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Conceptual fluency at test shifts recognition response bias in Alzheimer's disease: Implications for increased false recognition

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Abstract

The presence or absence of conceptual information in pictorial stimuli may explain the mixed findings of previous studies of false recognition in patients with mild Alzheimer's disease (AD). To test this hypothesis, 48 patients with AD were compared to 48 healthy older adults on a recognition task first described by Koutstaal et al. [Koutstaal, W., Reddy, C., Jackson, E. M., Prince, S., Cendan, D. L., & Schacter D. L. (2003). False recognition of abstract versus common objects in older and younger adults: Testing the semantic categorization account. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 29*, 499–510]. Participants studied and were tested on their memory for categorized ambiguous pictures of common objects. The presence of conceptual information at study and/or test was manipulated by providing or withholding disambiguating semantic labels. Analyses focused on testing two competing theories. The semantic encoding hypothesis, which posits that the inter-item perceptual details are not encoded by AD patients when conceptual information is present in the stimuli, was not supported by the findings. In contrast, the conceptual fluency hypothesis was supported. Enhanced conceptual fluency at test dramatically shifted AD patients to a more liberal response bias, raising their false recognition. These results suggest that patients with AD rely on the fluency of test items in making recognition memory decisions. We speculate that AD patients' over reliance upon fluency may be attributable to (1) dysfunction of the hippocampus, disrupting recollection, and/or (2) dysfunction of prefrontal cortex, disrupting post-retrieval processes.
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Keywords: False recognition; Alzheimer's disease; Conceptual fluency; Response bias; Ambiguous images

False recognition occurs when individuals mistakenly claim that they have previously encountered a novel item or event. In the laboratory, false recognition can be induced by a variety of experimental procedures (for reviews, see Gallo, 2006; Koriat, Goldsmith, & Pansky, 2000; Schacter & Slotnick, 2004; Yonelinas, 2002). Clinical memory distortions that may be mimicked by false recognition range from infrequent innocuous errors, such as remembering washing the dinner dishes when they actually sit dirty in the kitchen sink, to frequent and debilitating faulty memories. Elucidating the experimental conditions that affect the tendency to falsely recognize unstudied items may eventually lead to better understanding of the real-world memory distortions experienced by healthy and memory-disordered individuals.

Numerous studies of false recognition have revealed that healthy aging is often associated with increased false recognition (for reviews, see Jacoby & Rhodes, 2006; Koutstaal &

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Schacter, 2001; Schacter, Norman, & Koutstaal, 1998; Schacter, Verfaellie, Anes, & Racine, 1998). False recognition rates for older adults compared to younger adults have been most dramatically elevated when categorically related pictures of common objects served as the stimuli (Koutstaal & Schacter, 1997; Koutstaal, Schacter, & Brenner, 2001; Koutstaal, Schacter, Galluccio, & Stofer, 1999). For example, using categorized colored pictures of common objects, Koutstaal and Schacter (1997) found false recognition rates as high as 0.70 for healthy older adults, but only as high as 0.35 for younger adults.

In addition to studying the changes in false recognition associated with healthy aging, a large number of recent studies of false recognition have compared the performances of patients with mild AD to healthy older adults (e.g., Balota et al., 1999; Bartlett, Halpern, & Dowling, 1995; Budson, Daffner, Desikan, & Schacter, 2000; Budson, Dodson, Daffner, & Schacter, 2005; Budson, Droller, et al., 2005; Pierce, Sullivan, Schacter, & Budson, 2005; Sommers & Huff, 2003; Waldie & Kwong See, 2003). Particular emphasis has been placed on evaluating the false recognition of pictorial stimuli by AD patients. By studying the conditions that affect false recognition for experimental picture stimuli, researchers may be able to gain insight into misidentification, a troubling memory distortion exhibited by many AD patients (Cooper, Shanks, & Venneri, 2006). Misidentifications of people or situations may be attributable to false or otherwise faulty memories of visual stimuli (Borson & Raskind, 1997). Unfortunately, to this point the results of studies of false recognition for visual stimuli in AD have not been easily interpretable. Budson, Desikan, Daffner, and Schacter (2001) found equivalent false recognition performance between patients with AD and healthy older adults for categorized abstract images (multi-part, abstract, object-like images that do not possess any semantic or conceptual referent). In contrast, Budson, Sitarski, Daffner, and Schacter (2002) reported a significant increase in the rate of false recognition for AD patients compared to older controls when the test probes were black-and-white line drawings of familiar objects and simple scenes combined with semantically related auditory cues, as opposed to auditory cues alone. Using categorized color photographs of common objects as the stimuli, Budson et al. (2003) also found an elevated rate of false recognition for patients with AD compared to healthy older adults. We believe that understanding why AD patients falsely recognize some, but not all, pictorial stimuli at an elevated rate compared to healthy older controls requires a closer look at the pictures themselves.

A picture may convey perceptual information, conceptual information, or both. Perceptual information includes the size, colors, shapes, perspective, relative orientations, shading, and other physical details that make a particular picture visually distinct from other pictures. For example, the low-level perceptual information conveyed by a photograph of a dog includes the shape of the dog's body, the pattern of spots on the dog's coat, and the direction of the dog's gaze. The specific perceptual information present in the photograph would make this photograph discernible from other photographs of the same dog and from pictures of other dogs. The primary conceptual information conveyed by the photograph mentioned above is the concept of "dog". Other conceptual information that might be encoded by a person studying the photograph includes the concepts of "pet" and "animal." Differences in the amount of perceptual and conceptual information in experimental stimuli may be critical to understanding false recognition in AD.

When previous studies of false recognition in AD are classified in terms of the conceptual and perceptual information present in the pictorial stimuli, a pattern emerges. The findings of Budson, Sitarski, et al. (2002) and Budson et al. (2003) suggest that when tested with stimuli that are both perceptually detailed and conceptually meaningful, such as black-and-white line drawings or photographs of common objects, patients with AD demonstrated increased false recognition compared to older adults. In contrast, when the stimuli were perceptually distinct, but conceptually empty, like the abstract drawings used in Budson et al. (2001), AD patients and healthy older adults were equally likely to falsely recognize unstudied items. In the current study, we conducted a single experiment to further investigate this pattern.

The experiment reported here compared the false recognition performance of patients with AD and healthy older adult controls in the paradigm described in Experiment 1 of Koutstaal et al. (2003), a study which compared false recognition in healthy older and younger adults. In the paradigm, categorized abstract colored line drawings of common objects served as the experimental stimuli. When presented alone, the drawings were intended to be so abstract as to be unidentifiable and therefore devoid of conceptual information. For example, a squiggly, vaguely rectangular line drawing (Fig. 1, left) presented alone was intended to be perceptually similar to but distinct from other drawings within its category (Fig. 1, center and right), and to carry no conceptual meaning. However, when presented in conjunction with a descriptive category label, the stimuli could be readily identified as common objects and thus became conceptually meaningful. When the category label "TRUCK" immediately preceded the presentation of any of the abstract images in Fig. 1, the drawing would retain its perceptual distinctiveness, but also would be identifiable as a big rig. With the label, each stimulus would convey the primary concept of "truck." The presence of disambiguating labels was manipulated at study and test such that four between-participants conditions existed: clear-clear (CC; no labels present at study or test), label-label (LL; labels present at both study and test), clear-label (CL; labels absent at study, but present at test) and label-clear (LC; labels present at study, but not at test).

