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# Convergent Behavioral and Neuropsychological Evidence for a Distinction Between Identification and Production Forms of Repetition Priming

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Four experiments examined a distinction between kinds of repetition priming which involve either the identification of the form or meaning of a stimulus or the production of a response on the basis of a cue. Patients with Alzheimer's disease had intact priming on picture-naming and category-exemplar identification tasks and impaired priming on word-stem completion and category-exemplar production tasks. Division of study-phase attention in healthy participants reduced priming on word-stem completion and category-exemplar production tasks but not on picture-naming and category-exemplar identification tasks. The parallel dissociations in normal and abnormal memory cannot be explained by implicit–explicit or perceptual–conceptual distinctions but are explained by an identification–production distinction. There may be separable cognitive and neural bases for implicit modulation of identification and production forms of knowledge.

The distinction between explicit and implicit retrieval in tests of memory has become a focus of intense research because it may reveal how the functional neural architecture of memory subserves and constrains human learning. Explicit retrieval is invoked in the conscious remembrance of events and facts (Graf & Schacter, 1985) and is measured by tests that make direct (M. K. Johnson & Hasher, 1987) reference to prior experience, such as tests of recall or recognition. Implicit retrieval occurs incidentally in the course of task performance and is measured indirectly by changes in performance that can be attributed to prior experience with a task or a stimulus. Such memory can be measured by delay classical-conditioning, skill-learning, or repetition-priming tasks that make no reference, at the time

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of retrieval, to prior experience. Repetition priming refers to changes in speed, accuracy, or bias in processing a previously experienced stimulus (usually a word or picture) relative to an appropriate baseline.

The distinction between explicit and implicit retrieval is supported by convergent evidence from normal and abnormal memory performance. For example, if healthy participants are presented with words during a study phase (e.g., STAMP) and are later asked to complete three-letter stems (e.g., STA) to the first word that comes to mind, they exhibit priming by being biased to complete the stems to form the study-phase words more often than they would by chance. Study-phase manipulations, such as semantic versus nonsemantic encoding or generating versus reading words, that have a profound impact on explicit recall or recognition have no effect or even the opposite effect on priming in word-stem completion (e.g., Fleischman et al., 1997; Gabrieli et al., 1994; Graf & Mandler, 1984; Graf, Mandler, & Haden, 1982; Roediger, Weldon, Stadler, & Riegler, 1992; Schwartz, 1989; but see Challis & Brodbeck, 1992).

The same dissociation between explicit and implicit retrieval occurs in patients with global amnesia who have severe and pervasive deficits in explicit memory performance that are due to bilateral medial-temporal or diencephalic lesions. Amnesic patients exhibit intact word-stem completion priming despite impaired recall and recognition for study-phase words (Gabrieli et al., 1994; Graf, Squire, & Mandler, 1984; Keane, Gabrieli, Mapstone, Johnson, & Corkin, 1995; Warrington & Weiskrantz, 1970). Parallel dissociations in healthy and amnesic memory performance have been found on other tasks, including identification of words at threshold durations, where priming is measured as superior identification of studied versus baseline words (Cermak, Talbot, Chandler, & Wolbarst, 1985; Jacoby & Dallas, 1981; Keane et al., 1995; Schwartz, 1989), and speeded picture naming, where priming is measured as faster naming of studied than of baseline pictures (Carroll, Byrne, & Kirsner, 1985; Cave & Squire, 1992; Verfaellie, Gabrieli, Vaidya, Croce, & Reminger, 1996). The functional dissociations between implicit and explicit memory, therefore, reflect the anatomic separation between neural systems that mediate the two kinds of memory retrieval.

Repetition priming is further dissociable into perceptual and conceptual forms (e.g., Blaxton, 1989; Roediger, Weldon, & Challis, 1989). Perceptual priming reflects implicit memory for stimulus *form* and is reduced when there is a study–test change in stimulus form. Perceptual priming is, therefore, modality specific. For example, there is less word-stem completion priming with visually presented stems when study-phase words are heard than when they are seen (Gabrieli, Fleischman, Keane, Reminger, & Morrell, 1995; Graf, Shimamura, & Squire, 1985). Word-identification priming is also reduced when the stimulus modality changes from study to test (Jacoby & Dallas, 1981; Keane, Gabrieli, Fennema, Growdon, & Corkin, 1991). Within a modality, perceptual priming is reduced when there is a study–test change in notation (e.g., a picture of a cat and the word *cat* are two different visual notations of the same concept). Priming is greater for pictures named at test when pictures rather than the corresponding words (picture names) have been presented at study (Brown, Neblett, Jones, & Mitchell, 1991; Durso & Johnson, 1979; Lachman & Lachman, 1980; Park & Gabrieli, 1995).

Conceptual priming, in contrast, reflects implicit memory for stimulus *meaning*. Conceptual priming is often enhanced by conceptual elaboration at study (e.g., Keane et al., 1997; Monti et al., 1996; Srinivas & Roediger, 1990; Vaidya et al., 1997) and is often intact in global amnesia (e.g., Graf et al., 1985; Keane et al., 1997; Shimamura & Squire, 1984; Vaidya, Gabrieli, Keane, & Monti, 1995). Perceptual and conceptual forms of priming are often dissociable because modality and notation manipulations affect perceptual but not conceptual priming, whereas manipulation of conceptual encoding affects conceptual but not perceptual priming.

The functional dissociations between perceptual and conceptual priming appear to reflect corresponding anatomic separation between neural systems that mediate the two kinds of implicit memory. Lesion evidence and neuroimaging evidence indicate that perceptual priming reflects plasticity in modality-specific neocortex. Thus, visual priming for words and pictures has been tied to visual regions of the occipital neocortex (e.g., Blaxton et al., 1996; Blaxton et al., 1999; Buckner et al., 1995; Fleischman et al., 1995; Gabrieli et al., 1995; Keane et al., 1995; Schacter, Alpert, Savage, Rausch, & Albert, 1996; Squire et al., 1992). Presumably, auditory and tactual priming reflect plasticity in auditory and somatosensory regions, respectively. Conceptual priming has been tied to left frontal and temporal-parietal brain regions (Blaxton et al., 1996; Demb et al., 1995; Gabrieli et al., 1996; Raichle et al., 1994; Swick & Knight, 1996).

Patients with Alzheimer's disease (AD) provide further support for both implicit–explicit and perceptual–conceptual distinctions. AD patients, like amnesic patients, exhibit a dissociation between impaired recall and recognition for words and intact word-identification priming (e.g., Abbenhuis, Raajmakers, Raajmakers, & Van Woerden, 1990; Fleischman et al., 1995; Keane et al., 1991; Koivisto, Portin, & Rinne, 1996; Russo & Spinnler, 1994). AD patients, unlike amnesic patients, exhibit reduced conceptual priming on word-association and category-exemplar production tests (Brandt, Spencer, McSorely, & Folstein, 1988; Carlesimo, Fadda, Marfia, & Caltagirone, 1995; Monti et al., 1996; Salmon, Shimamura, Butters, & Smith, 1988). Thus, AD patients demonstrate a dissociation not seen in amnesia—intact perceptual priming and impaired conceptual priming (the opposite dissociation was reported in focal-lesion patients by Fleischman et al., 1995, Gabrieli et al., 1995, and Keane et al., 1995).

The AD pattern of impaired explicit memory, impaired conceptual priming, and intact perceptual priming may be understood in terms of how the characteristic neuropathology of the disease affects memory systems. Impaired explicit memory is thought to reflect, in large part, early and extensive medial temporal-lobe damage in AD (Hyman, Van Hoesen, Damasio, & Barnes, 1984; Hyman, Van Hoesen, Kromer, & Damasio, 1986). This area corresponds to the site of primary damage in many cases of amnesia, and AD patients typically have an explicit memory disorder comparable to that seen in amnesic patients (e.g., Corkin, 1982; Gabrieli et al., 1994; Heindel, Salmon, Shults, Walicke, & Butters, 1989; Shimamura, Salmon, Squire, & Butters, 1987). Impaired conceptual priming is thought to reflect substantial damage to association neocortices in the frontal, parietal, and temporal lobes (Brun & Englund, 1981). The neocortical damage results in multiple cognitive deficits (i.e., dementia) in language, reasoning, and other nonmnemonic domains. In this regard, AD differs from pure amnesia: In amnesia, nonmnemonic abilities are relatively spared, neocortical areas are uninjured, and conceptual priming remains intact. Spared perceptual priming in AD is thought to reflect the relative sparing of primary and secondary modality-specific neocortical regions. In vivo metabolic imaging studies (e.g., Frackowiak et al., 1981; K. A. Johnson, Mueller, Walshe, English, & Holman, 1987) and postmortem studies of late-stage AD patients (Arnold, Hyman, Flory, Damasio, & Van Hoesen, 1991; Brun & Englund, 1981; Lewis, Campbell, Terry, & Morrison, 1987) showed relatively little compromise of primary visual, somatosensory, and auditory cortices. Secondary cortices showed intermediate degrees of injury (Lewis et al., 1987).

AD patients often show an additional priming deficit, however, that cannot be accounted for by either implicit–explicit or perceptual–conceptual distinctions. AD patients often exhibit a marked deficit in word-stem completion priming (Bondi & Kaszniak, 1991; Carlesimo et al., 1995; Gabrieli et al., 1994; Heindel et al., 1989; Keane et al., 1991; Salmon et al., 1988; Shimamura et al., 1987; but see Fleischman & Gabrieli, 1998, for a review of studies reporting intact priming). The word-stem completion deficit cannot be accounted for either by explicit memory failure in AD, because such priming is intact in amnesia, or by conceptual priming failure in AD, because word-stem completion is a perceptual form of priming that is typically unaffected by conceptual encoding manipulations. Indeed, the AD deficit is manifest under conditions that yield normal priming in amnesic patients and in which control participants show no effect of conceptual encoding on priming (Gabrieli et al., 1994). Further, a single group of AD patients demonstrated a dissociation between impaired word-stem completion priming and intact word-identification priming (Keane et al., 1991). Such a dissociation is not predicted by the implicit–explicit distinction: Both kinds of priming are consistently dissociated from explicit memory in healthy and amnesic participants. The dissociation is not predicted by the perceptual–conceptual distinction: Both kinds of priming are consistently characterized as perceptual and not conceptual.

Another distinction in memory processing, however, may explain the dissociations between perceptual priming tasks in AD—that between identification and production forms of repetition priming (Gabrieli et al., 1994). Identification priming tasks instruct participants to identify presented stimuli. Identification can involve the analysis of form or meaning. Stimuli may be presented normally, such as in tasks of word or picture naming, lexical decision, or semantic verification. Stimuli may also be presented in degraded forms, such as in tasks of identification of briefly presented or fragmented words and pictures. In all of these cases, participants attempt to identify some feature of the presented cue. Production priming tasks, in contrast, instruct participants to use a presented cue to guide retrieval of a response. The cue could be a word stem (e.g., STA), a word associate (e.g., BABY–?), or a semantic category (e.g., BIRDS–?). Production tasks cannot be performed by mere identification of the cue. In this view, intact word-identification priming and impaired word-stem completion priming in AD reflect the selective sparing of identification priming processes and compromise of production priming processes.

The dissociation in AD raises the possibility that identification and production forms of priming differ in their neural bases, but it does not specify what psychological property distinguishes the two classes of priming. There is some evidence from studies with healthy people that identification and production forms of priming differ in their demands on attention. Auditory division of attention during visual study of words reduces word-stem completion priming but does not affect word-identification priming (Gabrieli et al., 1999). Thus, divided attention in healthy participants yields the same novel dissociation seen in AD between two implicit, perceptual forms of memory. This attention-driven dissociation cannot be explained by explicit–implicit or perceptual–conceptual distinctions but is consistent with the identification–production distinction.

Our goal in the present research was to determine whether the identification–production distinction is a broad principle of implicit memory that extends across a range of paradigms. One question we asked was whether the distinction would apply to another perceptual priming task, picture naming. In Experiment 1, a single group of AD patients performed two perceptual priming tasks, one of identification (picture naming) and one of production (word-stem completion). In Experiment 2, we examined whether dividing the attention of healthy participants at study would differentially affect priming on the same two kinds of perceptual priming tasks. In Experiments 3 and 4, we examined whether the identification–production distinction would extend to conceptual forms of priming. In Experiment 3, a single group of AD patients performed two conceptual priming tasks, one of identification (category-exemplar verification) and one of production (category-exemplar production). In Experiment 4, we examined whether dividing the attention of healthy participants at study would differentially affect priming on the same two kinds of conceptual priming tasks.

Support for the identification–production distinction would be obtained if division of attention and AD reduced priming on production tasks (word-stem completion and category-exemplar production) but not on identification tasks (word identification and category-exemplar verification). Neither implicit–explicit nor perceptual–conceptual theories predict these dissociations. Parallel consequences of the division of normal attention and AD would suggest a third major functional distinction in memory processes.

