findings, we have suggested that the status of new associative priming in amnesia (and by inference, the role of the hippocampus in forming associations that support implicit memory) critically depends on the nature of the association that is established (Verfaellie & Keane, 2001; 2002). Specifically, we proposed that amnesic patients may show normal priming for novel perceptual associations, but impaired priming for novel conceptual associations (Roediger et al., 1989b). Associative priming in perceptual identification and lexical decision – both of which are preserved in amnesia – do not require establishment of a conceptual link but depend on establishment of a perceptual link, and thus provide examples of priming for novel perceptual associations. Confirming the perceptual basis of associative priming in lexical decision, Goshen-Gottstein and Moscovitch (1995a, 1995b) demonstrated that such priming is sensitive to a shift in perceptual modality, but not to a manipulation of depth of processing. By contrast, new associative priming in the stem-completion task – which is impaired in amnesia – depends on the establishment of a meaningful link between the words at study (Schacter & Graf, 1986a), and is therefore conceptual in nature. Findings from the stem-completion task, however, need to be interpreted with caution, as associative priming in that task is sometimes unreliable even in normal participants (Cermak et al., 1988).

The purpose of the present study was to evaluate further the status of implicit memory for new conceptual associations in amnesia, using tasks that lead to robust associative priming in normal individuals. We evaluated priming in two tasks, a category exemplar generation task that was adapted to assess associative priming by incorporating contextual information on each trial, and a relatedness judgment task in which participants judged whether pairs of words were related in meaning (Goshen-Gottstein & Moscovitch, 1995a). Both of these tasks require analysis of stimulus meaning and are therefore considered to be conceptual in nature; yet, they also differ in their response demands (generation versus classification). It has been suggested in the context of studies of single item priming that generation and classification tasks may be mediated by distinct conceptual priming mechanisms (Vaidya et al., 1997). This suggestion is supported by evidence from studies of normal cognition (Vaidya et al., 1997) as well as studies of neuropsychological populations (Fleischman & Gabrieli, 1998). Because it is possible that associative priming in these two types of tasks also depends on distinct priming mechanisms, the present study included both a generation task and a classification task to assess the status of conceptual associative priming in amnesia.

EXPERIMENT 1A

To adapt the category exemplar generation task to assess new associative priming, we used a design similar to that used in previous word stem completion studies of associative priming. During the study phase, participants were exposed to a series of word pairs in which the first word served as the context word and the second word as the target (e.g. moss-newspaper; banana-airplane). During the test phase, participants were presented with a context word and were asked to generate the first four exemplars of a specified category that came to mind when hearing the context word. On some trials, the context word and category prompt corresponded to a studied word pair (old condition; e.g. moss-reading material?), whereas on other trials the context word and category prompt corresponded to words that had occurred in different word pairs at study (recombined condition; e.g. moss-vehicle?). A higher proportion of target generations in the old than in the recombined condition would be evidence of implicit memory for the novel association established at study. We also included trials in which both the context word and the category prompt were new (new condition). The comparison between the recombined and new condition provided a measure of single item priming. In line with previous studies of single item priming in the category exemplar task, we predicted that item priming would be intact in amnesic patients (Graf et al., 1985; Keane et al., 1997). More importantly, we predicted that associative priming would be impaired because the exemplar generation task assesses implicit memory for a novel conceptual association between the context word and target. In parallel with the implicit category exemplar generation task, an explicit category-cued recall task was also administered to verify amnesics' impairment in explicit memory.

METHODS

Participants—Twenty amnesic individuals (12 male, 8 female) participated in this study. Six had a diagnosis of Korsakoff syndrome while the remaining 14 patients had a variety of non-alcoholic etiologies including anoxia (n=9), encephalitis (n=3), bithalamic stroke (n=1), and anterior communicating artery aneurysm (n=1). The combined amnesic group had a mean age of 57 years, a mean education of 14.3 years, and a mean verbal IQ score of 101.5, as measured by the Wechsler Adult Intelligence Scale-III (WAIS-III). Their attentional abilities, as measured by the Wechsler Memory Scale-III (WMS-III) Working Memory Index were also intact, as indicated by a mean score of 96.3. Their memory functioning was severely compromised, as indicated by a mean General Memory Index of 59.4, a mean Visual Delay Index of 65.0, and a mean Auditory Delay Index of 61.3.