Koutstaal et al. (2003) designed this paradigm to test their semantic categorization account of the healthy aging-related increase in false recognition of pictorial stimuli found in pre-

Fig. 1. Examples of the ambiguous stimuli used in the experiment. These three items are each exemplars of the category *truck*. Note that although, for illustrative purposes here, the stimuli are shown in black and white, the stimuli shown to participants were filled with color, with color being an important attribute that was varied both within and across categories.

vious studies (e.g., Koutstaal & Schacter, 1997; Koutstaal et al., 2001, 1999). We used the paradigm to examine the increased rate of false recognition for conceptually and perceptually meaningful pictures previously found in individuals with AD by testing two competing hypotheses: the semantic encoding hypothesis and the conceptual fluency hypothesis.

The semantic encoding hypothesis posits that when individuals with AD study conceptually meaningful and perceptually detailed pictorial stimuli, they focus on pre-existing semantic or conceptual information to the extent that they fail to encode perceptual differences between category exemplars. The processing of conceptual or semantic information may diminish or even prevent the encoding of item-specific perceptual information. For example, an individual with AD studying a particular photograph of a dog might encode the concept of "dog" while failing to encode enough perceptual information to subsequently distinguish the image from other photographs of dogs. This leads to diminished veridical recognition and elevated false recognition, since within a given category all of the probes carry the same primary conceptual information. The semantic encoding hypothesis may explain the findings of the previous studies of false recognition for pictorial stimuli in AD patients. Budson, Sitarski, et al. (2002), Budson, Sullivan, et al. (2002) and Budson et al. (2003) reported elevated false recognition for AD patients compared to healthy older adults when the pictorial stimuli – line drawings and color photographs of categorized common objects – conveyed both perceptual and conceptual information. The conceptual information in the pictures may have diminished perceptual processing by both groups, but more so by AD patients. Also in accordance with the semantic encoding hypothesis, Budson et al. (2001) found that the rate of false recognition of AD patients was equivalent to that of healthy older adults when the stimuli were abstract images devoid of conceptual information. In the absence of conceptual information, patients with AD may have been able to encode and recognize perceptual picture information as successfully as healthy older adults did. If the semantic encoding hypothesis were an appropriate explanation for these results, then we would predict in the current experiment that compared to healthy older adult controls, AD patients would show elevated false recognition when disambiguating labels were present at study, but not when the labels were absent. The presence of disambiguating labels at study would introduce conceptual information that AD patients would encode to the exclusion of encoding perceptual differences between items, leading to elevated false recognition. In the absence of such labels at study, the stimuli would be free of conceptual information, forcing AD patients to encode inter-item perceptual differences.[1]

In addition to testing the semantic encoding hypothesis, the current experiment provided an opportunity to assess the role of conceptual processing *fluency* in recognition memory decisions in AD. Fluency denotes the relative ease or difficulty of processing a stimulus, such that processing a highly fluent stimulus is less effortful than processing a less fluent stimulus (for reviews, see Wolk et al., 2005; Yonelinas, 2002). Prior work has suggested that one important cause of a subjective feeling of familiarity on a recognition memory test is related to how fluent the test item is (Jacoby & Whitehouse, 1989). This idea stems from the finding that prior presentation of an item leads to easier identification when the item is re-represented in a degraded fashion (Jacoby & Dallas, 1981). Thus, when making recognition judgments, subjects will often use enhanced processing fluency as a cue that an item was previously studied (Jacoby & Dallas, 1981; Jacoby & Whitehouse, 1989; Kelly & Jacoby, 2000; Whittlesea, 1993; Whittlesea, Jacoby, & Girard, 1990). Supporting this notion, manipulations that alter *perceptual fluency*, such as varying the visual clarity of the test items, influence how subjects respond on tests of recognition memory. Items that are more fluent (that is, easier to perceive) are more likely to be endorsed as being on a prior study list than are less fluent items (Jacoby & Whitehouse, 1989; Whittlesea et al., 1990), regardless of whether the items at test were studied or non-studied. In other words, participants will show a more liberal response bias toward endorsing more fluent test items as having been studied compared to less fluent items, elevating both true and false recognition (Wolk et al., 2005).

Similarly, manipulations of *conceptual fluency* (the ease of conceptual processing) can also influence recognition memory judgments. For example, experimental manipulation of the conceptual fluency of semantic stimuli affects recognition memory judgments in healthy younger adults (e.g., Rajaram & Geraci, 2000; Whittlesea & Williams, 2000, 2001). In the paradigm developed by Whittlesea and colleagues, either conceptually predictive or non-predictive sentence stems precede test words. True and false recognition rates were found to be elevated by the presence of the conceptually predictive context compared to the non-predictive context (e.g., Whittlesea & Williams, 2001). For example, subjects are more likely to say that the word "boat" was on a study list if it follows the predictive context, "The stormy seas tossed the. . ." than the non-predictive context, "She saved up her money and bought a. . ." The predictive context is thought to enhance the ease of conceptual processing (i.e., enhancing fluency), which is then mistaken as a cue of prior study. Wolk et al. (2005) studied AD patients in the Whittlesea paradigm and found that they were also likelier to endorse items as "old" in the higher fluency condition. In the current experiment, the abstract drawings presented at test with disambiguating labels would be easier to process by being more conceptually meaningful, and thus more conceptually fluent (less effortfully semantically processed), than those presented without labels. If participants were to attribute this conceptual fluency at test to a feeling of familiarity caused by previously studying the stimuli, then the presence of labels at test should lead to a more liberal response bias, elevating both true and false recognition.

Thus, the present experiment allowed us to examine two competing hypotheses to explain AD patients' increased false recognition of pictures relative to healthy older adult controls. According to the semantic encoding hypothesis, when disam-

[1] Note that the semantic encoding hypothesis proposed and tested here differs from the semantic categorization hypothesis of Koutstaal et al. (2003) in that the encoding hypothesis focuses exclusively on processes operative at encoding, whereas the categorization hypothesis of Koutstaal et al. (2003) concerned processes at encoding and/or retrieval.