## Experiments 1a, 1b, and 1c

Our main goal in Experiment 1 was to test and to extend the observation that two forms of perceptual priming can be dissociated in AD (Keane et al., 1991). In the present study, the tests of perceptual priming were word-stem completion and picture naming. Picture-naming priming is well documented as being dissociable from explicit memory retrieval because such priming is unaffected by global amnesia (Cave & Squire, 1992; Verfaellie et al., 1996), by semantic versus nonsemantic encoding (Carroll et al., 1985), by a 6-week versus 1-week study–test interval (Mitchell & Brown, 1988), by developmental changes in 5-, 7-, and 10-year-old children that enhance recognition memory (Carroll et al., 1985), and by age-related changes in people 63–80 versus 19–32 years old that reduce recognition memory (Mitchell, 1989). Picture-naming priming is not conceptual because it is unaffected by semantic versus nonsemantic encoding. Such priming is perceptual in nature because it is reduced when participants see picture names (words) rather than pictures at study (Brown et al., 1991; Durso & Johnson, 1979; Lachman & Lachman, 1980; Park & Gabrieli, 1995).

Thus, word-stem completion and picture naming provide two measures of perceptual priming that are dissociable both from implicit-conceptual and from explicit memory retrieval. The two tasks differ, however, in that picture naming is a test of stimulus identification, whereas word-stem completion is a test of cue-guided production. Therefore, we predicted that AD patients would show intact priming as measured by picture naming but not as measured by word-stem completion.

In Experiments 1a, 1b, and 1c, AD patients performed one picture-naming task (Experiment 1a) and two word-stem completion tasks. The picture-naming task included a measure of explicit recognition memory for pictures. One word-stem completion task used the names of the pictures that were used in the picture-naming task (Experiment 1b). The second word-stem completion task (Experiment 1c) examined the importance of semantic versus nonsemantic encoding, word frequency, and the strength of the relation between a stem cue and the studied target completion. Experiment 1c also included a matched measure of explicit cued recall.

### *Method*

#### *Participants*

Groups of 12 AD patients and 12 normal control (NC) participants took part in Experiments 1a and 1c; 2 additional NC participants took part in Experiment 1b to increase statistical power. There was no significant difference between the groups with regard to age or educational level. The 24 participants (12 AD and 12 NC) who performed all three tasks were tested in two sessions that took place from 7 to 28 days apart. They performed the picture-naming, picture-recognition, and stem-cued recall tests in the first session and the two word-stem completion tests in the second session. The 2 additional NC participants were tested in a single session.

*AD group.* The 6 men and 6 women in this group had a mean age of 71.8 years (range = 62–82 years) and a mean educational level of 14.4 years (range = 8–18 years). All patients were community dwelling and were referred from the Rush Alzheimer's Disease Center. All patients met the criteria of the National Institute of Neurological and Communicative Disorders and Stroke—Alzheimer's Disease and Related Disorders Association for the diagnosis of probable AD (McKhann et al., 1984) following a standard diagnostic evaluation that included a medical history, neurological examination, neuropsychological testing, magnetic resonance imaging scan, electrocardiogram, chest X-ray, and routine blood tests. Thus, all patients had a history of progressive cognitive decline with onset between the ages of 50 and 90 years, impaired explicit memory, and a deficit in at least one other area of cognition. Additional inclusion criteria were at least 8 years of formal education and fluency in English. Exclusion criteria included disturbance of consciousness, other disorders believed to contribute to the patients' cognitive dysfunction, a history of major psychiatric disorder, or use of anxiolytic, antidepressant, neuroleptic, or sedative medication. Out of a possible 30 points on the Mini-Mental State (MMS) Exam (Folstein, Folstein, & McHugh, 1975), a measure of dementia severity, the AD group had a mean score of 23.3 (range = 17–26; $SD$ = 2.9). Thus, these patients fell within the mild range of dementia severity.

*NC group.* The NC group consisted of spouses of the AD patients and participants recruited from the hospital or the community through notices. The 2 men and 10 women in this group had a mean age of 67.9 years (range = 50–78 years) and a mean educational level of 13.8 years (range = 8–17 years). Except for the diagnosis of AD, NC participants met the same inclusion–exclusion criteria as the AD patients. The NC participants had no history of major medical, neurological, or psychiatric disease and were not taking any psychoactive medications. The NC group had intact cognition and a mean MMS score of 28.9 (range = 27–30; $SD$ = 1.2). With the addition of 2 participants for Experiment 1b, the NC group consisted of 4 men and 10 women with a mean age of 67.3 years (range = 50–78 years), a mean educational level of 13.8 years (range = 8–17 years), and a mean MMS score of 29.1 ($SD$ = 1.1; range = 27–30 years).

### *Experiment 1a (Picture Naming and Recognition)*

*Materials.* The critical stimuli were 58 digitized pictures (line drawings) of common objects and animals taken from a study by Snodgrass and Vanderwart (1980) and from the Boston Naming Test (Kaplan, Goodglass, & Weintraub, 1983). The pictures were selected so that their names could be used in a word-stem completion task in Experiment 1b—each name was from four to seven letters in length and had a stem (the first three letters) that was unique in the experiment, was not a word itself, and could be completed to form at least 10 different words. The 58 pictures were placed in a fixed, random order for the study phase (there were also 8 practice-picture trials that preceded the study phase). Alternate pictures in the study list were assigned to Lists A and B. Two 29-trial recognition-memory test forms were created by pairing each picture from List A or List B with another set of 29 foil pictures. Each trial consisted of a previously presented (old) picture and a foil (new) picture shown side by side. The old pictures were ordered randomly and appeared on the left side in 14 trials, on the right side in 15 trials, and not on the same side for more than 3 consecutive trials. Two test-phase naming forms were created by randomly reordering the 29 pictures from Lists A and B. Half of the participants in each group proceeded through one test order (study list, Recognition Test A, and Naming Test B), and the other half proceeded through the other test order (study list, Recognition Test B, and Naming Test A). Thus, the experiment counterbalanced the use of stimuli in the recognition and naming tests; for each participant, different studied items were tested on the recognition and naming tests. Testing was done on a Macintosh IIci microcomputer, and naming latencies were recorded on the microcomputer with a Lafayette voice-activated relay.

*Procedure.* Testing consisted of three phases: (a) naming 58 pictures, (b) performing a two-alternative forced-choice recognition test for 29 of those pictures, and (c) naming again the 29 pictures seen in the first phase but not in the second phase. Each naming trial was initiated by the examiner and consisted of (a) a central fixation plus sign (+) appearing for 250 ms, (b) a blank display appearing for 250 ms, and (c) a picture that remained in view until the participant responded. For naming trials, participants were asked to name each picture aloud as quickly and accurately as possible. For recognition trials, they were asked to select which of the two pictures in each display had appeared in the preceding naming phase. The examiner recorded responses and noted naming trials in which naming latencies were invalid.

### *Experiment 1b (Word-Stem Completion With Picture Names)*

*Materials.* The 58 picture names (words) from Experiment 1b were divided into two sets (Sets A and B) balanced for mean word frequency (Kučera & Francis, 1967) of the picture names (*Ms* = 22.4 per million and 21.2 per million for Sets A and B, respectively) and mean letter length (*Ms* = 5.3 letters for Sets A and B). Two study lists (A and B) were created by randomizing each set of 29 words; in addition, 4 words at the beginning and 4 words at the end of each study list were added in order to blunt any primacy or recency effects. One 58-item word-stem completion test list was created by pseudorandomly mixing the stems from the words in both study lists so that each successive pair of stems included one from Set A and one from Set B. Half of each group read Set A in the study phase, and the other half read Set B, so study and baseline items were counterbalanced within each group. The stimuli were displayed and naming latencies recorded as in Experiment 1a.

*Procedure.* In the study phase, participants were instructed to read aloud each of the individually appearing words as quickly and as accurately as possible. Eight practice trials preceded the 37-word study list. Each trial began with a warning signal (******) that appeared for 250 ms, followed by a blank screen for 250 ms. A word then appeared and disappeared upon triggering of the voice-activated relay. There was a 500-ms interval before the beginning of the next trial sequence. The examiner recorded any incorrect readings and invalid response times. In the test phase, participants were presented, one at a time, with 4 practice stems followed by the 58 test stems and were told to complete each stem to make the first word that came to mind. Each trial was initiated and terminated by the examiner.

### *Experiment 1c (Word-Stem Cued Recall and Completion)*

*Materials.* The stimulus words were derived from 48 different stems, each consisting of three letters that were the beginnings of 10 or more entries in *Webster's New Collegiate Dictionary* (1974). For each stem, three different words 4–6 letters long were selected as target completions (each participant saw only one of those words). One word was the most common completion of that stem according to a pilot study with 50 young, healthy participants. The most-common completions were provided on 26.5% of the pilot study trials and had a mean absolute word frequency (Kučera & Francis, 1967) of 34.7 per million (range = 1–163 per million). A second word beginning with the same stem was selected to be high in absolute word frequency but to be a less common completion. The 48 high-frequency words were provided on 3.1% of the pilot study trials and had a mean absolute frequency of 106.2 per million (range = 29–787 per million). A third word beginning with the same stem was selected to be low in absolute word frequency. The 48 low-frequency words were provided on 2.5% of the trials and had a mean absolute frequency of 3.1 per million (range = 0–15 per million).

The 48 stems were randomly assigned to two sets (Sets A and B) of 24 stems each, and a pseudorandom ordering was created for both sets of stems. Each set of stems was used to create three different study lists, with the most-common word for a given stem appearing in one list, the high-frequency word for the same stem in a second list, and the low-frequency word for the same stem in the third list. In each 24-word study list there were 8 most-common words, 8 high-frequency words, and 8 low-frequency words in a pseudorandom order with the constraint that no more than three of one type appear consecutively. Thus, there were six study lists that were fully balanced for word type; for each participant, different study lists were used for word-stem completion and cued recall.

There were two study conditions, a shallow (nonsemantic) condition and a deep (semantic) condition. In the shallow condition, participants had to decide if the presented word included the letter *a*. In the deep condition, participants had to decide if the presented word was the name of something that could be touched. Within a study list, four of the most-common, high-frequency, and low-frequency words were studied under the shallow condition, and the other four most-common, high-frequency, and low-frequency words were studied under the deep condition. Words in a study list were pseudorandomly assigned to one of the study conditions with the constraint that there be no more than three consecutive trials with the same study condition. In an alternate form, the same word list was presented with the reverse study conditions, so that each word was studied in both conditions across the two test forms. Thus, there were a total of 12 study lists that were counterbalanced for word type and study condition. In addition, four filler words were added to the beginning and to the end of each list in order to blunt any primacy or recency effects.

The word-stem completion test consisted of a pseudorandomization of the 48 stems from Set A and Set B with the constraint that the first 24 stems include the 12 stems from the first half of each study list and the second 24 stems include the 12 stems from the second half of the two lists (this was done to minimize any confounding effects of study–test interval). The 24 stems that came from the unseen stem set provided a baseline measure of how often participants randomly completed stems to form study words. The 24-trial cued-recall test was identical to the word completion test except that the baseline stems were removed so that each of the two cued-recall test forms included only stems that corresponded to studied words. Stimuli were displayed on an Epson (PC-compatible) microcomputer.

*Procedure.* On each trial of the two study phases, a question cue appeared for 3 s on the computer monitor prior to the appearance of the study word. For shallow-condition trials, the cue was "letter a," and the examiner said, "Does this word have the letter *a* in it?" For deep-condition trials, the cue was "touch," and the examiner said, "Is this word the name of something you could touch?" For both trial types, participants were asked to answer aloud yes or no as quickly as possible. As soon as the participant responded, the examiner pressed a button that removed the study word and began the next study trial. There was a 1-s interval between the removal of a study word and the presentation of the next question cue.

In the cued-recall test, after one study phase, participants saw a stem on each trial and were asked to provide the word they had seen in the study list that began with those three letters. They were encouraged to guess when uncertain. The word-stem completion test followed the other study phase and was identical to the cued-recall test except for the instructions (participants were asked to complete each stem to form the first word that came to mind) and the number of items (there were twice as many because of the inclusion of baseline stems).

## *Results*

### *Experiment 1a (Picture Naming and Recognition)*

The scores of the AD and NC groups were analyzed for recognition accuracy, naming accuracy, and repetition priming as measured by naming speed.

*Recognition.* Scores were calculated as the percentage of previously seen pictures selected correctly in the two-alternative forced-choice recognition test. The NC group ($M$ = 99.1%, $SD$ = 1.6%) was more accurate than the AD group ($M$ = 83.6%, $SD$ = 11.4%) in recognizing which pictures they had named in the preceding study phase, $t(22) = 4.67, p < .001$.

