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# Preserved verb generation priming in global amnesia

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**Abstract**—In the verb generation task, participants are presented with nouns and generate for each one an appropriate verb. Raichle *et al.* (*Cerebral Cortex*, 1994, **4**, 8–26) found that when participants generated verbs to repeated nouns, generation latencies were reduced and different patterns of brain activation were present. In order to examine whether verb generation priming is dependent or independent of declarative memory, verb generation priming was compared between 13 amnesic (seven with alcoholic Korsakoff's syndrome, six with other etiologies) and 19 control participants (10 with a history of alcoholism). Both amnesic and control participants became faster across blocks on repeated nouns and slowed when novel nouns were introduced. Priming was verb specific for both groups: it was equivalent whether generated to a repeated or a novel noun. Verb generation priming, therefore, can occur independently of declarative memory. © 1997 Elsevier Science Ltd

Key Words: conceptual priming; hippocampus; Korsakoff's syndrome; semantic processing; non-declarative memory.

## Introduction

Verb generation is a widely used task in functional neuroimaging investigations of the brain bases of semantic processing [11, 13–15, 24]. Participants are presented with nouns (e.g., ant) and are asked to generate for each one a related verb (e.g., crawl). In neuroimaging studies, brain activation during verb generation is compared to that occurring when participants read the presented nouns aloud. The generation and reading tasks are thought to have similar perceptual (visual analysis of words) and motor (speaking a word) demands, but to differ in the degree of semantic analysis required to generate a verb versus read a noun. The difference in semantic analysis produces greater activation in the left inferior prefrontal cortex, anterior cingulate gyrus and right inferior lateral cerebellum [13–15]. When nouns are repeated across blocks, performance changes, as do the brain systems that support performance: primed verbs are generated more quickly, and the left prefrontal, cingulate and cerebellar activations are reduced. The right and left sylvian insular cortexes show corresponding activation increases [15]. Reintroduction of novel nouns reverses these changes: participants respond more slowly, and the pattern of brain activity returns to what it was when participants were first generating verbs to novel nouns. The shifts in neural activity underlying verb generation priming are better understood than any other form of priming.

Seger *et al.* [19] performed a series of behavioral experiments exploring verb generation priming, with generation time as the dependent measure. They found that priming was specific to verbs rather than to nouns or to noun–verb pairs: repeated verbs were generated more quickly than unrepeated verbs when participants were transferred to novel nouns, and repeated verbs were generated as quickly to novel nouns as to repeated nouns. Priming was equivalent after overt or covert generation. Priming for translation equivalents of verbs transferred across languages in bilinguals without any cost due to the change in language. The magnitude of priming for a verb on a generation task was the same after reading it as after generating it to a noun. Priming, however, was reduced when verbs were processed orthographically from the levels achieved when verbs were processed semantically.

Based on these results, Seger *et al.* [19] proposed that verb generation priming meets some, but not all, of the criteria that have been proposed to define conceptual repetition priming. Conceptual forms of repetition prim-

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ing are expressed on tests in which participants are given cue stimuli that are semantically related to previously studied target items, in contrast to perceptual repetition priming tests in which participants are given cue stimuli that are identical to or perceptually overlap the target stimuli. Roediger and McDermott [17] proposed two criteria for conceptual priming tasks: they should not be affected by variations in perceptual presentation of the stimuli, and should be affected by variations in conceptual processing of the stimuli, due to either a level of processing manipulation or a read/generate manipulation. Verb generation meets the first criterion: it is not affected by a change in language, and therefore by a change in the surface structure of stimuli. Verb generation, however, is not affected by all manipulations of conceptual processing: it is affected by levels of processing manipulation, but not a read/generate manipulation. Seger *et al.* [19] hypothesized that the semantic processing due to reading was sufficient for full priming of the verb for the generation task. Additional semantic processing due to generation did not increase priming, but reduced semantic processing due to orthographic judgment was insufficient to support full priming. In terms of brain systems, verb generation priming yields a reduction in left frontal brain activation, as do other conceptual priming tasks [3, 7, 15].

Global amnesia in humans is characterized by profound impairment in memory for events and the information encountered during those events. Amnesic patients perform poorly on explicit tests of declarative memory, such as recall and recognition [21]. However, amnesic patients can perform normally on implicit tests of non-declarative or procedural memory. Some theorists have argued that all forms of conceptual priming are impaired in amnesia [2]. Others, however, have argued that conceptual priming can occur normally in amnesia [5, 6, 10, 23]. Conceptual priming tasks that are unimpaired in amnesia include word associate priming, in which participants are required to generate responses to semantic associates of previously studied words [5, 6, 20, 23], and category exemplar priming, in which participants generate members of semantic categories following exposure to exemplars of these categories [9, 10]. Other tasks that researchers have identified as being conceptual priming tasks, such as general knowledge priming, are impaired in amnesia [2, 22]. The general knowledge test, however, may be reliant on explicit memory, and hence be an inappropriate test of implicit memory [22].