Table 1
Experimental hypotheses

Semantic encoding hypothesis	AD patients will show elevated false recognition when labels are present at study (conditions label-label [LL] & label-clear [LC]), compared to when labels are absent at study (conditions clear-clear [CC] & clear-label [CL]).
Conceptual fluency hypothesis	AD patients will show elevated false recognition when labels are present at test (conditions label-label [LL]& clear-label [CL]), compared to when labels are absent at test (conditions clear-clear [CC] & label-clear [LC]).

biguating labels are present at study, false recognition should be elevated. According to the conceptual fluency hypothesis, when disambiguating labels are present at test, false recognition should be elevated (see Table 1 for a summary of our experimental hypotheses). Given the results of Wolk et al. (2005), which found that AD patients were strongly susceptible to the effects of conceptual fluency, we predicted that, in line with the conceptual fluency hypothesis, AD patients would show a higher rate of false recognition when disambiguating labels were present at test (conditions LL & CL) compared to when they were not (conditions CC & LC), and that rates of false recognition would be similar regardless of whether labels were present at study (conditions LL & LC) or not (conditions CC & CL).

To test these hypotheses, the primary analyses of interest will be comparisons of false recognition by study condition (clear at study versus label at study) to examine the semantic encoding hypothesis, and by test condition (clear at test versus label at test) to examine the conceptual fluency hypothesis. Because the semantic encoding hypothesis only applies to false recognition of related categorized items, whereas the conceptual fluency hypothesis applies equally to false recognition of related categorized items and to false recognition of unrelated novel items, analyses of uncorrected false recognition (not novel-corrected false recognition) will provide the best comparisons between the competing hypotheses. Lastly, if the conceptual fluency hypothesis were correct, then it would apply to all items at test, studied and unstudied. Thus, we will also present analyses of the response bias measure *C* to examine the conceptual fluency hypothesis.

1. Method

1.1. Participants

Forty-eight healthy older adult controls and 48 patients with a clinical diagnosis of probable AD, as determined by the National Institute of Neurological and Communicative Disorders and Stroke-Alzheimer's Disease and Related Disorders Association criteria (McKhann et al., 1984), were recruited for the experiment. Many of the healthy older adult controls were recruited from a pool of individuals who were already participating in a longitudinal study of normal aging at Brigham and Women's Hospital. The remaining healthy elderly participants were spouses and friends, but not blood relatives, of the AD patients who participated in the present study. The participants with AD were recruited from the clinical populations of the Memory Disorders Unit, Brigham and Women's Hospital, Boston, Massachusetts, and the Memory Clinic, Southwestern Vermont Medical Center, Bennington, Vermont. The human subjects committees of Brigham and Women's Hospital and Southwestern Vermont Medical Center approved this study. Written informed consents were obtained from all participants and from their caregivers where appropriate. Participants were paid US$ 10 per hour for their participation.

The average age of healthy older adult controls was 74.8 years (S.D. = 6.69); they reported an average of 14.8 years (S.D. = 2.90) of education and scored an average of 29.0 (S.D. = 1.17) on the Mini-Mental Status Exam (MMSE; Folstein, Folstein, & McHugh, 1975). The average age of the participants with AD was 77.0 years (S.D. = 7.73). AD participants reported an average of 14.5 years (S.D. = 3.07) of education and scored an average of 23.2 (S.D. = 3.56) on the MMSE. There were no effects of age or years of education between the healthy older adult control and AD groups. As expected, healthy older adult controls scored significantly higher on the MMSE than patients with AD, $F(1, 94) = 111.27$, $p < 0.001$. For the different conditions (CC, CL, LC, LL), the AD patients were matched for age, education, and MMSE score, and the control participants were matched for age and education.

Of the 48 AD patients, 25 were male and 23 were female. Of the 48 older controls, 16 were male and 32 were female. The male to female ratios by condition for AD were as follows: CC, 6:6; CL, 8:4; LC, 6:6; LL, 5:7. The male to female ratios by condition for older controls were as follows: CC, 4:8; CL, 4:8; LC, 5:7; LL, 3:9. Analyses were performed to determine if there were any effects of gender. These analyses revealed no significant overall effects of gender and no interactions of gender with any other variable.

1.2. Design

The experimental design included a within-participants factor of category size and two between-participants factors: group (AD patients versus older controls), and condition (CC, LL, CL, LC). In the study phase, there were three levels of category size, plus primacy and recency buffers: large, single, and unrelated. For studied items at test there were three levels of category size: large, single, and unrelated. Items in the large category were categorically related to six items that had been presented at study, while items in the single category were categorically related to one item that had been presented at study. Unrelated items were noncategorized and unrelated to other items at study or test. Four levels of category size existed for nonstudied items: large, single, unrelated, and novel. Novel items were those for which no related items were presented at study. The proportion of "old" responses to novel items provided an estimate of the baseline false alarm rate. (Note that the unrelated items were included by Koutstaal et al. (2003) to increase the length and variety of the study and test lists. For brevity, because these items do not pertain to the hypotheses presented in the Introduction, results for these items are not presented or analyzed).

1.3. Stimuli

The stimuli were colored ambiguous pictorial representations of common objects, created for Koutstaal et al. (2003) using Aldus FreeHand 7.0 (Macromedia, 1996). The stimuli were designed to meet three criteria. First, each stimulus was intended to be sufficiently abstract so that when presented without a label the stimulus would not be identifiable as a particular common object. Second, when presented in conjunction with a label, the shape of each stimulus was designed to be adequately distinct such that it could reasonably belong to the category of objects named by the label. Third, the shape of each stimulus within a particular category was supposed to be similar enough to the shapes of the other stimuli within that category to be identifiable as belonging to that category, and not to other categories within the list. During experimental piloting, Koutstaal et al. (2003) conducted a norming process to ensure that these three design criteria were met for all of the stimuli included in the experiment.

In the present experiment the stimuli included 18 categories of nine items each and 18 pairs of two items each. To counterbalance the large, single, and novel category sizes, the 18 categories were divided into three sets of six categories each. At test, each of the categories assigned to the large category size was tested three times with studied items and three times with categorically related lures. Items in the novel category size were tested three times with items from an unstudied category. For the single category size, only one item from each of six categories was presented at study. At test, this one studied item per category and one related lure per category were presented.

1.4. Procedure

Each participant was tested individually in a single session. Stimuli were presented on an Apple Macintosh Powerbook computer via PsyScope software (Cohen, MacWhinney, Flatt, & Provost, 1993). The procedure consisted of three phases.

In the study phase, participants viewed a total of 60 items (six items per category from each of six large categories, one item from each of six single categories, one item from each of 12 unrelated groups, three primacy buffers, and three recency buffers). All participants were told that abstract colored forms would appear on the screen. Participants in the label at study condition were also informed that a written word would appear immediately before each picture and would remain on screen for 2 s. In the clear at study condition, a fixation symbol ("+") was shown in place of the label. Each study item was presented for 3 s. All participants were asked to verbally report a "like" or "dislike" rating for each item. In formulating these ratings, participants were asked to look carefully at the items and to use all available visual information. A retention interval of five minutes duration followed the study phase. During this interval, all participants performed Raven's progressive matrices (Raven, 1941). If any participant completed the matrices within the 5-min interval, he or she then worked on simple arithmetic problems.