*Picture-naming accuracy.* Responses were counted as correct if they were reasonable names for a picture, regardless of whether they were the most common names and whether the naming latencies were valid. Naming scores were transformed into percentages so that the naming accuracies in the 58-picture study phase and the 29-picture test phase could be compared, and they were analyzed in a repeated measures analysis of variance (ANOVA) with the between-subjects variable of group (AD or NC) and the within-subject variable of repetition (first or second naming). The NC group ($M$ = 91.2%) provided more acceptable names than did the AD group ($M$ = 85.5%). The 5.7% difference was nearly significant, $F(1, 22) = 3.90$, $MSE = 0.010$, $p = .06$. Pictures were named more accurately when appearing the second time (88.9%) than when appearing the first time (87.8%), demonstrating an effect of repetition, $F(1, 22) = 4.29$, $MSE = 0.002$, $p = .05$. There was an interaction between group and repetition, $F(1, 22) = 13.15$, $p < .01$: The NC participants improved their accuracy (from 89.7% to 92.8%) from the first to the second appearance of a picture, whereas the AD patients did not improve (from 85.9% to 85.1%).

*Picture-naming speed.* Response latencies were included only if (a) the name provided was acceptable, (b) the same name was provided in both namings, and (c) both latencies for a given picture were otherwise valid. A latency could be invalid either because a participant made a sound that was not the response (such as an "umm") or because the voice relay was triggered by a sound other than the participant's response. With these criteria, the NC and AD groups had means of 76.0% and 68.0%, respectively, of their naming trials included in the latency analysis; the 8% difference was not statistically significant. Median latencies to name pictures in the study and test phases (see Figure 1) were analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and the within-subject variable of repetition (first or second). Participants exhibited repetition priming by naming pictures 103 ms more quickly the second time than the first time, demonstrating an effect of repetition, $F(1, 22) = 21.0$, $MSE = 6.019$, $p < .001$. There was no main effect of group ($p = .27$), indicating that the two groups named pictures with similar speeds. NC priming ($M$ = 98 ms) and AD priming ($M$ = 107 ms) were equivalent, as indicated by the absence of a Group × Repetition interaction ($p = .83$).

Although the AD patients did not differ significantly from the NC group in overall naming latency, the AD group was 90 ms slower than the NC group in naming pictures. The difference in baseline performance, although statistically nonsignificant, raises the possibility that the AD group may have shown less proportional priming than the NC group. To examine this possibility, we recalculated each participant's priming score as a percentage reduction (the difference between the mean first and second latencies divided by the

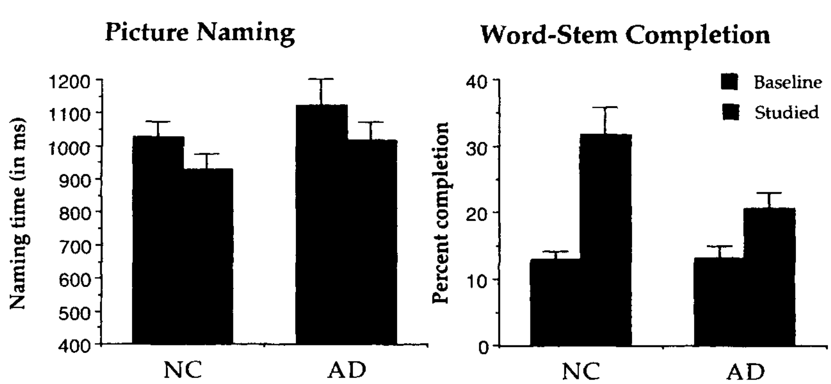


*Figure 1.* Mean picture-naming times and mean percentages of target word-stem completions in patients with Alzheimer's disease (AD) and normal controls (NC) in Experiments 1a and 1b. Bars depict standard errors.

mean first latency) and compared the percentage-reduction priming scores of the AD ($M = 8.6\%$, SD = 8.0) and NC ($M = 9.1\%$, SD = 8.4) groups. The difference did not approach significance ($p = .86$), again indicating that the AD and NC groups showed equivalent priming.

### *Experiment 1b (Word-Stem Completion With Picture Names)*

Participants made no errors when reading study-phase words. NC participants read the words more quickly ($M = 603$ ms, $SD = 54$) than did AD patients ($M = 714$ ms, $SD = 218$), $t(24) = 1.84, p < .05$ (one-tailed). A test-phase completion was scored as correct only if it matched its studied or baseline target exactly (e.g., plurals did not count). Baseline rates of target-word completions were almost identical for the NC and AD groups (see Figure 1). Priming was analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and the within-subject variable of repetition (baseline or study). Participants exhibited priming by completing stems to form study-list words more often (26.7%) than would be expected by chance (13.1%), an effect of repetition, $F(1, 24) = 27.8$. $MSE = 85.5, p < .01$. The AD group exhibited less priming (7.5%) than the NC group (18.7%), as indicated by a significant Group × Repetition interaction, $F(1, 24) = 4.70$, $p < .05$, which also resulted in a marginally significant effect of group ($p = .06$).

### *Experiment 1c (Word-Stem Cued Recall and Completion)*

*Word-stem cued recall.* Each participant's cued-recall score was the percentage of study words recalled correctly (see Table 1). Scores were analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and within-subject variables of word type (most common, high frequency, or low frequency) and study condition (shallow or deep). The NC group recalled more words correctly (43.4%) than did the AD group (24.7%), demonstrating an effect of group, $F(1, 22) = 18.3$, $MSE = 690$, $p < .001$. Participants recalled more words following deep (40.6%) than shallow (27.4%) study, an effect of study condition, $F(1, 22) = 394$, $MSE = 394$, $p < .001$. There was a main effect of word type, $F(2, 44) = 27.12$, $MSE = 564$, $p < .001$. Planned pairwise comparisons indicated that more most-common words (53.6%) were recalled than high-frequency (29.7%) or low-frequency words (18.8%) and that more high-frequency words were recalled than low-frequency words ($ps < .05$). There was a Study Condition × Word Type interaction, $F(2, 44) = 3.77$, $p < .05$. Planned comparisons indicated that deep, relative to shallow, study significantly enhanced recall for most-common words (by 15.8%) and for low-frequency words (by 22.9%; $ps < .01$), but not for high-frequency words (1.1%). No other interaction was significant.

Table 1
*Mean Percentages and Standard Deviations of Words Recalled With Stem Cues by Normal Control and Alzheimer's Disease Groups in Experiment 1c*

| Study condition and word type | Normal control | | Alzheimer's disease | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| Shallow | | | | |
| Most common | 56.3 | 18.8 | 35.4 | 24.9 |
| High frequency | 39.6 | 16.7 | 18.8 | 26.4 |
| Low frequency | 12.5 | 13.1 | 2.1 | 7.2 |
| Deep | | | | |
| Most common | 75.0 | 26.1 | 47.9 | 22.5 |
| High frequency | 33.3 | 28.9 | 27.1 | 22.5 |
| Low frequency | 43.8 | 30.4 | 16.7 | 19.5 |

Table 2
*Mean Percentages and Standard Deviations of Target Word-Stem Completions by Normal Control and Alzheimer's Disease Groups in Experiment 1c*

| Study condition and word type | Normal control | | Alzheimer's disease | |
|---|---|---|---|---|
| | *M* | *SD* | *M* | *SD* |
| Baseline | | | | |
| Most common | 27.1 | 14.5 | 28.1 | 22.2 |
| High frequency | 9.4 | 9.2 | 9.4 | 9.2 |
| Low frequency | 6.3 | 6.4 | 4.2 | 6.0 |
| Shallow | | | | |
| Most common | 54.1 | 17.9 | 39.6 | 31.0 |
| High frequency | 31.3 | 28.5 | 18.8 | 21.7 |
| Low frequency | 16.7 | 19.5 | 10.4 | 16.7 |
| Deep | | | | |
| Most common | 50.0 | 18.5 | 44.2 | 29.0 |
| High frequency | 27.1 | 22.5 | 8.3 | 12.3 |
| Low frequency | 27.1 | 16.7 | 10.4 | 12.9 |

*Word-stem completion priming.* Completions were scored as in Experiment 1b and are presented in Table 2. Each baseline stem was matched with only one of its three target completions in a given study list; across the three lists in which it served as a baseline item it was matched with all three target completions. We did this so that for each participant, each stem, whether studied or baseline, had one target completion.

Baseline completions were analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and the within-subject variable of word type (most common, high frequency, or low frequency). NC (14.2%) and AD (13.9%) groups had similar rates of baseline completions to target words (effect of group, $p > .9$). Participants produced most-common completions most often (27.6%), high-frequency completions less often (9.4%), and low-frequency completions least often (5.2%), demonstrating an effect of word type, $F(2, 44) = 21.3$, $MSE = 159.4$, $p < .001$. The baseline response patterns of the two groups were similar.

Priming was analyzed in a repeated measures ANOVA with the between-subjects variable of group (AD or NC) and the within-subject variables of repetition (baseline or studied), study condition (shallow or deep), and word type (most common, high frequency, or low frequency). Participants exhibited priming by completing stems to form study-list words more often (28.2%) than would be expected by chance (14.1%), an effect of repetition, $F(1, 22) = 30.06$, $MSE = 476.0$, $p < .001$. The AD group exhibited less priming ($M = 8.0\%$) than the NC group ($M = 20.1\%$), as indicated by a significant Group × Repetition interaction, $F(1, 22) = 5.52$, $p < .05$, which also yielded a significant effect of group, $F(1, 22) = 5.91$, $MSE = 497.6$, $p < .05$. Participants provided more most-common completions (37.3%) than either high-frequency (15.4%) or low-frequency (10.7%) completions, an effect of word type, $F(2, 44) = 46.2$, $MSE = 419.8$, $p < .001$. Contrasts indicated a difference between most-common completions and the other two word types ($p < .05$), but not between high-frequency and low-frequency completions. Unlike the cued-recall results, there were no significant effects of either study condition or word type on priming. No other interactions were significant.

### *Discussion*

There were three major results in Experiments 1a, 1b, and 1c. First, AD patients exhibited impaired explicit memory on tests of picture recognition and word-stem cued recall. Second, AD patients twice showed impaired word-stem completion priming. Third, the same AD patients demonstrated intact picture-naming priming. Thus, AD patients demonstrated a dissociation between two forms of perceptual priming (as in Keane et al., 1991). In both studies, AD patients showed impaired performance on the perceptual priming task involving production but intact performance on the perceptual priming task involving identification.

Despite showing impaired recognition memory for recently named pictures, AD patients showed a normal priming effect in that their latencies in renaming pictures were reduced as much as those of NC participants (in terms of both absolute and percentage priming). This finding is in accord with the results of other studies that reported unimpaired priming by AD patients on tasks of picture naming (Mitchell, 1988) and fragmented-picture identification (Gabrieli et al., 1994). AD patients have shown normal magnitudes of repetition priming on other tasks, but often they have demonstrated significantly worse baseline performance than NC groups (Mitchell [1988] did not report baseline performance and Gabrieli et al. [1994] reported impaired AD baseline performance). Baseline differences are not unexpected given the pervasive consequences of dementia and the sensitivity of millisecond latency or threshold-accuracy measures. Such performance differences, however, complicate comparisons of priming across groups. Prior studies have often used subsidiary analyses to support a conclusion of intact priming in AD patients with baseline performance impairments, comparing, for example, only patients and control participants with similar baseline performances (e.g., Fleischman et al., 1995; Keane et al., 1991). In the present study, there was a small and nonsignificant difference between the AD and NC groups in baseline performance. The finding of intact priming in AD patients with near-normal baseline performance supports not only the dissociation between implicit and explicit memory for pictures but also the more general claim that intact magnitudes of repetition priming in AD are not simply an artifact of baseline performance deficits (Ostergaard, 1994).

An unexpected result was the NC group's small (3%) but reliable gain in the accuracy of naming pictures, a gain not exhibited by the AD group. Accuracy is not used as a measure of priming in picture-naming studies with young adults because performance is usually near perfect. The 10% and 15% error rates in the NC and AD groups, respectively, likely reflect a small degree of age-related anomia that was exacerbated by AD. NC participants may have recognized poor naming responses in the study phase and purposefully altered those responses in the test phase. AD patients had little, if any, explicit memory for study-phase errors and therefore could not correct test-phase naming performance. It may be hypothesized that this gain is a product of the NC group's explicit memory advantage.

The same AD patients who showed unambiguously intact picture-naming priming also showed unambiguously impaired word-stem completion: AD priming was reduced by 50% and 60%, respectively, in Experiments 1b and 1c. The experimental design and outcomes rule out a number of potential explanations for the AD priming deficit. Semantic processing enhanced word-stem cued recall accuracy by nearly 50% but had no effect at all on word-stem completion priming (similar to the results of Graf & Mandler, 1984; Graf et al., 1982; Roediger et al., 1992). The absence of a levels-of-processing effect indicates that word-stem completion priming was neither contaminated by explicit memory retrieval nor influenced by conceptual elaboration during encoding. Thus, the AD deficit in word-stem completion priming cannot be explained by the explicit-memory or conceptual-priming deficits that co-occur in AD (in agreement with findings from Gabrieli et al., 1994).