The goal of the present study was to determine the status of verb generation priming in amnesia. By the view that all forms of conceptual memory are impaired in amnesia, verb generation should be impaired [2]. Furthermore, normal participants in verb generation priming experiments are aware of the repeated nature of nouns, and aware of their own tendencies to respond to repeated nouns with repeated verbs. This awareness may indicate a contribution of explicit memory to verb generation priming [19]. In that case, priming should be impaired in amnesia. However, neuroimaging studies have not found hippocampal or diencephalic activations in repeated verb generation, favoring the possibility that such priming is intact in amnesia. Direct testing with amnesic patients will reveal the dependence or independence of verb generation priming on the hippocampal–diencephalic declarative memory systems compromised in amnesia.

## Methods

### *Participants*

There were four groups of participants in this experiment, two groups of amnesic patients and two control groups. Age, years of education, etiology, Wechsler Adult Intelligence Scale—Revised (WAIS-R) verbal IQ and Wechsler Memory Scale (WMS) measures for each amnesic patient are given in Table 1. The patients with Korsakoff's amnesia were seven men with a mean age of 63.7 years, a mean of 10.7 years of education and mean WAIS-R verbal IQ of 92.3; the corresponding alcoholic controls were 10 men with a mean age of 60.7 years, a mean of 11.8 years of education and a mean WAIS-R verbal IQ of 99.3. The patients with amnesia due to other etiologies were three men and three women without neurological impairment, with a mean age of 53.2 years, a mean of 16.0 years of education and a mean WAIS-R verbal IQ of 107.0; the non-alcoholic controls were four women and five men with a mean age of 55.3 years, a mean of 15.6 years of education and a mean WAIS-R verbal IQ of 111.0.

### *Materials*

The stimuli consisted of two different noun lists of 40 words each (lists 1 and 2 in the Appendix) that were used by Raichle *et al.* [15]. Ambiguous words (e.g., saw) and nouns which tend to generate the same verb (e.g., fork–eat, food–eat) were avoided within the lists (Buckner, R., personal communication). The semantic similarity of the nouns and association of different nouns with common verbs across lists were not controlled. The experiment consisted of five blocks of 40 trials each. The same noun list (repeated list) was used for Blocks 1–4, with the nouns presented in a different random order in each block. In Block 5, the other, novel, list of nouns was presented. Noun lists 1 and 2 were counterbalanced as repeated and novel items across participants. The recognition test list consisted of 80 nouns, 20 from list 1, 20 from list 2 and 40 novel distracters. In addition, there was a practice list of 15 nouns, none of which appeared on the repeated or novel noun lists.

### *Procedure*

Participants were asked to generate an appropriate verb for each noun presented to them on the computer screen. An appropriate verb was defined as one that is related to the noun that appears on the screen; that is, one that describes what the presented noun might do, or what it might be used for. Participants were instructed to generate the verbs as quickly as possible, without worrying about the quality or novelty of the chosen verb. Participants were not informed that the nouns might be repeated. Participants were instructed verbally by the experimenter, and in addition a card with the instructions written on it was placed by the computer so that the participant could refer to it during testing if needed.

Table 1. Patient characteristics*

| Patient | Age | Etiology | Years of education | WAIS-R verbal IQ | WMS | | |
|---|---|---|---|---|---|---|---|
| | | | | | Attention | Delay | Overall |
| 1 | 68 | Korsakoff's | 9 | 93 | 109 | 62 | 76 |
| 2 | 61 | Korsakoff's | 11 | 90 | 99 | 61 | 99 |
| 3 | 50 | Korsakoff's | 12 | 95 | 97 | 55 | 84 |
| 4 | 67 | Korsakoff's | 7 | 88 | 96 | 53 | 76 |
| 5 | 80 | Korsakoff's | 12 | 108 | 104 | 54 | 67 |
| 6 | 65 | Korsakoff's | 12 | 83 | 99 | 50 | 66 |
| 7 | 57 | Korsakoff's | 12 | 89 | 91 | 50 | 62 |
| 8 | 45 | Aneurysm | 12 | 89 | 95 | 52 | 70 |
| 9 | 67 | Encephalitis | 18 | 126 | 114 | <50 | 102 |
| 10 | 38 | Anoxia | 12 | 104 | 108 | 71 | 88 |
| 11 | 67 | Anoxia | 18 | 103 | 93 | 66 | 68 |
| 12 | 45 | Encephalitis | 16 | 111 | 107 | 69 | 81 |
| 13 | 58 | Anoxia | 20 | 109 | 89 | 61 | 65 |

*WAIS-R, Wechsler Adult Intelligence Scale—Revised; WMS, Wechsler Memory Scale. Two patients (patient 9 in 1971; patient 12 in 1990) became amnesic following encephalitis. Patient 8 became amnesic following an aneurysm of the right posterior communicating artery in 1990. The remaining patients became amnesic following a period of anoxia due to cardiac arrest (patient 13 in 1981; patient 11 in 1995) or to drug overdose (patient 10 in 1993).