The control group consisted of 21 participants (9 male, 12 female), who had been screened using an extensive health questionnaire. Six control participants had a history of alcoholism and served as controls for the Korsakoff amnesic patients, whereas 15 individuals without a history of alcoholism served as controls for the non-Korsakoff amnesic patients. Participants with a history of alcoholism had abstained from alcohol for at least 3 month prior to taking part in the experiment. The control group was matched to the amnesic group in terms of age (mean=58 years), education (mean=14.2 years), and WAIS-III Verbal IQ (mean=104.3; all t's <1).

Materials—Two exemplars from each of 36 categories were selected, with the proviso that neither exemplar was the most often generated exemplar for its category (Battig & Montague, 1969). From these exemplars, two lists of target stimuli were created, consisting of one exemplar from each category. These lists were used in the implicit and explicit tasks, with assignment of lists counterbalanced across subjects. Each target was paired with a unique unrelated word that served as its context word. Two master lists of 36 word pairs thus constructed were matched in terms of frequency of target exemplar production

(mean=272; Battig & Montague, 1969), word frequency (Francis & Kucera, 1982) of the target word (mean=40), and word frequency of the context word (mean=39).

Each master list of word pairs was divided into three sets of 12, to be rotated through the old, recombined and new conditions. The three sets were also matched in terms of mean exemplar production frequency, frequency of the target word, and frequency of the context word. Three study forms were created for each master list, each consisting of a different combination of two sets of 12 items. For one set of items, which served to create the old condition, the pairs were kept intact. For the other set of items, which served to create the recombined condition, the context word and target from each pair were randomly rearranged. Pairs were presented pseudorandomly in each study form, with the proviso that no more than three items from the same set occur in a row. Two filler pairs were added to the beginning and end of the study list. There was one test form corresponding to each master list. Each test form comprised 36 trials, on each of which a context word was presented with the category label corresponding to the target word with which the context word was paired in the master list.

Procedure—During the study phase of the implicit and explicit task, word pairs (e.g. “moss” – “newspaper”) were presented one at the time on the screen, with the context word presented above the target word. Participants were asked to read the words aloud, and were then read a statement that related both words (e.g. “adding moss to compost helps decompose newspaper”). They were asked to indicate on a 3-point scale how believable the statement was. Participants responded verbally, and 1500 msec. after their response, the next trial was initiated. During the implicit test phase, on each trial participants were given a context word and a category and were asked to generate the first four exemplars of the category that came to mind upon hearing the context word (e.g. when I say “moss”, what are the first four types of reading material that come to mind?). During the explicit test phase, on each trial participants were given a context word followed by a category and were asked to remember if an item from that particular category was on the list of words they had seen earlier, and if so, to provide that exemplar. They were told that not all categories had been on the study list and to refrain from answering if they could not remember having seen an exemplar from a particular category.

RESULTS

Preliminary analyses indicated that the pattern of results did not differ for participants with and without a history of alcohol abuse. Therefore, results from the two control subgroups were combined, as were the results of the two amnesic subgroups.

Implicit memory—Table 1 presents the proportion of target words generated by the amnesic and control group in the different test conditions. As can be seen, only the control group showed clear evidence of associative priming, as reflected in the higher rate of target completions in the old compared to the recombined condition. In contrast, both groups showed item priming, as evidenced by a higher rate of target completions in the recombined compared to new condition.

Separate analyses, performed on the arcsine-transformed data, were used to evaluate associative and item priming. Associative priming was evaluated in an ANOVA with group as the between-subjects factor and condition (old, recombined) as the within-subjects factor. This analysis revealed a main effect of group ($F(1,39)=9.40$, $p<.01$), a main effect of condition ($F(1,39)=7.16$, $p=.01$) and a marginal group x condition interaction ($F(1,39)=3.14$, $p=.08$). Associative priming was significant in the control group ($t(20)=3.1$, $p<.01$), but not in the amnesic group ($t(19)<1$). Item priming was evaluated in an ANOVA with group as the

between-subjects factor and condition (recombined, new) as the within-subjects factor. This analysis revealed a main effect of condition ($F(1,39)=10.40$, $p<.01$). Neither the effect of group ($F(1,39)=1.93$) nor the group x condition interaction ($F(1,39)<1$) were significant.