Further, there is some evidence that AD patients exhibit item-specific semantic deficits that reoccur for particular items across notations (words and pictures) and tasks (e.g., lexical decision, category exemplar production, picture naming, and picture–word matching; Chertkow & Bub, 1990; Chertkow, Bub, & Seidenberg, 1989; Huff, Corkin, & Growdon, 1986). Item-specific deficits in AD, however, cannot account for the word-stem completion deficit because the very same items yielded intact picture-naming priming.

Finally, the AD group's pattern of performance across different conditions provides two more clues about the priming deficit. Experiments 1b and 1c included three encoding conditions (reading, semantic encoding, and nonsemantic encoding) and four types of words (concrete picture names, most-common completions, high-frequency words, and low-frequency words). The AD priming deficits were similar after all three encoding conditions and for all four types of words. Thus, none of the semantic or lexical factors that were examined appears to account for the priming deficit. Also, despite their priming impairment, the AD group demonstrated a remarkably normal pattern of baseline performance across the word types (a normal frequency effect was also found by Keane et al., 1991). The normal pattern of baseline retrieval of word-stem completions raises the possibility that the AD priming deficit arises during encoding or storage of the relevant implicit memory.

## Experiment 2

AD patients have demonstrated a dissociation between intact word-identification priming and impaired word-stem completion (Keane et al., 1991) that parallels the consequence of auditory division of attention during visual encoding in normal participants (Gabrieli et al., 1999). Our aim in Experiment 2 was to test the hypothesis that the dissociation between intact picture-naming priming and impaired word-stem completion priming exhibited by AD patients in Experiment 1 could also be accounted for by attentional factors. In Experiment 2, young, healthy participants saw the same pictures or picture names in a study phase and then performed either picture-naming or word-stem completion tasks with primed and baseline items. Attention at study was divided for half the participants performing each task. If division of study-phase attention selectively affects production forms of priming, then division of attention should reduce priming on the word-stem completion task but not on the picture-naming task.

### *Method*

#### *Participants*

Seventy-two Stanford University undergraduates, who were 18–30 years old and native English speakers, participated for course credit. Half the participants were assigned to perform picture naming, and the other half were assigned to perform word-stem completion. Half the participants performing each task were assigned to a focused-attention condition, and the other half were assigned to a divided-attention condition.

#### *Materials*

The pictures and words (picture names) used were those used in Experiments 1a and 1b. Two word study lists (A and B) and a test list (AB) of all stems from both lists were identical to those in Experiment 1b and were used for the word-stem completion task in Experiment 2. Two picture study lists and a single test list were constructed by substituting pictures for the corresponding picture names and stems in Lists A, B, and AB. For the divided-attention conditions, digit–letter strings were generated randomly as described by Mulligan and Hartman (1996). Each 6-item-long string began with a digit and was composed of alternating digits (from 1 through 9) and letters (B, C, D, F, G, H, K, J, and L). No digits or letters appeared more than once per string. Study lists (A and B) were counterbalanced across study conditions (focused and divided).

#### *Procedure*

At study, participants in the focused-attention conditions saw on each trial a fixation cross presented for 250 ms that was replaced by either a picture or a word appearing for 1 s. Participants were instructed either to name the picture or to read the word aloud quickly and accurately into a microphone. In the divided-attention conditions, each trial consisted of (a) a fixation cross for 500 ms, (b) a digit–letter string for 3 s, (c) a 500-ms blank interval, (d) a picture or word presented for 1 s, and (e) the word "Recall." Participants were instructed to read aloud and remember the digit–letter string, either to name the picture or to read the word aloud quickly and accurately into a microphone, and to recall the digit–letter string when cued with "Recall." At test, participants who had named pictures in the study phase named old and new pictures aloud that remained on the screen until response. Participants who had read words in the study phase completed old (corresponding to study-phase words) and new three-letter word stems to form the first word that came to mind. They were given 10 s to produce a response. The experimenter recorded responses.

### *Results*

#### *Picture Naming*

Picture naming was scored as in Experiment 1. Naming latencies (see Figure 2) were analyzed in a repeated measures ANOVA with the within-subject variable of repetition (baseline or studied) and the between-subjects variable of attention (focused or divided). Participants showed priming by naming studied pictures ($M$ = 778 ms) more quickly than baseline pictures ($M$ = 905 ms), an effect of repetition, $F$(1,

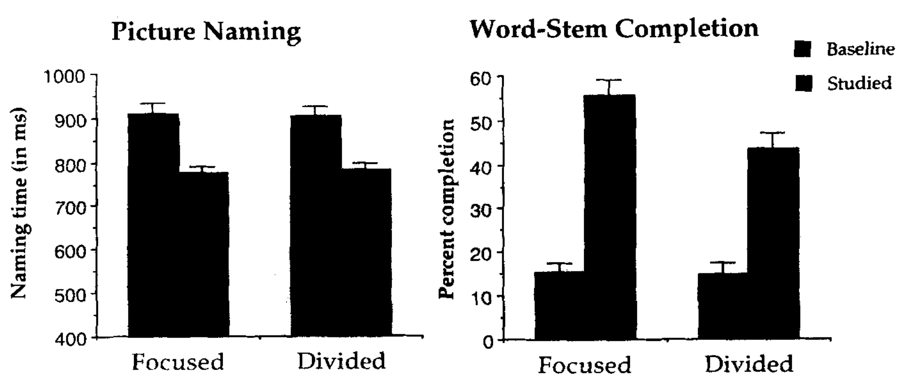


*Figure 2.* Mean picture-naming times and mean percentages of target word-stem completions in healthy young participants as a function of division of attention in Experiment 2. Bars depict standard errors.

34) = 116.58, $MSE$ = 2,495, $p < .01$. Priming did not differ reliably after focused ($M$ = 133 ms) versus divided ($M$ = 122 ms) attention, as indicated by the absence of a Repetition × Attention interaction ($F < 1$). Thus, study-phase division of attention did not affect picture-naming priming.

### *Word-Stem Completion*

Word-stem completion was scored as in Experiment 1 (see Figure 2). Stem completions were analyzed in a repeated measures ANOVA with the within-subject variable of repetition (baseline or studied) and the between-subjects variable of attention (focused or divided). Participants showed priming by providing more target-word completions after study (49.6%) than randomly with baseline stems (15.1%), an effect of repetition, $F(1, 34) = 147.60$, $MSE = 0.014$, $p < .0001$. Participants showed greater priming after focused ($M$ = 40.4%) than after divided ($M$ = 28.6%) attention, indicating a Repetition × Attention interaction, $F(1, 34) = 4.38$, $p < .05$. Thus, study-phase division of attention reduced word-stem completion priming.

### *Discussion*

In healthy participants, study-phase division of attention reduced word-stem completion priming but did not affect picture-naming priming. The failure to obtain a division-of-attention effect on picture-naming priming does not appear to have been due to insufficient statistical power. Using J. Cohen's (1988) procedure, we determined that the statistical power of the present design to detect a division-of-attention effect size of .70 (one-tailed, $\alpha = .05$), as estimated from the word-stem completion test, was .90, which is substantial enough to suggest that the lack of an effect of study-phase division of attention on picture-naming priming was not due to statistical inadequacies of our design. Further, an ineffective division-of-attention procedure cannot account for the null effect on picture naming because the identical procedure substantially reduced word-stem completion priming. Thus, study-phase division of attention dissociated priming on two implicit perceptual tests: Priming was reduced on the test of production but unaffected on the test of identification.

## Experiment 3

AD and study-phase division of attention do not affect word-identification and picture-naming priming but do affect word-stem completion priming (present Experiments 1 and 2; Gabrieli et al., 1999; Keane et al., 1991). We have hypothesized that these dissociations between different forms of perceptual priming reflect a distinction between identification and production forms of priming. This hypothesis does not emphasize the perceptual nature of the priming tasks, and our aim in Experiments 3 and 4 was to examine whether AD and study-phase division of attention would have parallel dissociative effects on conceptual priming tasks.

To examine conceptual priming on a production test, we used the category-exemplar production task. In this task, participants are exposed to exemplars (e.g., CUCUMBER) in a study phase and are asked, at test, to produce the first exemplars that come to mind for specified categories (e.g., VEGETABLES). The measure of priming is how much more often than at baseline participants provide studied exemplars. Category-exemplar production priming is well documented as being conceptual and not perceptual (e.g., Keane et al., 1997; Monti et al., 1996; Srinivas & Roediger, 1990; Vaidya et al., 1997). This kind of priming is dissociable from explicit retrieval by virtue of its being intact in global amnesia (Graf et al., 1985; Keane et al., 1997) and unaffected by age-related changes in memory that reduce category-cued recall (Light & Albertson, 1989; Monti et al., 1996). Category-exemplar production priming is severely impaired in AD (Monti et al., 1996).

To measure conceptual priming in a test that requires identification, we used a category-exemplar verification task (Vaidya et al., 1997). In this task, participants answer questions (e.g., "Is this a type of vegetable?") about exemplars (e.g., CUCUMBER) in a study phase. In the test phase, they answer the same questions for studied and baseline (not studied) exemplars. The measure of priming is how much more quickly participants respond to studied than to baseline exemplars. Exemplar verification requires conceptual identification of the stimuli in order to answer questions but does not require production at test. Exemplar verification priming is unaffected by a study–test shift in modality and therefore is not a form of perceptual priming (Vaidya et al., 1997). Its status in amnesia or AD is unknown.

The category-exemplar production and verification tasks probe the same long-term conceptual knowledge of category-exemplar relations. Priming, therefore, reflects changes in the same underlying conceptual representations. What differs between the tasks are the retrieval demands of exemplar production and those of exemplar verification.

### *Method*

#### *Participants*

Groups of 32 AD patients and 32 normal control (NC) participants took part in Experiment 3. AD patients were recruited from the Rush Alzheimer's Disease Center and the Stanford Alzheimer's Disease Center. Participants met the same inclusion–exclusion criteria as those in Experiment 1. There were no significant differences between the groups with regard to age or educational level. Age, education, and dementia severity were almost identical for the corresponding groups in Experiments 1 and 3.

*AD group.* The 11 men and 21 women in this group had a mean age of 70.3 years (range = 51–83 years) and a mean educational level of 13.0 years (range = 7–22 years). On the MMS Exam, the AD group had a mean score of 21.3 (range = 17–26, $SD$ = 2.7). Thus, these patients fell within the mild range of dementia severity.

*NC group.* The 5 men and 27 women in this group had a mean age of 70.1 years (range = 55–81 years) and a mean educational level of 13.8 years (range = 8–21 years). On the MMS Exam, the NC group had a mean score of 29.0 (range = 24–30, $SD$ = 1.3). Thus, the NC group was intact cognitively.

### Materials

Eight exemplars from each of 12 categories were selected from the Battig and Montague (1969) norms of category dominance. The mean dominance or typicality rank was 14.6 (range = 3–46). The 96 category exemplars were divided into Sets A and B by randomly assigning exemplars belonging to six categories (furniture, cloth, dwelling, flowers, insects, and body parts) to one set and the remaining six categories (clothing, musical instruments, kitchen utensils, fish, vegetables, and trees) to another set. Within Sets A and B, Study Lists 1 and 2 were created by randomly assigning four exemplars from each of the six categories to each study list. Thus, each study list consisted of 24 exemplars. Each exemplar was randomly assigned to a category-verification question (e.g., "Is this a type of furniture?") such that half the words from each study list were members of the category named in the question (e.g., DESK), and the remaining half were not members of the category named in the question (e.g., ORCHID). Thus, half of the questions could be answered with yes and the remaining half with no. Two forms of each study list were created by counterbalancing the verification question assigned to each exemplar (yes or no). Thus, there were a total of eight study lists, four for Set A and four for Set B. The order of presentation of study stimuli was pseudorandomized with the constraint that there not be more than three consecutive trials of the same type (i.e., yes or no).

For the category-verification test phase, two test lists consisting of 48 stimuli each were created for Set A and Set B by combining two of the four study forms. For any given participant, half the test exemplars and the verification questions paired with them were studied, and the remaining half were nonstudied. The order of presentation of study words was pseudorandomized with the constraint that there not be more than three consecutive trials of the same type (i.e., studied or nonstudied, yes or no).

For the category-production test phase, one test list was created that consisted of the category labels from Set A and Set B. For any given participant, half the category labels (e.g., Set A) represented exemplars encountered in either the category-verification study or test phases, and the remaining half of the category labels (e.g., Set B) represented nonstudied exemplars.