At the start of each block, the word READY appeared in the center of the screen. For each trial, a noun was presented in the center of the screen, and remained there until the microphone recorded a response. All reaction times were recorded using a Macintosh computer system running Psychlab software. A voice key gated by the amplitude of a microphone input was used to measure voice onset times. The verb generated was written down by the experimenter and recorded onto a cassette tape to allow the experimenter to check the accuracy of the verbs recorded. When the voice key was triggered, the display was cleared and the next noun was presented.

The experiment consisted of a practice block using the practice list, followed by five blocks, four using the repeated list and the final block using the novel list. Ten participants (two Korsakoff's amnesic patients, two normal controls and six alcoholic controls) did not perform the practice block. Participants received a short break (approximately 10 sec in duration) between blocks. After the verb generation blocks, participants performed the recognition test using the recognition test list. Nouns were presented as in the verb generation trials, but rather than generating a verb participants said 'yes' if the noun had appeared in the verb generation blocks and 'no' if it had not.

## Results

For each participant, median reaction times were calculated for each block (Fig. 1). Trials on which the voice key was triggered accidentally, as noted by the experimenter during testing, were eliminated from the analysis. On Block 5 (novel nouns), median reaction times were calculated separately for repeated and unrepeated verbs. A repeated verb was defined as one that had been generated by the participant in at least two of the preceding four blocks. Overall, 53% of the verbs in Block 5 were repeated. Amnesic participants generated slightly more repeated verbs (mean = 58% repeated) than control participants (mean = 50% repeated) [$F(1,28) = 5.3$, $MSE = 108.9$, $P < 0.05$]; there was no main effect of alcohol abuse history or interaction of amnesia and alcohol abuse.

A three-way analysis of variance (ANOVA) with between-participants factors of amnesia and alcohol history and a within-participant factor of noun block (1–4) was performed. Participants became faster across blocks [$F(3,84) = 11.60$, $MSE = 5372965$, $P < 0.001$]. There was a trend towards an interaction between block and alcohol

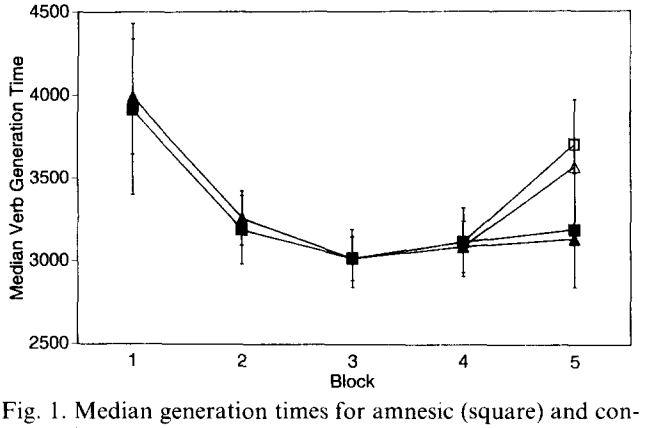


Fig. 1. Median generation times for amnesic (square) and control (triangle) participants by block. In Blocks 1–4 the same nouns were repeated. In Block 5, novel nouns were used; reactions times for repeated (filled symbols) and unrepeated (open symbols) verbs are represented separately. Brackets indicate standard errors.

history [$F(3,84)=2.25$, $MSE=1043119$, $P=0.088$]; patients with a history of alcohol abuse were slower than the non-alcoholic participants in the first block, but only slightly slower in Blocks 2–4. It is unclear whether this difference is due to alcohol abuse history or the somewhat older age of the alcoholic participants. There was no main effect of amnesia or alcohol history and no other interaction (all $F<1.0$), indicating that priming was similar in control and amnesic groups.

Generation times for novel and repeated verbs in Block 5 were compared in a three-way ANOVA with factors of amnesia, alcohol history and verb repetition within Block 5 in order to investigate the degree to which priming was verb specific. Because all of the nouns in Block 5 were novel, a difference in generation time between repeated and novel verbs indicates verb-specific priming. There was a main effect of verb repetition, such that repeated verbs were generated more quickly than unrepeated verbs [$F(1,28)=6.16$, $MSE=3571897$, $P<0.05$]. There were no significant effects of amnesia or alcohol history, and no significant interactions.