Explicit memory—Table 2 presents the proportion of targets recalled by amnesic and control participants in the various conditions. Target responses in the new condition, representing baseline guessing, were minimal in both groups. As expected, cued recall was poorer in the amnesic group than in the control group, but both groups showed better recall when the context word had previously been studied with the to-be-remembered target (old) than when it had been studied with another target (recombined).

For the purpose of analysis, proportions were arcsine transformed and submitted to an ANOVA with group as the between-subjects variable and condition (old, recombined) as the within-subjects variable. Results of the analysis revealed a significant main effect of group ($F(1,38)=21.4$, $p<.01$) and a significant effect of condition ($F(1,38)=26.97$, $p<.01$), confirming the above impressions. The group x condition interaction was not significant ($F(1,38)=1.89$).

DISCUSSION

In the implicit memory task, control participants generated more target exemplars when the category cue was presented with the same context word with which the target had been paired at study (old condition) than when it was presented with a different context word (recombined condition), indicating implicit memory for the associative relationship established between the context word and the exemplar during the study phase. Amnesic patients, in contrast, failed to show such associative priming. The amnesic group, however, did show significant single item priming, as evidenced by their greater rate of generating target exemplars in the recombined condition than in the new condition. Moreover, the magnitude of single item priming in the amnesic group was similar to that in the control group. Amnesics' selective failure to show associative priming is consistent with the hypothesis that conceptual priming for novel associations is impaired in amnesia, and suggests that the establishment of associations that can support conceptual implicit associative memory depends critically on the integrity of the hippocampus.

Before accepting this conclusion, however, it is important to rule out the possibility that associative priming in control participants was merely due to explicit memory contamination. It is possible that when presented with the category cue in the implicit exemplar generation task, control subjects intentionally retrieved a target from the study list. Such intentional retrieval would be expected to be more likely and/or more successful in the old condition than in the recombined condition, thus leading to a pattern of performance similar to that characterizing associative priming. If such were the case, the failure of amnesics to show associative priming would not reflect a genuine impairment in implicit associative memory, but rather a failure to use explicit memory in a nominally implicit task. Experiment 1B was designed to evaluate this possibility.

EXPERIMENT 1B

In their studies of priming for new associations in the stem completion task, Schacter and Graf (1986a) demonstrated that the type of associative elaboration at encoding – sentence rating versus sentence generation – affected explicit memory for novel associations, but had no effect on implicit memory for novel associations. The differential effect of the encoding manipulation on explicit and implicit memory allowed them to rule out the possibility that subjects used explicit strategies in the implicit test (Schacter et al., 1989). Here, we use a similar encoding manipulation to evaluate whether associative priming in the category

exemplar generation task is dissociable from explicit category cued recall. Control participants in this experiment performed the category exemplar generation and category cued recall task following a study phase in which they generated sentences containing the context and target word, and their performance was compared to that of the non-alcoholic control participants in Experiment 1A, who performed a sentence rating task in the study phase.

METHODS

Participants—Sixteen normal participants (5 male, 11 female), who had been screened using an extensive health questionnaire, participated in this experiment. The group was matched to the non-alcoholic control group in Experiment 1A in terms of age (mean=58 years), education (mean=14.4 years), and WAIS-III Verbal IQ (mean=103.7, all t's <1). Results from one female participant were excluded because her sentence generation indicated that several target words were interpreted in a manner different from that intended by the experimenter.

Materials and Procedure—The materials and procedure were identical to those used in Experiment 1A, with the exception of the encoding task used during the study phase. Word pairs were presented one at the time on the screen, with the context word presented above the target word. Participants were asked to read the words aloud and to generate a sentence that meaningfully incorporated both words.

RESULTS

Table 3 presents results for both the implicit and explicit tasks for participants in experiment 1B who generated sentences, as well as for the non-alcoholic control participants in experiment 1A who generated sentences. As in experiment 1A, data were arcsine transformed for the purpose of analysis. First, we analyzed results from Experiment 1B in isolation. In the implicit task, participants generated more target exemplars in the old than in the recombined condition ($t(14)=1.61$, $p<.07$, 1-tailed). Similarly, in the explicit task, they recalled more targets in the old than in the recombined condition ($t(14)=4.68$, $p<.01$).