### Procedure

In the study phase, participants were told that they would be answering questions about a word's category membership. Each trial began with a fixation cross for 500 ms, which was followed by an interval of 500 ms, a category-verification question for 4 s, and then a word that remained on the screen until the participant answered the processing question by saying yes or no into the microphone. Response times (RTs) were collected via a voice-activated relay. There was an intertrial interval of 1,000 ms. At the end of the study phase, participants were instructed for the category-verification test phase. Participants were told they would be answering some more category-verification questions. The test trial procedure was identical to the study-phase procedure except that there were double the number of trials. At the end of the verification test phase, participants were instructed for the category-generation test phase. Participants were told to provide eight exemplars of categories named by the experimenter. Participants were allowed a maximum of 3 min to respond. The experimenter recorded the participants' responses and presented the next category name. At the end of the session, participants were debriefed about the purpose of the experiment.

## Results

### Category-Exemplar Verification

Error rates and median RTs for correct *yes* and *no* category-verification responses were computed for each participant. Correct responses were conditional on correct study-phase performance (fewer than 1% of the responses had to be discarded under these criteria).

*Verification accuracy.* Percentages of correct responses were analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and the within-subject variable of repetition (baseline or studied). Both groups performed nearly perfectly, but the NC group ($M$ = 99.5%, $SD$ = 0.8) was more accurate than the AD group ($M$ = 98.2%, $SD$ = 2.1), indicating an effect of group, $F(1, 62) = 9.15$, $MSE = 5.35$, $p < .01$. There was neither an effect of repetition ($t < 1$) nor a Group × Repetition interaction ($p = .23$). Thus, accuracy did not exhibit a priming effect.

*Verification speed.* Median latencies for correct verifications (see Figure 3) were analyzed in a repeated measures ANOVA with the between-subjects variable of group (NC or

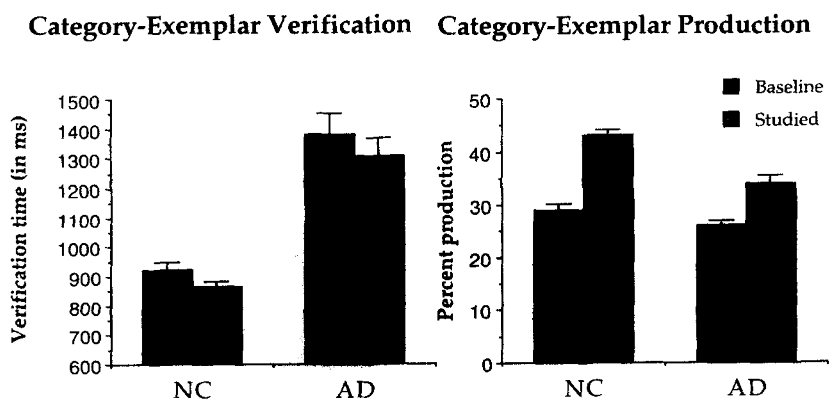


*Figure 3.* Mean category-exemplar verification times and mean percentages of target category-exemplar productions in patients with Alzheimer's disease (AD) and normal controls (NC) in Experiment 3. Bars depict standard errors.

AD) and the within-subject variables of repetition (baseline or studied) and response (yes or no). The NC group responded 450 ms more quickly than the AD group, indicating an effect of group, $F(1, 62) = 24.97$, $MSE = 519{,}939$, $p < .001$. Participants provided *yes* responses 136 ms more quickly than *no* responses, demonstrating an effect of response, $F(1, 62) = 48.6$, $MSE = 23{,}884$, $p < .001$, and this difference was greater for AD (189 ms) than NC (80 ms) participants, indicating a significant Group × Response interaction, $F(1, 62) = 7.97$, $p < .01$. Participants demonstrated repetition priming by responding 68 ms more quickly for studied exemplars than baseline exemplars, an effect of repetition, $F(1, 62) = 15.8$, $MSE = 18{,}449$, $p < .001$. NC (59 ms) and AD (76 ms) groups showed equivalent priming, as indicated by the absence of a Group × Repetition interaction ($F < 1$). The magnitude of priming did not differ for *yes* and *no* responses (Repetition × Response interaction, $F < 1$) for either the AD or the NC group (Group × Repetition × Response interaction, $F < 1$). Because the AD group responded more slowly overall than did the NC group, priming was also calculated in terms of percentage of priming [(baseline RT − studied RT)/baseline RT]. The mean percentage of priming did not differ between the AD ($M = 4.3\%$, $SD = 10.4$) and NC ($M = 5.9\%$, $SD = 6.4$) groups ($t < 1$).

### *Category-Exemplar Production*

For each participant, three scores were computed for studied and baseline categories: (a) target exemplars (produced exemplars that were the same as or the plural of the target exemplar); (b) legitimate exemplars (only produced exemplars that belonged to the named category); and (c) total exemplars (all produced exemplars including those that did not belong to the named category). The maximum score in each case was 8 exemplars.

To examine whether baseline exemplar-production rates differed, irrespective of priming, in the AD and NC groups, we analyzed the mean numbers of legitimate and total exemplars produced per category. By both measures, NC participants generated more exemplars than did AD patients: legitimate (NC: $M = 47.2$, $SD = 2.1$; AD: $M = 33.8$, $SD = 9.5$), $t(62) = 7.1$, $p < .001$, and total (NC: $M = 47.4$, $SD = 1.9$; AD: $M = 35.3$, $SD = 9.4$), $t(62) = 7.8$, $p < .001$. Given the group differences in baseline exemplar generation, further analyses were performed with priming calculated as a proportion of legitimate exemplars generated. This calculation minimized the influence of the AD baseline production deficit on priming. Thus, for each participant, mean proportions of legitimate targets were computed for studied and nonstudied exemplars.

To examine category-exemplar production priming, we analyzed the mean proportions of target exemplars (see Figure 3) in a repeated measures ANOVA with the between-subjects variable of group (NC or AD) and the within-subject variable of repetition (baseline or studied). Participants exhibited priming by producing a higher proportion of target exemplars in studied ($M = 38.6\%$) than in baseline ($M = 27.4\%$) categories, demonstrating an effect of repetition, $F(1, 62) = 72.2$, $MSE = 0.01$, $p < .0001$. The NC group produced a greater proportion of target exemplars than did the AD group, an effect of group, $F(1, 62) = 23.52$, $MSE = 0.01$, $p < .0001$. This effect reflected the critical finding that the NC group ($M = 14\%$) showed greater priming than the AD group ($M = 8\%$), indicating a significant Group × Repetition interaction, $F(1, 62) = 5.6$, $p < .05$. The AD group did show priming, albeit less than that of the NC group, $t(31) = 4.12$, $p < .001$. Analyses that used the total number of exemplars produced, regardless of legitimacy, yielded almost identical results.

### *Discussion*

The main finding was that a single group of AD patients exhibited intact category-exemplar verification priming but impaired category-exemplar production priming. AD priming on the category-verification task was nearly identical to that shown by the NC group. In contrast, AD patients showed about half the priming exhibited by the NC group on the category-exemplar production task. The AD impairment in category-production priming replicates a prior finding (Monti et al., 1996). This dissociation is striking in that both tasks probed knowledge of the same category-exemplar relations, and priming on both tasks reflected experimentally induced changes in the representations of those relations. AD performance on both conceptual tasks reflected the semantic deficits commonly seen in early AD (Nebes, 1989). AD patients were slower and less accurate on the category-verification task and also impaired in their ability to produce eight legitimate exemplars per category. Thus, both intact and impaired priming occurred in the context of baseline deficits in semantic performance.

## Experiment 4

Our aim in Experiment 4 was to test the hypothesis that the dissociation between intact category-exemplar verification priming and impaired category-exemplar production priming exhibited by AD patients in Experiment 3 could be accounted for by attentional factors. In Experiment 4, young, healthy participants saw exemplars in a study phase and decided whether each exemplar was natural or manufactured. Attention at study was divided for half the participants. Participants then performed either a category-exemplar verification task or a category-exemplar production task. If division of study-phase attention in healthy participants selectively affects production forms of conceptual priming, then division of attention should reduce priming on the category-exemplar production task but not on the category-exemplar verification task.

### *Method*

#### *Participants*

Sixty-four Stanford undergraduates, who were 18–30 years old and native English speakers, participated and received either course credit or $5 for their participation. Half the participants were assigned to perform category-exemplar production at test, and the other half were assigned to perform category-exemplar verification at test. Half the participants performing each test were assigned to a focused-attention condition, and the other half were assigned to a divided-attention condition.

### Materials

Stimulus materials consisted of the 96 category exemplars used in Experiment 3. Exemplars were divided into two study lists by assigning exemplars belonging to three naturally occurring categories (flowers, insects, and body parts) and three manufactured categories (furniture, cloth, and dwelling) to one list and those from three other naturally occurring categories (fish, vegetables, and trees) and three other manufactured categories (clothing, musical instruments, and kitchen utensils) to another list. Thus, each study list consisted of the names of 24 naturally occurring and 24 manufactured exemplars. The order of presentation of study stimuli was pseudorandomized with the constraint that there not be more than three consecutive trials of the same type (i.e., natural or manufactured).

For the category-exemplar verification test phase, one test list consisting of 96 exemplars was created by combining the two study lists. Each exemplar was randomly assigned to a category-verification question (e.g., "Is this a type of furniture?") such that half the words from each study list were members of the category named in the question (e.g., DESK), and the remaining half were not members of the category named in the question (e.g., ORCHID). Thus, 48 questions could be answered by yes and 48 questions by no. Two forms of the test list were created by counterbalancing the verification question assigned to each exemplar (yes or no). For any given participant, half the test exemplars were studied, and the remaining half were nonstudied. The order of presentation of study words was pseudorandomized with the constraint that there not be more than three consecutive trials of the same type (i.e., studied or nonstudied, yes or no).

For the category-exemplar production test phase, one test list was created that consisted of all 12 category labels. For any given participant, six category labels belonged to studied exemplars and six to nonstudied exemplars. The order of presentation of category labels was pseudorandomized with the constraint that there not be more than three consecutive labels of the same type (i.e., studied or nonstudied).

For the secondary task in the divided-attention condition, a list of 224 digits, consisting of randomly generated numbers and 43 target sequences of three consecutive odd numbers, was recorded on a computer in a male voice at the rate of 2 s per digit. The list was constructed with the constraint that there be a minimum of 1 and a maximum of 8 digits between target sequences and not more than 3 consecutive even digits.

### Procedure

In the study phase, participants in both the focused-attention and divided-attention conditions were told that they were to decide whether a word represented a manufactured or a naturally occurring object. Each trial began with a fixation cross for 500 ms, which was followed by a blank interval of 500 ms and then a word for 2,000 ms. Participants responded verbally, after which the experimenter pressed the space bar to advance to the next trial. Participants in the divided-attention condition were told that they would performs two tasks simultaneously, one being the manufactured–natural task and the other a mathematical task in which they would hear digits through headphones and keep count of the number of sequences with three consecutive odd digits. The experimenter started and ended the digit-counting task at the same time as the manufactured–natural task. At the end of the study phase, participants verbally reported the number of target sequences they had heard. Participants were encouraged to perform both tasks to the best of their ability. At the end of the study phase, participants in both the focused- and divided-attention conditions were given instructions for either the category-exemplar verification test or the category-exemplar production test.

For category-exemplar verification, participants were told that they would be answering questions about a word's category membership. Each trial began with a fixation cross for 500 ms, which was followed by a blank interval of 500 ms, a category verification question for 2,000 ms, and then a word that remained on the screen until the participant verified the word as belonging or not belonging to that category by saying yes or no into the microphone. RTs were collected via a voice-activated relay. The computer advanced to the next trial after an intertrial interval of 1,000 ms. For category-exemplar production, participants were told that they were performing a test of their knowledge about categories. Participants were asked to provide eight exemplars of each category named by the experimenter and were allowed a maximum of 3 min to respond. The experimenter recorded the participant's responses.

Across participants, materials were counterbalanced with regard to target status (studied or baseline), attention at study (focused or divided), test-phase task (verification or production), and verification response (yes or no).

## Results

### Category-Exemplar Verification

Median latencies (see Figure 4) for correct verifications were analyzed in a repeated measures ANOVA with the between-subjects variable of attention (focused or divided) and within-subject variables of repetition (baseline or studied) and response (yes or no). Participants demonstrated repetition priming by responding 23 ms more quickly for studied exemplars than baseline exemplars, demonstrating an effect of repetition, $F(1, 30) = 12.68$, $MSE = 1{,}337$, $p < .01$. No other main effect or interaction approached significance. Critically, there was no Attention × Repetition interaction ($F < 1$; p = .84): Priming was virtually identical after focused (22 ms) and after divided (24 ms) attention at study. Thus, study-phase division of attention did not reduce category-exemplar verification priming.