In the test phase, participants viewed stimuli and were asked to report whether each item was "old" (previously studied and rated for like or dislike) or "new" (previously unseen during the experiment). It was emphasized to participants that they should report "old" only if the specific item was studied, and that they should not report "old" solely because the item belonged to a category that was studied. The test list consisted of 90 items, including 30 items that had been presented at study and 60 items that had not been previously presented. Of the 30 studied items, 18 were selected from the large categories (three items from each of six categories), six were selected from the single categories (one from each of six categories), and six were unrelated items. Of the 60 nonstudied items, 36 were lures and 24 were novel items. The lures consisted of 18 large category lures (three items from each of six large categories), six single category lures (one item from each of six single categories), and 12 unrelated lures (one item from each of 12 groups). Of the novel items, 18 were three items each from six unstudied categories, and six were one item each from six unstudied categories.

2. Results

2.1. True and false recognition by condition

Table 2 presents uncorrected true and false recognition data by category size for AD patients and healthy older adult controls in the LL, CC, LC, and CL conditions. To analyze uncorrected true recognition, a 2 (group: AD patients, healthy older adult controls) × 4 (condition: LL, CC, LC, CL) × 2 (category size: large, single) repeated measures analysis of variance (ANOVA) was performed. This ANOVA revealed no effect of group, $F(1, 88) = 1.20$, MSE = 0.084, $p = 0.276$, $\eta^2 = 0.013$, or condition $F(3, 88) = 1.75$, MSE = 0.084, $p = 0.162$, $\eta^2 = 0.06$, and no group × condition interaction, $F(3, 88) = 1.23$, MSE = 0.084, $p = 0.303$, $\eta^2 = 0.04$. There was a within-participants effect of category size, $F(1, 88) = 76.95$, MSE = 0.025, $p < 0.001$, $\eta^2 = 0.47$, which demonstrated that participants with AD and healthy older adult controls both exhibited greater true recognition performance for items in the large category size than for items in the single category size. No interactions were found for category size × group, $F(1, 88) < 1$, for category size × condition, $F(3, 88) = 2.10$, MSE = 0.025, $p = 0.106$, $\eta^2 = 0.07$, or for category size × group × condition, $F(3, 88) = 1.50$, MSE = 0.025, $p = 0.221$, $\eta^2 = 0.05$.

Table 2
True and false recognition by group and condition

	Older adult controls				AD patients			
	LL	CC	LC	CL	LL	CC	LC	CL
True								
Large	0.76	0.81	0.71	0.73	0.76	0.61	0.70	0.73
S.D.	0.15	0.15	0.20	0.17	0.26	0.24	0.22	0.26
Single	0.61	0.57	0.49	0.50	0.62	0.46	0.33	0.61
S.D.	0.22	0.25	0.21	0.28	0.33	0.27	0.17	0.29
False								
Large	0.53	0.57	0.57	0.52	0.75	0.59	0.59	0.74
S.D.	0.20	0.19	0.20	0.19	0.28	0.26	0.22	0.22
Single	0.39	0.21	0.25	0.29	0.61	0.29	0.28	0.61
S.D.	0.23	0.20	0.17	0.24	0.27	0.28	0.25	0.31
Novel	0.05	0.17	0.08	0.18	0.41	0.34	0.24	0.56
S.D.	0.06	0.11	0.18	0.15	0.34	0.26	0.19	0.29

A 2 (group: AD patients, healthy older adult controls) × 4 (condition: LL, CC, LC, CL) × 3 (category size: large, single, novel) repeated measures ANOVA was used to analyze uncorrected false recognition performance. The ANOVA revealed between-participants effects of condition, $F(3, 88) = 3.30$, MSE = 0.114, $p = 0.024$, $\eta^2 = 0.10$, and group, $F(1, 88) = 21.42$, MSE = 0.114, $p < 0.001$, $\eta^2 = 0.20$, but no interaction of group × condition, $F(3, 88) = 2.26$, MSE = 0.114, $p = 0.087$, $\eta^2 = 0.07$. The effect of group was present because AD patients showed higher overall levels of uncorrected false recognition compared to healthy older adult controls. Within-participants effects and interactions were found for category size, $F(2, 176) = 150.53$, MSE = 0.021, $p < 0.001$, $\eta^2 = 0.63$, category size × condition, $F(6, 176) = 5.29$, MSE = 0.021, $p < 0.001$, $\eta^2 = 0.15$, and category size × group, $F(2, 176) = 6.25$, MSE = 0.021, $p = 0.002$, $\eta^2 = 0.07$, but not for category size × condition × group, $F(6, 176) < 1$. Pairwise comparisons revealed that the effect of category size was present because false recognition of large category items was greater than that of single category items, which was in turn greater than that of novel items ($ps < 0.001$). To further examine the effect of condition and the interactions, and to assess the competing hypotheses discussed in the introduction, false recognition was next analyzed by the presence or absence of labels at study (LL and LC versus CC and CL) and by the presence or absence of labels at test (LL and CL versus CC and LC).

2.2. False recognition by study condition

The clear-at-study condition was composed of the CC and CL conditions. The label-at-study condition was composed of the LL and LC conditions. See Table 3 for mean false recognition as a function of study condition. A 2 (group: AD patients, healthy older adult controls) × 2 (study condition: clear, label) × 3 (category size: large, single, novel) repeated measures ANOVA revealed effects and interactions of group, $F(1, 92) = 18.93$, MSE = 0.129, $p < 0.001$, $\eta^2 = 0.17$, category size, $F(2, 184) = 143.00$, MSE = 0.022, $p < 0.001$, $\eta^2 = 0.61$, category size × study condition, $F(2, 184) = 6.74$, MSE = 0.022, $p = 0.001$, $\eta^2 = 0.07$, and category size × group, $F(2, 184) = 5.93$,

Table 3
False recognition by study condition and category type

Group	Clear at study			Label at study		
	Large	Single	Novel	Large	Single	Novel
AD	0.67	0.45	0.45	0.67	0.44	0.32
Control	0.54	0.25	0.17	0.55	0.32	0.06

MSE = 0.022, $p = 0.003$, $\eta^2 = 0.06$. There was no effect of study condition, $F(1, 92) < 1$, and no interactions of group × study condition, $F(1, 92) < 1$, or category size × study condition × group, $F(2, 184) < 1$. The effects of group and category size have been discussed above. The category size × group interaction is likely attributable to the fact that the effect of category size was lesser for the AD patients ($\eta^2 = 0.54$) than for the older adult controls ($\eta^2 = 0.70$). Similarly, the category size × study condition interaction is likely attributable to the effect of category size being greater for the label at study condition ($\eta^2 = 0.65$) than for the clear at study condition ($\eta^2 = 0.54$).