Next, we compared implicit test results from experiments 1A and 1B in a two-way ANOVA with a between-subjects factor of encoding task (rating, generation) and a within-subjects factor of condition (old, recombined). This analysis revealed a main effect of encoding task ($F(1,28)=7.10$, $p<.05$), indicating that participants who rated sentences generated more target exemplars than those who generated sentences during the study phase. There was also a main effect of condition ($F(1,28)=7.17$, $p<.05$), indicating that more targets were generated in the old condition than in the recombined condition. Importantly, the encoding task x condition interaction was not significant ($F(1,28)<1$), indicating that the magnitude of associative priming was similar in the two encoding groups.

Finally, An ANOVA was performed on the explicit test data of experiments 1A and 1B with encoding task as the between-subjects factor and condition as the within-subjects factor. This analysis revealed a main effect of encoding task ($F(1,28)=5.84$, $p<.05$), indicating that cued recall was higher in participants who generated sentences than in those who rated sentences. There was also a main effect of condition ($F(1,28)=32.92$, $p<.01$), indicating higher recall in the old than in the recombined condition. The encoding task x condition interaction was not significant ($F(1,28)<1$).

To directly compare performance in the implicit and explicit test across the two encoding groups, we performed a 2 x 2 x 2 ANOVA with encoding (rating, generation) as the between-groups factor and test (implicit, explicit) and condition (old, recombined) as the

within-subjects factors. In addition to a main effect of condition ($F(1,28)=38.48$, $p<.01$), there was a test x condition interaction ($F(1,28)=4.62$, $p<.05$) and a test x encoding interaction ($F(1,28)=17.39$, $p<.01$). The former interaction indicated that the difference between same and different context performance was greater in the explicit test than in the implicit test. The latter interaction, more importantly, indicated that implicit memory performance was higher following rating than following sentence generation, whereas the opposite was true for explicit test performance.

DISCUSSION

Like sentence rating, sentence generation proved to be an effective encoding task to establish both implicit and explicit memory for new associations. In comparison to sentence rating, sentence generation led to an overall improvement in explicit cued recall, but to a decrement in implicit exemplar generation. The differential effects of encoding on performance in the implicit and explicit memory task provide evidence that performance on the implicit category generation task was not merely due to explicit memory contamination. Rather, it indicates that the processes that mediate performance on the two tasks are dissociable.

It should be noted, however, that despite the overall enhancement of explicit memory following sentence generation, the encoding manipulation did not differentially affect performance in the old compared to the recombined condition. The failure to obtain an effect of encoding specifically on the measure of associative explicit memory stands in contrast to the findings of Schacter and Graf (1986a)[1]. Importantly, it leaves unanswered the question as to whether implicit and explicit memory for new associations can be dissociated, as neither was affected by the encoding manipulation. To get further leverage on this question, we examined performance in a subgroup of participants in experiment 1B who had substantially greater associative explicit memory (n=7; old=.84; recombined=.41) than did the non-alcoholic participants in experiment 1A who performed the sentence rating task. As expected, an ANOVA comparing cued recall in this subgroup to that in the group who performed sentence rating revealed a significant encoding group x condition interaction ($F(1,20)=6.44$, $p<.05$). Critically, associative implicit memory in this subgroup (old=.56; recombined=.52) was no greater than in the group who performed the rating task. Confirming this impression, ANOVA comparing exemplar generation in this subgroup to the group who performed sentence rating revealed a marginal effect of encoding group ($F(1,20)=3.77$, $p<.07$), with higher completion rates for participants who performed sentence rating, but no group x condition interaction ($F(1,20)=1$). The differential effect of encoding on implicit and explicit associative memory was confirmed in an ANOVA that included test type as a factor. There was a significant interaction between test type, encoding task and condition ($F(1,20)=6.02$, $p<05$), reflecting the fact that the encoding manipulation affected explicit, but not implicit, associative memory. Thus, participants in the sentence generation condition, who showed greater associative explicit memory than those in the sentence rating condition, nonetheless showed no increase in implicit associative memory (and in fact, showed a nonsignificant decrease) compared to participants in the sentence rating condition.