### Category-Exemplar Production

Percentages of target responses were computed separately for studied and baseline exemplars for each participant (see Figure 4). Baseline performance was nearly identical in the divided-attention and focused-attention conditions. Scores were analyzed in a repeated measures ANOVA with the within-subject variable of repetition (baseline or studied) and the between-subjects variable of attention (focused or divided). Participants showed priming by providing more target exemplars after study ($M = 40.9\%$) than randomly at baseline ($M = 25.0\%$), an effect of repetition, $F(1, 30) = 132.92$, $MSE = 0.03$, $p < .0001$. Participants generated more target exemplars after focused attention than divided attention, demonstrating an effect of attention, $F(1, 30) =$

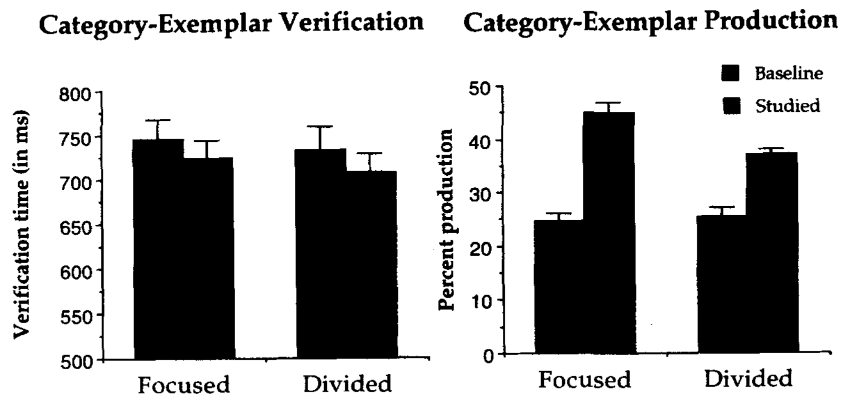


*Figure 4.* Mean category-exemplar verification times and mean percentages of target category-exemplar productions in healthy young participants as a function of division of attention in Experiment 4. Bars depict standard errors.

6.7, $MSE = 0.03$, $p < .05$. Participants showed greater priming after focused ($M = 20.2\%$) than after divided ($M = 11.6\%$) attention, indicating a significant Repetition × Attention interaction, $F(1, 30) = 9.57$, $p < .01$. Thus, study-phase division of attention reduced category-exemplar production priming.

### *Discussion*

The main finding of Experiment 4 was that study-phase division of attention reduced priming on category-exemplar production but did not affect priming on category-exemplar verification. Failure to obtain a division-of-attention effect on category-verification priming does not appear to have been due to insufficient statistical power. Using J. Cohen's (1988) procedure, we determined that the statistical power of the present design to detect a division-of-attention effect size of 1.0 (one-tailed, $\alpha = .05$), as estimated from the category-exemplar production test, was .99, which is substantial enough to indicate that the lack of an effect of study-phase division of attention on category-verification priming was not due to statistical inadequacies of our design. Further, an ineffective division-of-attention procedure cannot account for the null effect on category-exemplar verification because the identical procedure substantially reduced category-exemplar production priming. Thus, study-phase division of attention dissociated priming on two implicit conceptual tests: Priming was reduced on the test of production but unaffected on the test of identification.

## General Discussion

In Experiment 1, AD patients demonstrated a dissociation between impaired word-stem completion priming and intact picture-naming priming. In Experiment 3, AD patients demonstrated a dissociation between impaired category-exemplar production priming and intact category-exemplar verification priming. In Experiment 2, division of attention at study reduced word-stem completion priming but did not reduce picture-naming priming. In Experiment 4, division of attention at study reduced category-exemplar production priming but did not reduce category-exemplar verification priming.

These dissociations cannot be explained by a distinction between explicit and implicit retrieval, because priming in all four tasks measures implicit retrieval mechanisms that have been dissociated in the present or prior studies from explicit retrieval mechanisms. The dissociations cannot be explained by a distinction between perceptual and conceptual priming, because the dissociations are between two perceptual tasks (Experiments 1 and 2) and between two conceptual tasks (Experiments 3 and 4). All of the dissociations, however, are accounted for by the hypothesized distinction between identification and production forms of priming. The selective effects of AD and division of attention on production forms of priming were parallel and robust, resulting in about a 50% decrease in production priming and virtually no decrease in identification priming. These findings are discussed below first in regard to attention and second in regard to AD.

### *Attention and the Identification–Production Distinction*

The influence of attention on repetition priming was specific and substantial in Experiments 2 and 4. Division of study-phase attention did not affect priming on picture-naming and category-exemplar verification tasks but reduced priming by half on word-stem completion and category-exemplar production tasks. These substantial reductions are similar in magnitude to the amount by which conceptual priming is reduced by nonsemantic relative to semantic encoding and the amount by which perceptual priming is reduced by changing versus maintaining study–test modality in perceptual priming tasks.

What aspect of attention is critical for production priming but not for identification priming? The results of the present experiments point to the temporal stage when attention is important for production priming. We divided attention by having participants perform difficult concurrent tasks while simultaneously processing visual study-phase words or pictures. Therefore, the selective effects of division of attention on production priming must reflect attentional requirements of production priming at the encoding phase rather than during later storage or retrieval phases.

The present experiments, however, do not specify what aspect of attention at encoding is critical for production priming. The results of other studies indicate that various forms of implicit memory have very specific attentional demands. For example, dividing study-phase attention with auditory-verbal shadowing has no effect on word-identification priming (Gabrieli et al., 1999). Dividing study-phase attention with letter-search or color-naming tasks, however, reduces or eliminates word-identification priming (Hayman & Jacoby, 1989; Stone, Ladd, Vaidya, & Gabrieli, 1998). Color naming does not diminish priming on a lexical decision task (Szymanski & MacLeod, 1996). Thus, a particular division of attention can affect some but not other kinds of priming, and some but not other divisions of attention affect a particular form of priming.

The specificity of attentional demands is not unique to repetition priming but also appears in other kinds of implicit memory. For example, division of attention with an auditory task reduced perceptual-motor skill learning on a serial-reaction-time task when the cues had nonunique associations but did not reduce skill learning when the cues had unique associations (A. Cohen, Ivry, & Keele, 1990; Nissen & Bullemer, 1987). In a study of human eyeblink conditioning, a verbal task did not reduce delay conditioning, but a concurrent manual tapping task did reduce such conditioning (Papka, Ivry, & Woodruff-Pak, 1995). In another study, a concurrent verbal task did not affect either delay or trace conditioning, but it virtually eliminated discrimination conditioning (Carrillo, Gabrieli, & Disterhoft, 1996).

The selective effects of various divisions of attention on various forms of implicit memory may reflect variety among the attentional demands of implicit memory encoding mechanisms. For example, manual tapping may interfere with eyeblink delay conditioning because the temporal motor demands of both tasks draw on the same psychological and neural resources (perhaps in the cerebellum; Papka et al., 1995). Color naming may interfere with encoding of word form, which is critical for word-identification priming, because it diverts visual attention from a word's form to its color (Stone et al., 1998). Color naming may fail to diminish lexical-decision priming because implicit memory for word form may not underlie such priming. In the present experiments, one can only speculate about what specific attentional resources were reduced at study that selectively affected production priming. The concurrent tasks in Experiments 2 and 4 were cross-modal (i.e., not visual) and thus unlikely to interfere with early stages of visual stimulus processing. Therefore, the critical resources were likely involved in relatively late stages of stimulus processing, in contrast to the competition for attentional resources at earlier processing stages that underlies implicit learning on perceptual and motor tasks.

One may also hypothesize why production priming is more demanding of study-phase attentional resources than is identification priming: response competition at test (Gabrieli et al., 1999; Vaidya et al., 1997). Identification tasks, by definition, lack response competition because the stimulus is provided. For example, a word presented briefly (e.g., STAMP) has only one legitimate identity (STAMP). A picture presented for naming or a word presented for conceptual verification has only one identity. Most production tests involve response competition among multiple legitimate responses. Word-stem completion, as typically examined, has response competition at test because the stems (e.g., STA_) are selected to have 10 or more possible legitimate completions (e.g., STAND, STAR, STALL, STACK, STAFF, STAMP, STALLION, STAPLE, STATUE, STATE, etc.). Category production tasks (e.g., BIRDS include ROBIN, STORK, WREN, EAGLE, BUZZARD, CARDINAL, etc.) also involve response competition at test as participants select which of many exemplars are retrieved. Response competition at test may require more attention, or a different kind of attention, than at study for a representation to become fully primed.

More theoretical and experimental work is needed to better define the processes that underlie priming on various tasks and to identify what attentional resources those processes demand. The present results, however, do speak clearly to the idea that implicit memory is memory without awareness. Although this notion applies to awareness of prior experience during retrieval, it does not apply to awareness of current experience during encoding. The AD participants in Experiments 1 and 3 and the divided-attention participants in Experiments 2 and 4 were clearly aware of study-phase stimuli—they explicitly and accurately answered questions about those stimuli. That awareness at study, however, was not enough to yield complete priming. Thus, various forms of repetition priming, skill learning, and conditioning each have distinct attentional requirements that transform current experience into long-term implicit memory. Awareness at encoding is essential for implicit memory, but the specific kind of awareness varies for different implicit memory processes.

### *AD and the Identification–Production Distinction*

The influence of AD on repetition priming was specific and substantial in Experiments 2 and 4. AD did not affect priming on picture-naming and category-exemplar verification tasks whereas it reduced priming on word-stem completion and category-exemplar production tasks by half. These dissociations in patients with neurological disease indicate that different neural systems support identification and production priming. Indeed, AD patients often show intact priming on identification tasks, including word and nonword identification (e.g., Fleischman et al., 1995; Keane et al., 1991, 1994), lexical decision (Balota & Ferraro, 1996; Ober & Shenault, 1988; Ober, Shenault, Jagust, & Stillman, 1991), picture naming (Experiment 1 in the present study; Mitchell, 1988; Sullivan, Faust, & Balota, 1995), word naming (Balota & Duchek, 1991; Ober et al., 1991), and incomplete-picture identification (when compared with amnesic patients, Gabrieli et al., 1994). Conversely, AD patients often show impaired priming on production tasks, including word-stem completion (Experiment 1 in the present study; Gabrieli et al., 1994; Heindel et al., 1989; Keane et al., 1991; Salmon et al., 1988; Shimamura et al., 1987), word-association production (Brandt et al., 1988; Carlesimo et al., 1995; Salmon et al., 1988), and category-exemplar production (Experiment 3 in the present study; Monti et al., 1996). Not all AD priming results fit with an identification–production distinction, but that distinction appears to provide the best fit at present to the majority of findings (reviewed in Fleischman & Gabrieli, 1998).

The striking parallel between AD and division-of-attention influences on production priming but not identification priming begs the question as to whether diminished attentional resources in AD specifically account for these results. A limitation of the present study is that the pattern of spared and impaired repetition priming was not linked directly to attentional deficits per se in AD. AD patients have multiple cognitive deficits, and it is difficult to relate a specific performance impairment to either a single cognitive deficit or a single region of brain pathology. The prominent explicit memory deficit and medial-temporal pathology that characterize AD, however, appear irrelevant to the present findings. That explicit memory deficit did not prevent normal priming on the picture-naming and category-exemplar verification tasks. Further, amnesic patients with comparable explicit memory deficits and medial-temporal pathologies have repeatedly shown normal priming on two tasks on which AD patients were impaired: word-stem completion (Gabrieli et al., 1994; Graf et al., 1984; Keane et al., 1995; Warrington & Weiskrantz, 1970) and category-exemplar production (Graf et al., 1985; Keane et al., 1997).

The language or semantic deficits commonly seen in early AD also appear irrelevant to the dissociations demonstrated in the present study. All of the tasks involved language performance, and AD patients had impaired priming on a word-stem completion task that was not influenced by semantic analysis at test (Experiment 1c). Further, semantic deficits were evident in AD patients' baseline performances in both category-exemplar verification and production (Experiment 3), and they therefore do not account for the spared priming on one task and the compromised priming on the other.

Deficits in attention are evident, however, in early AD. Indeed, it has been argued that attentional deficits may be the second most common form of cognitive impairment in early AD (Parasuraman & Haxby, 1993). Attentional deficits are evidenced by many measures, including tests of selective attention (e.g., Freed, Corkin, Growdon, & Nissen, 1988; Parasuraman, Greenwood, Haxby, & Grady, 1992) and divided attention (e.g., Baddeley, Logie, Bressi, Della Sella, & Spinnler, 1986; Tinklenberg, Taylor, Peabody, Redington, & Gibson, 1984). These impairments may occur because the neuropathology of AD affects brain regions identified as critical for attention in lesion and functional imaging studies, including frontal, parietal, and cingulate regions (reviewed in Parasuraman & Haxby, 1993). The high prevalence of attention deficits in AD and the striking parallels between the effects of study-phase division of attention and AD on various forms of priming make an attentional deficit plausible as an explanation of intact and impaired priming in AD.