Generation times for repeated verbs in Block 4 (in which the nouns were also repeated) and repeated verbs in Block 5 (in which the nouns were novel) were compared in order to examine whether any amount of verb generation priming was attributable to a noun- or noun–verb pair-specific component. A three-way ANOVA with factors of amnesia, alcohol history and block indicated no difference between repeated verbs in Block 4 and repeated verbs in Block 5 ($F<1.0$), indicating that noun repetition did not play a role in verb generation priming for either amnesic or normal participants. There was no effect of amnesia or alcohol history, and no significant interactions.

A two-way ANOVA with factors of amnesia and alcohol history was performed on recognition scores. Amnesic participants (mean = 72.8% correct, S.D. = 8.1) performed significantly worse than control participants (mean = 94.0% correct, S.D. = 4.3) [$F(1,28)=89.66$, $MSE=3493$, $P<0.001$]. There was no effect of alcohol history and no interaction (all $F<1.0$).

## Discussion

Patients with global amnesia demonstrated normal verb generation priming. Amnesic patients showed a normal decrease in generation times across blocks of repeated nouns, and a normal transfer of priming to novel nouns. In both amnesic and control participants, priming was specific to the verb being generated and independent of the noun to which the verb was generated. Amnesic participants generated slightly more repeated verbs than control participants.

Verb generation priming was dissociable from declarative knowledge: amnesic patients recognized significantly fewer of the nouns that had appeared in the experiment than did control participants. Further, priming was independent of etiology; patients with alcoholic Korsakoff syndrome did not perform differently than patients with amnesia due to other etiologies. This implies that verb generation priming is not dependent on additional brain areas compromised in Korsakoff's disease.

These results may be compared with brain imaging studies. Practiced verb generation resulted in decreased activation in the left inferior prefrontal cortex, anterior cingulate gyrus and right inferior lateral cerebellum, and increased activation in a sylvian insular region [15]. All of these brain areas are typically undamaged in patients with amnesia, and thus could plausibly have mediated the patients' intact priming. Indeed, the left prefrontal activation decrease during repeated verb generation [15] corresponds to left prefrontal decreases in activation shown by amnesic patients performing another semantic repetition priming task [8]. Thus, it is plausible that the neural network that mediates verb generation priming is intact in patients with global amnesia.

Furthermore, Raichle *et al.* [15] found no hippocampal or diencephalic activations during initial or repeated verb generation. Also, a common finding in functional imaging studies of memory is right prefrontal activation during intentional retrieval from memory [12]. Activation in right prefrontal areas, however, did not change in practiced verb generation [15]. Abdullaev and Posner [1] found that right prefrontal areas were activated, as measured by evoked response potentials, when participants intentionally retrieved previously generated verbs. Because right prefrontal areas have been showed to be involved in retrieval from episodic memory [12], it would be expected that amnesic patients would be impaired on a verb generation task in which they were instructed to generate the same verb to each presentation of a particular noun. The absence of medial–temporal, diencephalic and right frontal activation during repeated verb generation provides a good correspondence between imaging and lesion findings in that brain areas critical for explicit retrieval are not involved in verb generation priming.

Preservation of verb generation priming in amnesia adds to a growing body of evidence that many conceptual tasks, including category exemplar priming and word association priming, are intact in amnesia [5, 6, 9, 10, 20, 23]. Preservation of verb generation priming in amnesia supports theories postulating that the core impairment in amnesia is one of explicit retrieval [5, 6, 23] rather than one of conceptual memory [2].

Implicit memory tasks are often defined in terms of unconscious knowledge: implicit tasks are ones in which participants need not be aware of a connection between study and test for learning to be measurable. However, normal explicit awareness of learning is a poor predictor of the relation between declarative memory processes that support awareness and implicit memory processes that mediate priming. It is possible for participants to be aware that test items are related to earlier studied items

without using an explicit recall strategy [4, 16]. In verb generation, normal participants are aware of the repeated nature of nouns, and aware of their own tendencies to respond to repeated nouns with repeated verbs [19]. Preservation in amnesia has been proposed as an alternative criterion for considering a task to be implicit [18], and using this criterion, verb generation is an implicit task.

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## Appendix: Word lists

Practice list: army, brain, church, cloud, disease, doctor, guest, hair, house, itch, joke, law, lollipop, statue, tax.

List 1: basket, bed, bee, beer, blanket, boat, brick, broom, chair, crayon, dog, fire, fist, food, foot, glove, gun, horn, hose, ice, job, key, lens, letter, match, money, needle, oven, paper, phone, pill, plane, pool, purse, razor, scale, school, soap, toy, tree.

List 2: ball, baton, bell, bench, bike, book, cane, car, cat, cigar, doll, dollar, door, fan, finger, flag, fork, gift, grave, gum, hammer, jet, knife, ladder, lake, lawn, milk, movie, oar, pen, radio, rifle, ruler, seed, shirt, song, stove, towel, wheel, yarn.