These findings provide more compelling evidence that implicit memory for novel associations in the category exemplar generation task is not contaminated by explicit memory for these associations. Correspondingly, it establishes that amnesics' failure to show associative priming in experiment 1A reflects a genuine impairment in implicit

[1]One procedural difference between the two experiments is that our rating task consisted of rating how believable the information was conveyed in each sentence, whereas in Schacter and Graf (1986a) it consisted of rating how meaningfully each sentence related the two target words. It is possible that our task encouraged participants to make more elaborate connections with pre-existing knowledge, thus leading to better explicit memory for the word pair (see also Graf & Schacter, 1989).

memory for new associations in the context of a generation task. To evaluate the generality of this impairment, experiment 2 evaluated implicit memory for novel associations in the context of a verification task.

EXPERIMENT 2A

To evaluate conceptual associative priming in the context of a verification task, we adopted the relatedness judgment task introduced by Goshen-Gottstein and Moscovitch (1995a). Following exposure to related and unrelated word pairs during a study phase, participants in that study were asked to make speeded relatedness judgments about previously encountered (old) word pairs and recombined word pairs. To assess priming for novel associations, reaction times were evaluated for old and recombined pairs that were unrelated, as only responses to unrelated word pairs provide evidence for the formation of a novel association. Goshen-Gottstein and Moscovitch found that "no" responses to old unrelated pairs were slower than "no" responses to recombined unrelated pairs. Thus, associative priming was reflected as a cost in reaction time: Participants were slower to generate a "no" response to previously paired unrelated words than to recombined unrelated words, presumably because they had a harder time inhibiting a "yes" response in the former than in the latter condition (for a similar effect, see Srinivas, Culp, & Rajaram, 2000). Associative priming for novel associations was not sensitive to modality of presentation, suggesting that it was not perceptually based (Goshen-Gottstein & Moscovitch, 1995a). Instead, since the relatedness judgment task requires evaluation of the semantic attributes of words, the authors suggested that new associative priming in their task was conceptually based. The present experiment uses this paradigm to evaluate priming for novel associations in amnesic patients with the aim of assessing whether the impairment observed in experiment 1A in the context of a generation task extends to a verification task.

METHODS

Participants—Seventeen amnesic individuals (12 male, 5 female) and twenty-five participants with intact memory abilities (10 male, 15 female) participated in the experiment. Six of the seventeen participants had a diagnosis of Korsakoff syndrome while the remaining 11 patients had a variety of non-alcoholic etiologies including anoxia (n=7), encephalitis (n= 3), and bithalamic stroke (n=1). The combined group of amnesics had a mean age of 58.3 with a mean education of 14.2 years. The mean verbal IQ of the patient group as measured by the Wechsler Adult Intelligence Scale- III (WAIS-III) was 99.9. Their attentional abilities, as measured by the Wechsler Memory Scale III (WMS- III) Working Memory Index were intact, as indicated by a mean score of 97.7. Their memory functioning was severely compromised, as indicated by a mean General Memory Index of 59.5, a mean Visual Delay Index of 63.8, and a mean Auditory Delay Index of 63.1.

The control group consisted of nine individuals with a history of alcoholism and sixteen individuals with no known history of alcoholism. All had been screened using an extensive health questionnaire. The control group had a mean age of 56.6, with a mean education of 14.5, and a mean WAIS-III verbal IQ score of 103.5. The control and amnesic participants did not differ significantly in age, education, or verbal IQ (all t's <1).

Materials—The stimuli consisted of 44 arrays of 4 related words, taken from Goshen-Gottstein and Moscovitch (1995a), with the exception of 5 words that were replaced because they occurred more than once in the stimulus lists. These arrays were divided into 4 sets of 11. For each subject, two of the sets were used to create related and unrelated pairs presented in the study list, whereas the other two sets were used to create related and unrelated pairs that served as unstudied stimuli in the test list. The assignment of sets to

related versus unrelated pairs and studied versus unstudied pairs was counterbalanced across subjects.

Each study list consisted of 22 related word pairs and 22 unrelated word pairs. Related word pairs were created by selecting the first two words of an array (R1 and R2) and the last two words of an array (R3 and R4). Unrelated word pairs were created by randomly repairing the first item of an array with the second item of a different array within the same set (U1-U2), and likewise, by repairing the third item of an array with the fourth item of a different array within the same set (U3-U4).