Convergent evidence for the attention hypothesis as an explanation for dissociations between various forms of repetition priming in AD comes from studies examining semantic priming in AD. Semantic priming differs from repetition priming: Semantic priming lasts very briefly, on the order of seconds, and is mediated by a different mechanism (den Heyer, Goring, & Dannenbring, 1985; Wilding, 1986). Semantic priming is usually measured in a lexical decision test in which participants decide whether target letter strings are real words (e.g., NURSE) or not real words (e.g., NARSE). Prior to each target word, a prime word is presented that is either semantically related (e.g., DOCTOR) or unrelated (e.g., HOUSE) to the target word. Presentation of a semantically related word, relative to an unrelated word, produces an enhancement in the speed of lexical decision with the target word that is termed *semantic priming.* A considerable literature on healthy individuals documents that there are two components of semantic priming, an automatic component that does not require attention and a controlled or attention-demanding component that does require attention (Neely, 1977; Posner & Snyder, 1975). Manipulation of the duration between prime and target presentation can eliminate the attention-demanding component of semantic priming. Very brief durations, less than 250 ms, do not allow individuals to use attention-demanding processes. AD patients show normal semantic priming with very brief prime–target intervals but impaired semantic priming with longer prime–target intervals (Shenault & Ober, 1996). Thus, AD patients show parallel dissociations in short-term semantic priming and long-term repetition priming that can both be accounted for by specific deficits in attention.

The distinction between identification and production priming also appears relevant to normal aging. One study compared word-stem and word-fragment completion repetition priming in younger and older individuals (Winocur, Moscovitch, & Stuss, 1996). Word-fragment completion, as usually performed, asks participants to identify a word based on partial presentation of the word (e.g., H_T_L). Most fragments have only one answer, so there is little or no response competition. Word-fragment completion is a test of perceptual priming (e.g., Roediger et al., 1989, 1992; Vaidya et al., 1995) that is not reduced by auditory division of attention at study (Experiment 2 in the present study; Gabrieli et al., 1999; Mulligan & Hartman, 1996). The older individuals in the study by Winocur et al. (1996) were either high functioning and community dwelling or less high functioning and living in institutions; the latter group did not, however, have AD. The community-dwelling older individuals had word-stem and word-fragment completion priming that was equivalent to that of young participants. The institutionalized individuals had impaired priming on the word-stem completion measure but intact priming on the word-fragment completion measure. Thus, they showed a dissociation between intact identification and reduced production priming. Studies of repetition priming in older adults have yielded a wide variety of results, but the identification–production distinction appears to fit with many of those findings (Fleischman & Gabrieli, 1998).

There are several lines of evidence that point to the frontal lobes as being important in production priming. First, Winocur et al. (1996) proposed that the frontal lobes may be important for word-stem completion priming because performance on neuropsychological tests sensitive to frontal-lobe lesions correlated with word-stem completion priming, but not word-fragment completion priming, in older adults. Second, functional neuroimaging studies suggest an important role of the left frontal lobe in the selection of one response among competing responses on word production tasks. One study compared activation when participants completed stems with many possible responses with activation when participants completed stems with few possible responses (Desmond, Gabrieli, & Glover, 1998). Even though responses were faster and more accurate for stems with many possible responses, there was greater activation in the left middle frontal gyrus when people completed stems with many possible completions than when they completed stems with few possible completions. Another study examined activation while people produced verbs that were related to presented nouns (Thompson-Schill, D'Esposito, Aguirre, & Farah, 1997). There was greater activation in the left inferior frontal gyrus for nouns that yielded many different verbs as responses than for nouns that yielded few different verbs as responses. Both studies indicate that left frontal cortex becomes more involved as response competition increases in a production task.

The selective effects of AD, aging, and division of attention on production priming may occur because of the importance of the frontal lobes for production priming. The frontal lobes are affected in AD, and there is evidence suggesting that the frontal lobes are disproportionately affected by aging (reviewed in Prull, Gabrieli, & Bunge, in press). Frontal cortex is activated during dual-task performance even when neither of the tasks in isolation activates the frontal lobes (D'Esposito et al., 1995). These findings make it plausible that AD, aging, and division of attention exert their effect on production priming by reducing frontal-lobe attentional resources. Performance on all priming tasks, however, likely involves a multiple-component, distributed neural network, and further research is needed to delineate the complete network.

## *Conclusion*

In the last decade of research on memory for words and pictures, two major distinctions were discovered that integrated psychological and neuroscience perspectives. One distinction was that between explicit and implicit retrieval. Another was that between perceptual and conceptual encoding and retrieval. The present results suggest a third fundamental distinction in the cognitive and neural organization of implicit memory, that between identification and production forms of knowledge retrieval.

## References


Abbenhuis, M. A., Raajmakers, W. G. M., Raajmakers, J. G. W., & Van Woerden, G. J. M. (1990). Episodic memory in dementia of the Alzheimer type and in normal aging: Similar impairment in automatic processing. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 42A,* 569–583.

Arnold, S. E., Hyman, B. T., Flory, J., Damasio, A. R., & Van Hoesen, G. W. (1991). The topographical and neuroanatomical distribution of neurofibrillary tangles and neuritic plaques in the cerebral cortex of patients with Alzheimer's disease. *Cerebral Cortex, 1,* 103–116.

Baddeley, A., Logie, R., Bressi, S., Della Sala, S., & Spinnler, H. (1986). Dementia and working memory. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 38A,* 603–618.

Balota, D. A., & Duchek, J. M. (1991). Semantic priming effects, lexical repetition effects, and contextual disambiguation effects in healthy aged individuals and individuals with senile dementia of the Alzheimer type. *Brain and Language, 40,* 181–201.

Balota, D. A., & Ferraro, F. R. (1996). Lexical, sublexical, and implicit memory processes in healthy young and healthy older adults and in individuals with dementia of the Alzheimer type. *Neuropsychology, 10,* 82–95.

Battig, W. F., & Montague, W. E. (1969). Category norms of verbal items in 56 categories: A replication and extension of the Connecticut category norms. *Journal of Experimental Psychology, 80* (3, Pt. 2), 1–46.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer-appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 657–668.

Blaxton, T. A., Bookheimer, S. Y., Zeffiro, T. A., Figlozzi, C. M., William, D. G., & Theodore, W. H. (1996). Functional mapping of human memory using PET: Comparisons of conceptual and perceptual tasks. *Canadian Journal of Experimental Psychology, 50,* 42–56.

Blaxton, T. A., Gabrieli, J. D. E., Park, S. M., Figlozzi, C. M., DeCarli, C., & Theodore, W. H. (1999). *Neural substrates for conceptual and perceptual processes in implicit memory: A PET study of primed picture naming.* Manuscript submitted for publication.

Bondi, M. W., & Kaszniak, W. (1991). Implicit and explicit memory in Alzheimer's disease and Parkinson's disease. *Journal of Clinical and Experimental Neuropsychology, 13,* 339–358.

Brandt, J., Spencer, M., McSorley, P., & Folstein, M. F. (1988). Semantic activation and implicit memory in Alzheimer's disease. *Alzheimer Disease and Associated Disorders, 2,* 112–119.

Brown, A. S., Neblett, D. R., Jones, T. C., & Mitchell, D. B. (1991). Transfer of processing in repetition priming: Some inappropriate findings. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 514–525.

Brun, A., & Englund, E. (1981). Regional pattern of degeneration in Alzheimer's disease: Neuronal loss and histopathological grading. *Histopathology, 5,* 549–564.

Buckner, R. L., Petersen, S. E., Ojemann, J. G., Miezin, F. M., Squire, L. R., & Raichle, M. E. (1995). Functional anatomical studies of explicit and implicit memory retrieval tasks. *Journal of Neuroscience, 12,* 12–29.

Carlesimo, G. A., Fadda, L., Marfia, G. A., & Caltagirone, C. (1995). Explicit memory and repetition priming in dementia: Evidence for a common basic mechanism underlying conscious and unconscious retrieval details. *Journal of Clinical and Experimental Neuropsychology, 17,* 44–57.

Carrillo, M. C., Gabrieli, J. D. E., & Disterhoft, J. F. (1996).

Distraction disrupts discrimination and discrimination reversal of eyeblink conditioning in humans. *Society for Neuroscience Abstracts, 22,* 1866.

Carroll, M., Byrne, B., & Kirsner, K. (1985). Autobiographical memory and perceptual learning: A developmental study using picture recognition, naming latency, and perceptual identification. *Memory & Cognition, 13,* 273–279.

Cave, C. B., & Squire, L. R. (1992). Intact and long-lasting repetition priming in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 509–520.

Cermak, L. S., Talbot, N., Chandler, K., & Wolbarst, L. R. (1985). The perceptual priming phenomenon in amnesia. *Neuropsychologia, 23,* 615–622.

Challis, B. H., & Brodbeck, D. R. (1992). Level of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 595–607.

Chertkow, H., & Bub, D. (1990). Semantic memory loss in dementia of Alzheimer's type. *Brain, 113,* 397–417.

Chertkow, H., Bub, D., & Seidenberg, M. (1989). Priming and semantic memory loss in Alzheimer's disease. *Brain and Language, 36,* 420–446.

Cohen, A., Ivry, R. I., & Keele, S. W. (1990). Attention and structure in sequence learning. *Journal of Experimental Psychology: Learning, Memory and Cognition, 16,* 17–30.

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences.* (2nd ed.). Hillsdale, NJ: Erlbaum.

Corkin, S. (1982). Some relationships between global amnesias and the memory impairments in Alzheimer's disease. In S. Corkin, K. L. Davis, J. H. Growdon & E. Usdin (Eds.), *Alzheimer's disease: A report of progress in research* (pp. 149–164). New York: Raven Press.

Demb, J. B., Desmond, J. E., Wagner, A. D., Vaidya, C. J., Glover, G. H., & Gabrieli, J. D. E. (1995). Semantic encoding and retrieval in the left inferior prefrontal cortex: A functional MRI study of task difficulty and process specificity. *Journal of Neuroscience, 15,* 5870–5878.

den Heyer, K., Goring, A., & Dannenbring, G. L. (1985). Semantic priming and word repetition: The two effects are additive. *Journal of Memory and Language, 24,* 699–716.

Desmond, J. E., Gabrieli, J. D. E., & Glover, G. H. (1998). Dissociation of frontal and cerebellar activation in a cognitive task: Evidence for a distinction between selection and search. *Neuroimage, 7,* 368–376.

D'Esposito, M., Detre, J., Alsop, D., Shun, R., Atlas, S., & Grossman, M. (1995). The neural basis of the central executive system of working memory. *Nature, 378,* 279–281.

Durso, F. T., & Johnson, M. K. (1979). Facilitation in naming and categorizing repeated pictures and words. *Journal of Experimental Psychology: Human Learning and Memory, 5,* 449–459.

Fleischman, D. A., & Gabrieli, J. D. E. (1998). Repetition priming in normal aging and Alzheimer's disease: A review of findings and theories. *Psychology and Aging, 13,* 88–119.

Fleischman, D. A., Gabrieli, J. D. E., Reminger, S., Rinaldi, J., Morrell, F., & Wilson, R. (1995). Conceptual priming in perceptual identification for patients with Alzheimer's disease and a patient with a right occipital lobectomy. *Neuropsychology, 9,* 187–197.

Fleischman, D. A., Gabrieli, J. D. E., Rinaldi, J., Reminger, S. L., Shapiro, R., & Wilson, R. S. (1997). Word-stem completion priming for perceptually and conceptually encoded words in Alzheimer's disease. *Neuropsychologia, 35,* 22–25.

Folstein, M. F., Folstein, S. E., & McHugh, P. R. (1975). Mini-mental state: A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12,* 189–198.

Frackowiak, R. S. J., Pozzilli, C., Legg, N. J., Du Boulay, G. H., Marshall, J., Lenzi, G. L., & Jones, T. (1981). Regional cerebral oxygen supply and utilization in dementia: A clinical and physiological study with oxygen-15 and positron tomography. *Brain, 104,* 753–778.

Freed, D. M., Corkin, S., Growdon, J. H., & Nissen, M. J. (1988). Selective attention in Alzheimer's disease: CSF correlates of behavioral impairments. *Neuropsychologia, 26,* 895–902.

Gabrieli, J. D. E., Desmond, J. E., Demb, J. B., Wagner, A. D., Stone, M. V., Vaidya, C. J., & Glover, G. H. (1996). Functional magnetic resonance imaging of semantic memory processes in the frontal lobes. *Psychological Science, 7,* 278–283.

Gabrieli, J. D. E., Fleischman, D. A., Keane, M. M., Reminger, S. L., & Morrell, F. (1995). Double dissociation between memory systems underlying explicit and implicit memory in the human brain. *Psychological Science, 6,* 76–82.

Gabrieli, J. D. E., Keane, M. M., Stanger, B. Z., Kjelgaard, M. M., Corkin, S., & Growdon, J. H. (1994). Dissociations among structural-perceptual, lexical-semantic, and even-fact memory systems in amnesic, Alzheimer's, and normal subjects. *Cortex, 30,* 75–103.

Gabrieli, J. D. E., Stone, M. V., Shackleton, K., Galan, J. B., Thompson-Schill, S. L., Seeley, W. W., & Chari, A. (1999). *Attention and implicit memory for words.* Manuscript submitted for publication.