2.3. False recognition by test condition

The clear-at-test condition combined the CC and LC conditions, while the label-at-test condition combined the LL and CL conditions. See Table 4 for mean false recognition as a function of test condition. A 2 (group: AD patients, healthy older adult controls) × 2 (test condition: clear, label) × 3 (category size: large, single, novel) repeated measures ANOVA revealed effects and interactions of group, $F(1, 92) = 22.24$, MSE = .110, $p < 0.001$, $\eta^2 = 0.20$, test condition, $F(1, 92) = 9.81$, MSE = 0.110, $p = 0.002$, $\eta^2 = 0.10$, group × test condition, $F(1, 92) = 6.88$, MSE = 0.110, $p = 0.010$, $\eta^2 = 0.07$, category size × group, $F(2, 184) = 5.98$, MSE = 0.022, $p = 0.003$, $\eta^2 = 0.06$, and category size × test condition, $F(2, 184) = 7.96$, MSE = 0.022, $p < 0.001$, $\eta^2 = 0.08$; the three-way interaction was not significant, $F(2, 184) < 0.1$. The effects of group and of category size and the group × category size interaction have been discussed above. The category size × test condition interaction is likely attributable to the effect of category size being lesser for the label at test condition ($\eta^2 = 0.54$) than for the clear at test condition ($\eta^2 = 0.67$). The effect of test condition is attributable to false recognition being greater when the label was present at test compared to when the label was absent at test. Importantly, the group × test condition interaction is attributable to this effect of test condition being present only for the AD patients, $F(1, 44) = 10.59$, MSE = 0.172, $p = 0.002$, $\eta^2 = 0.19$, and not for the healthy older adult controls, $F(1, 44) < 1$ (Fig. 2). These results, showing the elevation of false recognition in AD patients for the label condition at test, but not for the label condition at study, provide the first evidence that the conceptual fluency hypothesis – and not the semantic encoding hypothesis – is correct.

Table 4
False recognition by test condition and category type

Group	Clear at test			Label at test		
	Large	Single	Novel	Large	Single	Novel
AD	0.59	0.29	0.29	0.75	0.61	0.48
Control	0.57	0.23	0.12	0.52	0.34	0.12

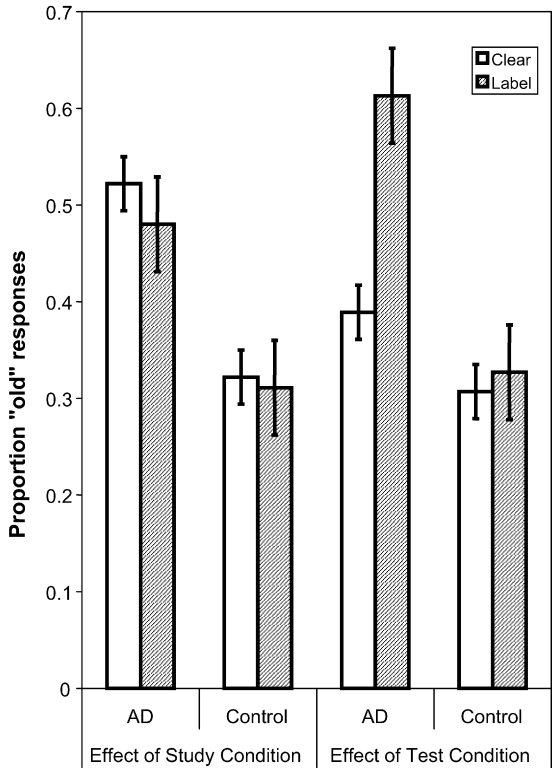

Fig. 2. Proportion "old" responses to unstudied items (false recognition) in patients with AD (AD) and healthy older adult controls (Control). Results illustrate false recognition depending upon whether the disambiguating label was present (Label) or absent (Clear) at study (Effect of Study Condition) and test (Effect of Test Condition). Error bars show standard error.

2.4. Response bias (C) by group and by study and test conditions

To further examine the conceptual fluency hypothesis we analyzed the response bias measure *C*. Because the number of items presented at test differed for the various item types (e.g., 18 large category items, six single category items), the item types were weighted such that an "old" response to any item would have equivalent impact, in order to provide a valid measure of bias (MacMillan & Creelman, 2005). In addition, because *C* is undefined when the proportion of responses equals 0 or 1, all responses were converted using the formulas provided by Snodgrass and Corwin (1988): $H = (\#\text{hits} + 0.5)/(\#\text{studied items} + 1)$; $\text{FA} = (\#\text{false alarms} + 0.5)/(\#\text{unstudied items} + 1)$. A negative *C* value denotes a liberal response bias, or the tendency to call items "old", while a positive *C* value indicates a conservative response bias. See Table 5 for values of *C* by group and condition. A 2 (group: AD patients, healthy older adult controls) × 4 (condition: LL, CC, LC, CL) × 1 (*C*) univariate ANOVA was performed to analyze *C*. There was a significant effect of group, $F(1, 88) = 4.41$, MSE = 0.344, $p = 0.039$, $\eta^2 = 0.05$, but no significant effect of condition, $F(3, 88) = 1.81$, MSE = 0.344, $p = 0.151$, $\eta^2 = 0.06$, or interaction

Table 5
Response bias (*C*) by group and condition

Older adult controls				AD patients			
LL	CC	LC	CL	LL	CC	LC	CL
0.00	−0.12	0.08	0.00	−0.48	0.00	0.02	−0.59

of group × condition, $F(3, 88) = 1.93$, MSE = 0.344, $p = 0.131$, $\eta^2 = 0.06$. The effect of group was present because AD patients overall displayed a more liberal response bias than healthy older adult controls.

As above, we used additional ANOVAs to provide the critical analyses of the effect of labels at study and test on *C* values (where CC + CL = clear at study, LC + LL = label at study, CC + LC = clear at test, and LL + CL = label at test). To analyze the effect of study condition on response bias, a 2 (group: AD patients, healthy older adult controls) × 2 (study condition: clear, label) univariate ANOVA revealed an effect of group, $F(1, 92) = 4.11$, MSE = 0.369, $p = 0.045$, $\eta^2 = 0.04$ (as described above), but no effect of study condition and no group × study condition interaction, Fs(1, 92) < 1. To analyze the effect of test condition on response bias, a 2 (group: AD patients, healthy older adult controls) × 2 (test condition: clear, label) univariate ANOVA revealed an effect of group, $F(1, 92) = 4.57$, MSE = 0.332, $p = 0.035$, $\eta^2 = 0.05$, an effect of test condition, $F(1, 92) = 5.06$, MSE = 0.332, $p = 0.027$, $\eta^2 = 0.05$, and a group × test condition interaction, $F(1, 92) = 5.59$, MSE = 0.332, $p = 0.020$, $\eta^2 = 0.06$. The effect of group was discussed above. The effect of test condition indicates that response bias was overall more liberal in the label condition at test compared to the clear condition. Critically, the interaction of group × test condition is attributable to the fact that patients with AD, $F(1, 46) = 6.92$, MSE = 0.511, $p = 0.012$, but not healthy older adult controls, $F(1, 46) < 0.1$, showed a more liberal response bias when labels were present at test compared to when they were not, further supporting the conceptual fluency hypothesis (Fig. 3).