Each test list consisted of 44 studied word pairs (22 related, 22 unrelated) and 44 unstudied word pairs (22 related, 22 unrelated). Half of the studied word pairs were presented in their studied pairing (e.g. R1-R2; U1-U2), whereas the other half were rearranged by pairing the first item of the array with the last item of the array. In this way, recombined pairs were formed, the elements of which were again related (e.g. R1-R4) or unrelated (U1-U4).

Procedure—During the study phase, each trial started with the presentation of a fixation cross for 500 msec. This was followed 500 msec. later by presentation of two words side by side for 5 seconds. Participants were asked to read each word aloud and to make a meaningful sentence that related both words in their stated order. During the test phase, each trial consisted of presentation of a fixation cross for 500 msec., followed by presentation of the word pairs side by side. Participants were asked to determine if the two words were related or unrelated. They were told that two words were to be considered related if they had a strong link between them, if they belonged to the same category, or if the two words were often seen or spoken together. Their response was recorded using a two-button response box and they were asked to respond as quickly and accurately as possible. Stimuli remained on the screen until a response was made, and the next trial was initiated 500 msec. later.

RESULTS

Because only the results from unrelated word pairs speak to the status of new associative priming in amnesia, the analysis is restricted to those items. Preliminary analyses indicated that the pattern of results did not differ for participants with and without a history of alcohol abuse. Therefore, results from the two control subgroups were combined, as were the results of the two amnesic subgroups.

As a group, amnesic participants (mean=92.6%) were less accurate at making relatedness judgments than were control participants (mean=95.6%, $t(40)=3.06$, $p<.01$). Analysis of latency data was restricted to those participants whose accuracy was at least 80% in each condition, to ensure a sufficient number of observations per condition. This resulted in elimination of the results of 4 amnesic patients and 1 alcoholic control subject.

As can be seen in Table 4, decision latencies in the amnesic group were longer and more variable than those in the control group. Nonetheless, the pattern of RTs as a function of condition was similar in the two groups. In both groups, RTs to old pairs were longer than to recombined pairs, reflecting the presence of an associative priming effect. Also, in both groups RTs to new pairs were longer than to recombined pairs, although this item priming effect was very small in the control group.

Analyses were performed on log-transformed data to evaluate each type of priming separately. To evaluate associative priming, we performed an ANOVA with group as the between-subjects factor and condition (old, recombined) as the within-subjects factor. There was a main effect of group ($F(1,35)=6.04$, $p<.05$) and a main effect of condition ($F(1,35)=13.13$, $p<.01$). Additionally, there was a marginal group x condition interaction

($F(1,35)=3.00$, $p<.10$), which indicated that, if anything, associative priming was greater in the amnesic group than in the control group. To evaluate item priming, we performed an ANOVA with group as the between-subjects factor and condition (recombined, new) as the within-subjects variable. Results of this analysis revealed a main effect of group ($F(1,35)=6.73$, $p<.05$), a marginal effect of condition ($F(1,35)=2.87$, $p<.10$) and a marginal group x condition interaction ($F(1,35)=2.87$, $p<.10$). Item priming was significant in the amnesic group ($t(12)=2.40$, $p<.05$) but not in the control group ($t(23)<1$).

DISCUSSION

Amnesic patients, like controls, were slower in judging that unrelated word pairs were not semantically related when the words constituting the pair had previously been seen together than when they had been seen as components of different word pairs. Moreover, this inhibitory effect, which constitutes evidence of associative priming, was at least as large in amnesic patients as in controls. Amnesics' ability to form novel conceptual associations that can support performance in a verification task is striking, especially in light of their impaired associative priming in the category exemplar generation task. However, the significance of this dissociation rests in part on the assumption that explicit memory for these associations would be impaired when tested in the context of a verification (recognition) task, just as it was in the context of a generation (cued recall) task. In Experiment 2B, we evaluated whether this was indeed the case.

EXPERIMENT 2B

To assess explicit memory for novel associations in the context of a verification task, we administered a recognition memory task using study and test presentations that were analogous to those in Experiment 2A. Following exposure to related and unrelated word pairs during a study phase, participants were asked to make recognition judgments about previously encountered (old), recombined, and novel word pairs. They were asked to endorse only those word pairs in which both words had been seen together in the study phase.