Graf, P., & Mandler, G. (1984). Activation makes words more accessible, but not necessarily more retrievable. *Journal of Verbal Learning and Verbal Behavior, 23,* 553–568.

Graf, P., Mandler, G., & Haden, P. E. (1982). Simulating amnesic symptoms in normal subjects. *Science, 218,* 1243–1244.

Graf, P., & Schacter, D. L. (1985). Implicit and explicit memory for new associations in normal and amnesic subjects. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 501–518.

Graf, P., Shimamura, A. P., & Squire, L. R. (1985). Priming across modalities and priming across category levels: Extending the domain of preserved function in amnesia. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 11,* 386–396.

Graf, P., Squire, L. R., & Mandler, G. (1984). The information that amnesic patients do not forget. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 10,* 164–178.

Hayman, C. A. G., & Jacoby, L. L. (1989). Specific word transfer as a measure of processing in the word-superiority paradigm. *Memory & Cognition, 17,* 125–133.

Heindel, W. C., Salmon, D. P., Shults, C. W., Walicke, P. A., & Butters, N. (1989). Neuropsychological evidence for multiple implicit memory systems: A comparison of Alzheimer's, Huntington's, and Parkinson's disease patients. *Journal of Neuroscience, 9,* 582–587.

Huff, F. J., Corkin, S., & Growdon, J. H. (1986). Semantic impairment and anomia in Alzheimer's disease. *Brain and Language, 34,* 262–278.

Hyman, B. T., Van Hoesen, G. W., Damasio, A. R., & Barnes, C. L. (1984). Alzheimer's disease: Cell-specific pathology isolates the hippocampal formation. *Science, 225,* 1168–1170.

Hyman, B. T., Van Hoesen, G. W., Kromer, L. J., & Damasio, A. R. (1986). Perforant pathway changes and the memory impairment of Alzheimer's disease. *Annals of Neurology, 20,* 472–481.

Jacoby, L. L., & Dallas, M. (1981). On the relationship between autobiographical memory and perceptual learning. *Journal of Experimental Psychology: General, 110,* 306–340.

Johnson, K. A., Mueller, S. T., Walshe, T. M., English, T. J., &

Holman, B. L. (1987). Cerebral perfusion imaging in Alzheimer's disease. *Archives of Neurology, 44,* 165–168.

Johnson, M. K., & Hasher, L. (1987). Human learning and memory. *Annual Review of Psychology, 38,* 631–668.

Kaplan, E., Goodglass, H., & Weintraub, S. (1983). *Boston Naming Test.* Philadelphia: Lea & Febiger.

Keane, M. M., Gabrieli, J. D. E., Fennema, A. C., Growdon, J. H., & Corkin, S. (1991). Evidence for a dissociation between perceptual and conceptual priming in Alzheimer's disease. *Behavioral Neuroscience, 105,* 326–342.

Keane, M. M., Gabrieli, J. D., Growdon, J. H., & Corkin, S. (1994). Priming in perceptual identification of pseudowords is normal in Alzheimer's disease. *Neuropsychologia, 32,* 343–356.

Keane, M. M., Gabrieli, J. D. E., Mapstone, H., Johnson, K. A., & Corkin, S. (1995). Double dissociation of memory capacities after bilateral occipital-lobe or medial temporal-lobe lesions. *Brain, 118,* 1129–1148.

Keane, M. M., Gabrieli, J. D. E., Monti, L. A., Fleischman, D. A., Cantor, J. M., & Noland, J. S. (1997). Intact and impaired conceptual memory processes in amnesia. *Neuropsychology, 11,* 59–69.

Koivisto, M., Portin, R., & Rinne, J. O. (1996). Perceptual priming in Alzheimer's and Parkinson's diseases. *Neuropsychologia, 34,* 449–457.

Kučera, H., & Francis, W. N. (1967). *Computational analysis of present-day American English.* Providence, RI: Brown University Press.

Lachman, R., & Lachman, J. L. (1980). Picture naming: Retrieval and activation of long-term memory. In L. W. Poon, J. L. Fozard, L. S. Cermak, D. Arenberg, & L. W. Thompson (Eds.), *New directions in memory and aging: Proceedings of the George A. Talland memorial conference* (pp. 313–343). Hillsdale, NJ: Erlbaum.

Lewis, D. A., Campbell, M. J., Terry, R. D., & Morrison, J. H. (1987). Laminar and regional distribution of neurofibrillary tangles and neuritic plaques in Alzheimer's disease: A quantitative study of visual and auditory cortices. *Journal of Neuroscience, 7,* 1799–1808.

Light, L. L., & Albertson, S. A. (1989). Direct and indirect tests of memory for category exemplars in young and older adults. *Psychology and Aging, 4,* 487–492.

McKhann, G., Drachman, D., Folstein, M., Katzman, R., Price, D., & Stadlan, E. (1984). Clinical diagnosis of Alzheimer's disease: Report of the NINCDS-ADRDA Work Group under the auspices of Department of Health and Human Services Task Force on Alzheimer's Disease. *Neurology, 34,* 939–944.

Mitchell, D. B. (1988). Memory and language deficits in Alzheimer's disease. In R. L. Dippel & J. T. Hutton (Eds.), *Caring for the Alzheimer patient* (pp. 81–93). Buffalo, NY: Prometheus Books.

Mitchell, D. B. (1989). How many memory systems? Evidence from aging. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 31–49.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 213–222.

Monti, L. A., Gabrieli, J. D. E., Reminger, S. L., Rinaldi, J. A., Wilson, R. S., & Fleischman, D. A. (1996). Differential effects of aging and Alzheimer's disease upon conceptual implicit and explicit memory. *Neuropsychology, 10,* 101–112.

Mulligan, N. W., & Hartman, M. (1996). Divided attention and indirect memory tests. *Memory & Cognition, 24,* 453–465.

Nebes, R. D. (1989). Semantic memory in Alzheimer's disease. *Psychological Bulletin, 106,* 377–394.

Neely, J. H. (1977). Semantic priming and retrieval from lexical memory: Roles of inhibitionless spreading activation and limited-capacity attention. *Journal of Experimental Psychology: General, 106,* 226–254.

Nissen, M. J., & Bullemer, P. (1987). Attentional requirements of learning: Evidence from performance measures. *Cognitive Psychology, 19,* 1–32.

Ober, B. A., & Shenault, G. K. (1988). Lexical decision and priming in Alzheimer's disease. *Neuropsychologia, 26,* 273–286.

Ober, B. A., Shenault, G. K., Jagust, W. J., & Stillman, R. C. (1991). Automatic semantic priming with various category relations in Alzheimer's disease and normal aging. *Psychology and Aging, 6,* 647–660.

Ostergaard, A. L. (1994). Dissociations between word priming effects in normal subjects and patients with memory disorders: Multiple memory systems or retrieval? *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 47A,* 331–364.

Papka, M., Ivry, R. B., & Woodruff-Pak, D. S. (1995). Selective disruption of eyeblink classical conditioning by concurrent tapping. *NeuroReport, 6,* 1493–1497.

Parasuraman, R., Greenwood, P. M., Haxby, J. V., & Grady, C. L. (1992). Visuospatial attention in dementia of the Alzheimer type. *Brain, 115,* 711–733.

Parasuraman, R., & Haxby, J. V. (1993). Attention and brain function in Alzheimer's disease: A review. *Neuropsychology, 7,* 242–272.

Park, S. M., & Gabrieli, J. D. E. (1995). Perceptual and nonperceptual components of implicit memory for pictures. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21,* 1583–1594.

Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. L. Solso (Eds.), *Information processing and cognition: The Loyola Symposium.* Hillsdale, NJ: Erlbaum.

Prull, M. W., Gabrieli, J. D. E., & Bunge, S. A. (in press). Age-related changes in memory: A cognitive neuroscience perspective. In F. I. M. Craik & T. A. Salthouse (Eds.), *Handbook of aging and cognition II.* Hillsdale, NJ: Erlbaum.

Raichle, M. E., Fiez, J. A., Videen, T. O., MacLeod, A. K., Pardo, J. V., Fox, P. E., & Petersen, S. E. (1994). Practice-related changes in human brain functional anatomy during nonmotor learning. *Cerebral Cortex, 4,* 8–26.

Roediger, H. L., Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honour of Endel Tulving* (pp. 3–14). Hillsdale, NJ: Erlbaum.

Roediger, H. L., Weldon, M. S., Stadler, M. L., & Riegler, G. L. (1992). Direct comparison of two implicit memory tests: Word fragment and word stem completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 1251–1269.

Russo, R., & Spinnler, H. (1994). Implicit verbal memory in Alzheimer's disease. *Cortex, 30,* 359–375.

Salmon, D. P., Shimamura, A. P., Butters, N., & Smith, S. (1988). Lexical and semantic deficits in patients with Alzheimer's disease. *Journal of Clinical and Experimental Neuropsychology, 10,* 477–494.

Schacter, D. L., Alpert, N. M., Savage, C. R., Rausch, S. L., & Albert, M. S. (1996). Conscious recollection and the human hippocampal formation: Evidence from positron emission tomography. *Proceedings of the National Academy of Sciences, USA, 93,* 321–325.

Schwartz, B. L. (1989). Effects of generation on indirect measures of memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 1119–1128.

Shenault, G. K., & Ober, B. A. (1996). Methodological control of semantic priming in Alzheimer's disease. *Psychology and Aging, 11,* 443–448.

Shimamura, A. P., Salmon, D. P., Squire, L. R., & Butters, N. (1987). Memory dysfunction and word priming in dementia and amnesia. *Behavioral Neuroscience, 101,* 347–351.

Shimamura, A. P., & Squire, L. R. (1984). Paired-associate learning and priming effects in amnesia: A neuropsychological study. *Journal of Experimental Psychology: General, 113,* 556–570.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Squire, L. R., Ojemann, J. G., Miezin, F. M., Petersen, S. E., Videen, T. O., & Raichle, M. E. (1992). Activation of the hippocampus in normal humans: A functional anatomical study of memory. *Proceedings from the National Academy of Science, 89,* 1837–1841.

Srinivas, K., & Roediger, H. L. (1990). Classifying implicit memory tests: Category association and anagram solution. *Journal of Memory and Language, 29,* 389–412.

Stone, M., Ladd, S. L., Vaidya, C. S., & Gabrieli, J. D. E. (1998). Word identification priming for ignored and attended words. *Consciousness and Cognition, 7,* 238–258.

Sullivan, M. P., Faust, M. E., & Balota, D. A. (1995). Identifying negative priming in older adults and individuals with dementia of the Alzheimer type. *Neuropsychology, 9,* 537–555.

Swick, D., & Knight, R. T. (1996). Is prefrontal cortex involved in cued recall? A neuropsychological test of PET findings. *Neuropsychologia, 34,* 1019–1028.

Szymanski, K. F., & MacLeod, C. M. (1996). Manipulation of attention at study affects an explicit but not an implicit test of memory. *Consciousness and Cognition, 5,* 165–175.

Thompson-Schill, S. L., D'Esposito, M., Aguirre, G. K., & Farah, M. J. (1997). Role of left inferior prefrontal cortex in retrieval of semantic knowledge: A re-evaluation. *Proceedings from the National Academy of Science, 94,* 14792–14797.

Tinklenberg, J. R., Taylor, J. L., Peabody, C. A., Redington, D., & Gibson, E. (1984). Dual-task performance measures in geriatric studies. *Psychopharmacology Bulletin, 20,* 441–444.

Vaidya, C. J., Gabrieli, J. D. E., Keane, M. M., & Monti, L. A. (1995). Perceptual and conceptual memory processes in global amnesia. *Neuropsychology, 9,* 580–591.

Vaidya, C. J., Gabrieli, J. D. E., Keane, M. M., Monti, L. A., Gutierrez-Rivas, H., & Zarella, M. M. (1997). Evidence for multiple mechanisms of conceptual priming on implicit memory tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 23,* 1324–1343.

Verfaellie, M., Gabrieli, J. D. E., Vaidya, C. J., Croce, P., & Reminger, S. L. (1996). Implicit memory for pictures in amnesia: Role of etiology and priming task. *Neuropsychology, 10,* 517–528.

Warrington, E. K., & Weiskrantz, L. (1970). The amnesic syndrome: Consolidation or retrieval? *Nature, 228,* 628–630.

*Webster's New Collegiate Dictionary.* (1974). Springfield, MA: Merriam.

Wilding, J. (1986). Joint effects of semantic priming and repetition in a lexical decision task: Implications for a model of lexical access. *Quarterly Journal of Experimental Psychology: Human Experimental Psychology, 38A,* 213–228.

Winocur, G., Moscovitch, M., & Stuss, D. T. (1996). Explicit and implicit memory in the elderly: Evidence for double dissociation involving medial-temporal and frontal-lobe functions. *Neuropsychology, 10,* 57–65.

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