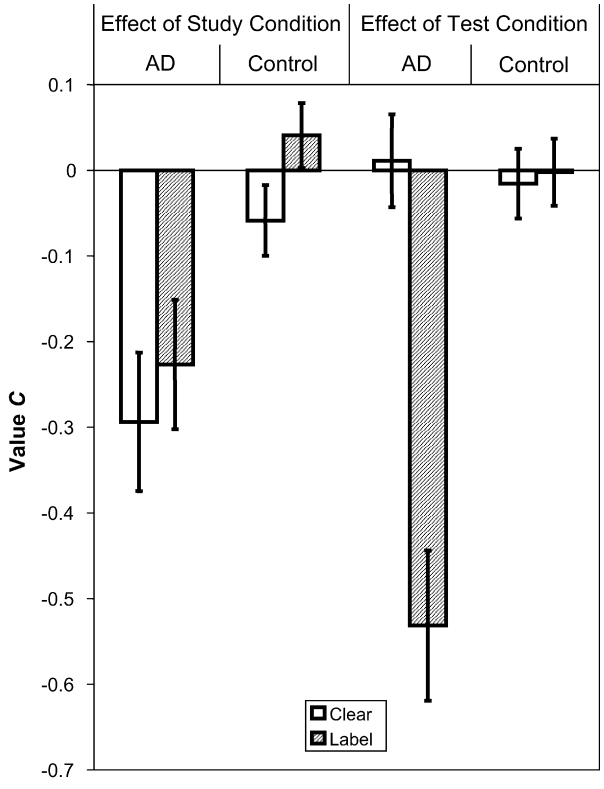

Fig. 3. *C* value, a measure of response bias, in patients with AD (AD) and healthy older adult controls (Control). Results illustrate response bias depending upon whether the disambiguating label was present (Label) or absent (Clear) at study (Effect of Study Condition) and test (Effect of Test Condition). Error bars show standard error.

3. Discussion

In this experiment, we investigated false recognition of pictorial stimuli by healthy older adult controls and patients with mild AD. Using a paradigm designed by Koutstaal et al. (2003), we manipulated the presence or absence of conceptual information at study and test by displaying disambiguating category labels preceding ambiguous abstract images at study, test, neither, or both, and measured the effects on false recognition. The current experiment tested two competing hypotheses, the semantic encoding hypothesis and the conceptual fluency hypothesis (Table 1).

The semantic encoding hypothesis proposes that the recognition performance of patients with AD most strongly depends upon the presence or absence of conceptual information at study, whereas the conceptual fluency hypothesis posits that recognition performance of this group most strongly depends upon the presence or absence of conceptual information at test. Our results were clear. Consistent with previous work, we found that, overall, patients with AD showed an elevation in uncorrected false recognition and a more liberal response bias compared with healthy older adult controls. Most importantly, we found that patients with AD – but not healthy older adult controls – showed higher levels of uncorrected false recognition and a more liberal response bias when labels were present at test compared to when they were absent (Figs. 2 and 3). These findings suggest that the conceptual fluency hypothesis, and not the semantic encoding hypothesis, provides the best explanation for the elevated rates of false recognition of pictorial stimuli in patients with mild AD. Furthermore, these findings support the pattern observed in previous studies of pictorial stimuli in which AD patients exhibited increased levels of false recognition for conceptually meaningful pictures at test (e.g., Budson, Sitarski, et al., 2002; Budson, Sullivan, et al., 2002; Budson et al., 2003), but not for conceptually empty pictures (e.g., Budson et al., 2001) compared to healthy older adult controls.

Our findings represent an important clue in understanding memorial response bias in AD. The present results are consistent with a growing body of literature that has demonstrated that response bias is more liberal in AD patients than in healthy older adult controls (for review see Budson, Wolk, Chong, & Waring, 2006). Looking at the data by individual conditions (LL, CC, LC, CL) in Table 5 or by study and test condition in Fig. 3, the response bias results are equally clear. Much more than simply

confirming these previous findings, the present study provides compelling data that suggests that the conceptual fluency of test items leads to more liberal responding in patients with AD. By contrast, enhancing conceptual fluency with labels at test has no effect whatsoever on the response bias of healthy older adult controls. Thus, unlike healthy older adults, patients with AD are highly likely to respond "Yes, I've seen that before," to a conceptually fluent categorized abstract shape turned into a picture by the label being present at test, but not to a less fluent categorized abstract shape without the label present.

Why should AD patients, but not healthy older adults, base memorial recognition decisions on the conceptual fluency of the test item? One likely possibility relates to the idea that recognition memory decisions can be based either upon recollection (the detailed retrieval of information regarding an item or event) or familiarity (a general sense of prior encounter) (for review, see Wixted, 2007; Yonelinas, 2002). Rajaram and Geraci (2000) have suggested that conceptual fluency preferentially enhances familiarity and not recollection. Using a Remember/Know paradigm, they asked participants to make memorial judgments on test words that were preceded by primes that were either semantically related or unrelated to the test word. They found that the related prime condition enhanced Know responses, but not Remember responses relative to the unrelated prime condition, suggesting that conceptual fluency enhances only familiarity. Many researchers have suggested that AD patients are likely to base their recognition memory decisions on familiarity, because their ability to use recollection is particularly impaired (Budson et al., 2000; Christensen, Kopelman, Stanhope, Lorentz, & Owen, 1998; Dalla Barba, 1997; Gallo, Sullivan, Daffner, Schacter, & Budson, 2004; Knight, 1998; Koivisto, Portin, Seinela, & Rinne, 1998; Smith & Knight, 2002). Thus, one possibility is that AD patients are particularly susceptible to effects of conceptual fluency because they depend upon familiarity for their memory judgments, and conceptual fluency enhances familiarity, but not recollection. Healthy older adults may also experience an increase in their sense of familiarity for conceptually fluent test items, but it may be countered by intact recollection (e.g., Budson et al., 2000) or by correctly attributing the sense of familiarity to enhanced fluency related to the disambiguating label, rather than a prior encounter with the item (e.g., Whittlesea & Williams, 2001).

The precise neural basis as to why patients with AD are so dramatically influenced by conceptual fluency when making recognition memory judgments is unknown, and deserves further study. We will speculate on two possible (and not mutually exclusive) candidates.

First, we suggested that AD patients are particularly susceptible to the effects of conceptual fluency at test because their ability to use recollection is impaired. Numerous studies support the idea that recollection is critically dependent upon intact hippocampal function (see Yonelinas, 2002, for review, and Wixted, 2007, for a contrasting perspective). The hippocampus, along with several other medial temporal lobe structures, is one of the earliest regions of the brain to be affected by AD pathology (Price & Morris, 1999). Thus, hippocampal dysfunction in AD patients may be one cause of these patients' increased susceptibility to the effects of conceptual fluency at test on their memory judgments.