METHODS

Participants—Fourteen amnesic individuals (10 male, 4 female) and fourteen subjects with intact memory abilities (4 male, 10 female), all of whom had participated in Experiment 2A, were available for participation in this experiment. Five of the amnesic participants had a diagnosis of Korsakoff syndrome, and nine had a variety of nonalcoholic etiologies (5 anoxia, 3 encephalitis and 1 bithalamic stroke). The combined group of amnesics had a mean age of 60.2 with a mean education of 15 years. The mean verbal IQ of the patient group as measured by the Wechsler Adult Intelligence Scale- III (WAIS-III) was 101.7. Their attentional abilities, as measured by the Wechsler Memory Scale III (WMS-III) Working Memory Index were intact, as indicated by a mean score of 99.8. Their memory functioning was severely compromised, as indicated by a mean General Memory Index of 60.1, a mean Visual Delay Index of 64.5, and a mean Auditory Delay Index of 63.4.

The control group consisted of 5 individuals with a history of alcoholism and 10 individuals with no known history of alcoholism. The control group had a mean age of 58.4, with a mean education of 14.8, and a mean WAIS-III verbal IQ score of 104.6. The control and amnesic participants did not differ significantly in age, education, or verbal IQ (all t's < 1).

Materials and Procedure—The stimuli and procedure were identical to those in Experiment 2A, with the exception of the instructions given during the test phase.

Participants were asked to respond "old" when the two words presented on the screen had been seen as a pair during the study phase, and to respond "new" when the words had not been seen as a pair during the study phase. Participants were tested using the same study and test list as in Experiment 2A. A minimum of 14 weeks had passed since their participation in that experiment.

RESULTS

Table 5 presents the proportion of word pairs endorsed as old by amnesic and control participants in the various test conditions. The amnesic group endorsed fewer old pairs than the control group (hits), but more recombined and more new pairs (false alarms). These impressions were confirmed in an ANOVA of the arcsine-transformed data, which revealed a significant effect of condition ($F(1,26)=181.71$, $p<.01$) and a significant group x condition interaction ($F(1,26)=14.83$, $p<.01$). Post hoc comparisons indicated a reduced hit rate for old pairs in amnesia ($t(26)=4.79$, $p<.01$), and an enhanced false alarm rate for new pairs ($t(26)=2.16$, $p<.05$). Group differences in false alarms to recombined pairs did not reach significance. A direct measure of associative memory, calculated as the difference between the proportion of old and recombined pairs endorsed, revealed a significant impairment in associative memory in the amnesic group ($t(26)=4.0$, $p<.01$).

GENERAL DISCUSSION

This study evaluated the performance of amnesic patients on two tasks of conceptual priming for novel associations, with the goal of further characterizing the role of the hippocampus in relational memory. While previous studies have shown preserved priming for novel perceptual associations in amnesia (Gabrieli et al., 1997; Goshen-Gottstein et al., 2000; Moscovitch et al., 1986), we hypothesized that priming for novel conceptual associations would be impaired. This hypothesis was only partially confirmed. Amnesic patients showed impaired associative priming in a category exemplar generation task in which contextual information associated with a target could increase the likelihood of target generation, but they showed intact associative priming in a relatedness judgment task, in which priming was manifest as slower latencies for old than for recombined pairs of unrelated words. Intact associative priming in the relatedness judgment task was seen notwithstanding a striking impairment in explicit memory for the same associations.

An important question raised by these findings concerns how differences in task demands may account for these different outcomes. In the relatedness judgment task (a verification task), both elements are presented at test, and the only requirement for task performance is that the complete configuration be processed. Priming is a manifestation of the ease of processing that is conferred by recent exposure to the configuration of elements, in this case leading to slower rejection of the items as being related. Priming in this task, therefore, merely requires co-activation of elements recently processed together. By contrast, in the category exemplar generation task, only one of the constituent elements (the context word) is presented at test, and priming depends on that constituent cueing reinstatement of the rest of the configuration. Thus, priming in this task requires the reconstruction of the stimulus configuration on the basis of partial information.