Second, in a study of young adults, Wolk et al. (2004) put forth the idea that a frontally-based event-related potential (ERP) component from 800 to 1600 ms that has been correlated with post-retrieval processes (e.g., Allan, Wilding, & Rugg, 1998; Ally & Budson, 2007; Budson, Dodson, et al., 2005; Budson, Droller, et al., 2005; Goldmann et al., 2003; Wilding & Rugg, 1996) was related to subjects' attribution of the subjective feeling engendered by enhanced conceptual fluency processing. In their study of AD patients, Wolk et al. (2005) found a trend for this frontally-based component to be blunted in the AD patients compared to healthy older adult controls. Although one cannot draw reliable neuroanatomical localizations from ERP studies, it is worth noting that prefrontal cortex has been identified as a key region in post-retrieval processing (for review see Fletcher & Henson, 2001). AD patients show evidence of pathologic changes in frontal cortex (Buckner et al., 2005; Lidstrom et al., 1998), and neuropsychological and neuroimaging studies of AD patients have demonstrated frontal lobe dysfunction (Baddeley, Bressi, Della Sala, Logie, & Spinnler, 1991; Buckner et al., 2005; Dalla Barba, Nedjam, & Dubois, 1999; Haxby et al., 1988; Mountjoy, Roth, Evans, & Evans, 1983). Thus, another possibility is that frontal lobe dysfunction in AD patients causes impaired post-retrieval verification and monitoring processes, leading these patients to incorrectly attribute the subjective feeling engendered by enhanced conceptual fluency at test to prior study of the item. Future studies, perhaps using functional or structural MRI techniques, will be better able to more precisely determine how the brain dysfunction associated with AD leads these patients to be so strongly influenced by conceptual fluency of the test item in their recognition memory judgments.

Additional studies using behavioral, ERP, and functional MRI (fMRI) approaches may also be able to aid our understanding of how conceptual fluency at test impacts recognition memory judgments in AD. For example, we suggested that conceptual fluency affects response bias on recognition memory tests by altering participants' familiarity of the test item. One way to more directly evaluate this suggestion would be to ask participants to make Remember/Know judgments on their responses. We would predict that conceptual fluency would impact items given a Know response, but not those given a Remember response, consistent with Rajaram and Geraci (2000).

In ERP studies, Wolk et al. (2004, 2005) found that enhanced conceptual fluency at test was related to a more positive N400 component measured from 300 to 550 ms. Similarly, Voss and Paller (2006) found that conceptual fluency was related to more positive brain potentials from 250 to 500 ms. Data from a large number of studies involving younger adults, healthy older adults, and AD patients have suggested that a more positive ERP around this time interval may reflect the neural correlate of increased familiarity (e.g., Ally & Budson, 2007; Curran & Cleary, 2003; Duzel, Yonelinas, Mangun, Heinze, & Tulving, 1997; Nessler, Mecklinger, & Penney, 2001; Rugg et al., 1998; Wolk et al., 2004, 2005). And as mentioned above, Wolk et al. (2004) also found that enhanced conceptual fluency was related to more pos-

itive frontally-based brain potentials from 800 to 1600 ms, which these authors suggested may reflect the neural activity related to participants attribution of the subjective feeling engendered by enhanced conceptual fluency. Thus, modifying the present experiment to allow the acquisition of ERP data would be informative regarding the neural correlates of both conceptual fluency and the attribution of conceptual fluency to memorial processes in these patients.

The findings from fMRI studies of conceptual priming may also be relevant for understanding conceptual fluency. As noted by Voss and Paller (2006), conceptual fluency may be responsible for implicit conceptual priming in addition to aspects of explicit episodic memory such as familiarity. Buckner et al. (1998) found that conceptual priming was associated with changes in activation of left prefrontal regions. Similarly, in their review, Schacter, Wig, and Stevens (2007) describe how regions of the inferior frontal gyrus and left inferior temporal cortex show changes in activation related to an item's abstract or conceptual properties. fMRI studies of conceptual priming may therefore suggest several anterior brain regions that may be modulated during conceptual fluency processing. Future behavioral, ERP, and fMRI studies will be able to continue to explore the relationship in AD patients between conceptual fluency on the one hand, and cognitive concepts, electrophysiologic components, and changes in regional brain activation on the other.

The findings that patients with mild AD make recognition memory decisions based upon the fluency of the test item have implications for our understanding of normal and impaired memory and may provide clinical insights that can improve the lives of patients. If conceptual fluency at test leads to an increased sense of familiarity which in turn leads to increased levels of false recognition and a more liberal response bias when individuals rely upon familiarity, then our results may be relevant for understanding false recognition and response bias in general, and not just in AD patients. Expanding on work by Whittlesea and Williams (2000, 2001), Rajaram and Geraci (2000), Wolk et al. (2005), and others, our study found that when individuals rely upon familiarity for the basis of their memorial decisions, they might be particularly susceptible to conceptual fluency increasing their false recognition. In addition to patients with AD, other patients with impaired recollection may also show increased false recognition attributable to enhanced conceptual fluency, such as patients with damage to frontal cortex (e.g., Budson, Sitarski, et al., 2002; Budson, Sullivan, et al., 2002; Parkin, Bindschaedler, Harsent, & Metzler, 1996), patients with damage to medial temporal lobes (e.g., Schacter, Norman, et al., 1998; Schacter, Verfaellie, et al., 1998), patients with closed head injury (e.g., Ries & Marks, 2006), and patients with schizophrenia (e.g., Lee, Iao, & Lin, 2006). Healthy younger and older adults may also be particularly susceptible to conceptual fluency increasing their false recognition when their recollection is diminished; such a result was found for perceptual fluency in the controls studied by Verfaellie and Cermak (1999).

Many researchers have investigated methods to reduce false recognition. These methods have included repetition of study materials (e.g., Budson et al., 2000; Budson, Sitarski, et al., 2002; Budson, Sullivan, et al., 2002; Schacter, Norman, et al., 1998; Schacter, Verfaellie, et al., 1998), pairing pictures with words (e.g., Budson, Dodson, et al., 2005; Budson, Droller, et al., 2005; Schacter, Israel, & Racine, 1999), and simply encouraging participants to engage in more careful scrutiny of items at encoding and/or retrieval (Koutstaal et al., 1999). Investigation into whether such manipulations can diminish the effects of conceptual fluency on false recognition will be an important area of future research. If successful in reducing false recognition, such research will be able to improve the lives of healthy older adults as well as patients with AD and other cognitive impairments.

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References

Allan, K., Wilding, E. L., & Rugg, M. D. (1998). Electrophysiological evidence for dissociable processes contributing to recollection. *Acta Psychologica*, *98*, 231–252.