We hypothesize that priming through co-activation and priming through reconstruction depend on different kinds of representations. In the verification task, a rigidly bound representation of the study configuration, without preservation of the individual status of the constituent elements, may be sufficient for priming. In contrast, in the generation task, the elements need to be linked flexibly into a representation that preserves the integrity of the constituents. Eichenbaum and colleagues (Eichenbaum & Cohen, 2001; Eichenbaum et al., 1997) have argued that these two types of representations (fused versus relational, in their

terminology) have distinct neural substrates, and particularly, that the hippocampus is critical for the creation of relational representations. By this view, amnesics' impairment in associative priming in the generation task may reflect their inability to create flexible, relational representations.

An alternative way to conceptualize differences between the generation and verification task is with regard to the role of the first constituent of a stimulus configuration at test. In the generation task, the first constituent need not be actively processed. Its effect on performance is incidental to the task at hand. In contrast, in the verification task, the first element needs to be actively processed, as does the second element. It is possible that amnesic patients show intact conceptual priming when both constituents are intentionally processed at test, but not when only one constituent is intentionally processed. Because both constituents were actively processed at study, such a pattern might represent an instantiation of transfer appropriate processing (Blaxton, 1989; Roediger et al., 1989a).

Of note, both of these interpretations not only account for the pattern of results obtained in the conceptual associative priming paradigms used here, but they also can accommodate the results from perceptual associative priming studies. The perceptual identification, lexical decision and reading paradigms that have been used to evaluate perceptual associative priming all are verification tasks in which priming occurs through co-activation (and thus can be mediated by a fused representation), and all of them also require intentional processing of the two constituent elements at study and at test. Amnesics' preserved priming in these tasks, therefore, is consistent with either hypothesis.

A potentially interesting paradigm that may help distinguish between these two hypotheses in the perceptual domain is the visual search task used by Chun and Phelps (1999). They found that amnesic patients, like controls, identified a target more quickly when the visual context in which it occurred consisted of a visual array that was repeated across multiple trials rather than a visual array that was novel. Because in this task the full visual array is presented at test, priming can be supported by a fused representation, yet the context as a whole is not processed intentionally, either at initial or at repeated presentation. Therefore, these findings might be taken as evidence that the status of associative priming in amnesia is better explained with reference to the kind of representation that supports the effect (fused versus relational) than with reference to the processing requirements associated with the task. However, a failure to replicate these findings calls into question this suggestion (Manns & Squire, 2001). Thus, future studies will be needed to evaluate which theoretical framework provides a better account of impaired and preserved new associative priming in amnesia and, by inference, a better understanding of the role of the hippocampus in associative memory.

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Table 1

Experiment 1a: Mean proportion of target words (and standard deviation) generated as a function of test condition.

	Old	Recombined	New
Amnesic	.53 (.15)	.50 (.14)	.40 (.15)
Control	.69 (.19)	.55 (.14)	.46 (.17)

Table 2

Experiment 1a: Mean proportion of target words (and standard deviation) recalled as a function of test condition. Items in the Old and Recombined conditions are recalled following study, items in the New condition reflect baseline guessing.

	Old	Recombined	New
Amnesic	.24 (.20)	.12 (.11)	.02 (.04)
Control	.57 (.28)	.34 (.24)	.00 (.00)

Table 3

Mean proportion of target words (and standard deviation) provided in the implicit and explicit test as a function of test condition for participants who generated sentences (in Experiment 1B) and for a matched subgroup of participants who rated sentences (in Experiment 1A).

	Old	Recombined	New
Generation			
Implicit	.57 (.14)	.48 (.15)	.47 (.17)
Explicit	.77 (.18)	.52 (.17)	.01 (.03)
Rating			
Implicit	.70 (.22)	.58 (.11)	.54 (.13)
Explicit	.57 (.30)	.37 (.25)	.00 (.00)

Table 4

Experiment 2A: Mean decision latency (and standard deviation) for unrelated word pairs as a function of test condition

	Old	Recombined	New
Amnesic	2739 (1737)	2410 (1624)	2504 (1402)
Control	1634 (555)	1539 (427)	1552 (486)

Table 5

Experiment 2B: Mean proportion (and standard deviation) of word pairs endorsed as old as a function of test condition

	Old	Recombined	New
Amnesic	.61 (.18)	.21 (.18)	.08 (.15)
Control	.89 (.14)	.14 (.20)	.00 (.01)