Ally, B. A., & Budson, A. E. (2007). The worth of pictures: Using high density event-related potentials to understand the memorial power of pictures and the dynamics of recognition memory. *Neuroimage*, *35*, 378–395.

Baddeley, A. D., Bressi, S., Della Sala, S., Logie, R., & Spinnler, H. (1991). The decline of working memory in Alzheimer's disease: A longitudinal study. *Brain*, *114*, 2521–2542.

Balota, D. A., Cortese, M. J., Duchek, J. M., Adams, D., Roediger, H. L., III, McDermott, K. B., et al. (1999). Veridical and false memories in healthy older adults and in dementia of the Alzheimer's type. *Cognitive Neuropsychology*, *16*, 361–384.

Bartlett, J. C., Halpern, A. R., & Dowling, W. J. (1995). Recognition of familiar and unfamiliar melodies in normal aging and Alzheimer's disease. *Memory & Cognition*, *23*, 531–546.

Borson, S., & Raskind, M. A. (1997). Clinical features and pharmacologic treatment of behavioral symptoms of Alzheimer's disease. *Neurology*, *48*, 17S–24S.

Buckner, R. L., Goodman, J., Burock, M., Rotte, M., Koutstaal, W., Schacter, D. L., et al. (1998). Functional-anatomic correlates of object priming in humans revealed by rapid presentation event-related fMRI. *Neuron*, *20*, 285–296.

Buckner, R. L., Snyder, A. Z., Shannon, B. J., LaRossa, G., Sachs, R., Fotenos, A. F., et al. (2005). Molecular, structural, and functional characterization of Alzheimer's disease: Evidence for a relationship between default activity, amyloid, and memory. *Journal of Neuroscience*, *25*, 7709–7717.

Budson, A. E., Daffner, K. R., Desikan, R., & Schacter, D. L. (2000). When false recognition is unopposed by true recognition: Gist-based memory distortion in Alzheimer's disease. *Neuropsychology*, *14*, 277–287.

Budson, A. E., Desikan, R., Daffner, K. R., & Schacter, D. L. (2001). Perceptual false recognition in Alzheimer's disease. *Neuropsychology*, *15*, 230–243.

Budson, A. E., Dodson, C. S., Daffner, K. R., & Schacter, D. L. (2005). Metacognition and false recognition in Alzheimer's disease: Further exploration of the distinctiveness heuristic. *Neuropsychology*, *19*, 253–258.

Budson, A. E., Droller, D. B., Dodson, C. S., Schacter, D. L., Rugg, M. D., Holcomb, P. J., et al. (2005). Electrophysiological dissociation of picture versus word encoding: The distinctiveness heuristic as a retrieval orientation. *Journal of Cognitive Neuroscience*, *17*, 1181–1193.

Budson, A. E., Michalska, K. J., Sullivan, A. L., Rentz, D. M., Daffner, K. R., & Schacter, D. L. (2003). False recognition in Alzheimer disease: Evidence from categorized pictures. *Cognitive and Behavioral Neurology*, *16*, 16–27.

Budson, A. E., Sitarski, J., Daffner, K. R., & Schacter, D. L. (2002). False recognition of pictures versus words in Alzheimer's

disease: The distinctiveness heuristic. *Neuropsychology*, *16*, 163–173.

Budson, A. E., Sullivan, A. L., Mayer, E., Daffner, K. R., Black, P. M., & Schacter, D. L. (2002). Suppression of false recognition in Alzheimer's disease and in patients with frontal lobe lesions. *Brain*, *125*, 2750–2765.

Budson, A. E., Wolk, D. A., Chong, H., & Waring, J. D. (2006). Episodic memory in Alzheimer's disease: Separating response bias from discrimination. *Neuropsychologia*, *44*, 2222–2232.

Christensen, H., Kopelman, M. D., Stanhope, N., Lorentz, L., & Owen, P. (1998). Rates of forgetting in Alzheimer dementia. *Neuropsychologia*, *36*, 547–557.

Cohen, J. D., MacWhinney, B., Flatt, M., & Provost, J. (1993). PsyScope: An interactive graphic system for designing and controlling experiments in the psychology laboratory using Macintosh computers. *Behavioral Research Methods, Instruments, and Computers*, *25*, 257–271.

Cooper, J. M., Shanks, M. F., & Venneri, A. (2006). Provoked confabulations in Alzheimer's disease. *Neuropsychologia*, *44*, 1697–1707.

Curran, T., & Cleary, A. M. (2003). Using ERPs to dissociate recollection from familiarity in picture recognition. *Brain Research and Cognitive Brain Research*, *15*, 191–205.

Dalla Barba, G. (1997). Recognition memory and recollective experience in Alzheimer's disease. *Memory*, *5*, 657–672.

Dalla Barba, G., Nedjam, Z., & Dubois, B. (1999). Confabulation, executive functions and source memory in Alzheimer's disease. *Cognitive Neuropsychology*, *16*, 385–398.

Duzel, E., Yonelinas, A. P., Mangun, G. R., Heinze, H. J., & Tulving, E. (1997). Event-related brain potential correlates of two states of conscious awareness in memory. *Proceedings of the National Academy of Sciences USA*, *94*, 5973–5978.

Fletcher, P. C., & Henson, R. N. (2001). Frontal lobes and human memory: Insights from functional neuroimaging. *Brain*, *124*, 849–881.

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.

Gallo, D. A. (2006). *Associative illusions of memory*. New York: Taylor & Francis.

Gallo, D. A., Sullivan, A. L., Daffner, K. R., Schacter, D. L., & Budson, A. E. (2004). Associative recognition in Alzheimer's disease: Evidence for impaired recall-to-reject. *Neuropsychology*, *18*, 556–563.

Goldmann, R. E., Sullivan, A. L., Droller, D. B., Rugg, M. D., Curran, T., Holcomb, P. J., et al. (2003). Late frontal brain potentials distinguish true and false recognition. *NeuroReport*, *14*, 1717–1720.

Haxby, J. V., Grady, C. L., Koss, E., Horwitz, B., Schapiro, M., Friedland, R. P., et al. (1988). Heterogeneous anterior-posterior metabolic patterns in dementia of the Alzheimer type. *Neurology*, *38*, 1853–1863.

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

Jacoby, L. L., & Rhodes, M. G. (2006). False remembering in the aged. *Current Directions in Psychological Science*, *15*, 49–53.

Jacoby, L. L., & Whitehouse, K. (1989). An illusion of memory: False recognition influenced by unconscious perception. *Journal of Experimental Psychology: General*, *118*, 126–135.

Kelly, C. M., & Jacoby, L. L. (2000). Recollection and familiarity: Process-dissociation. In F. I. M. Craik & E. Tulving (Eds.), *The oxford handbook of memory* (pp. 215–228). New York: Oxford University Press.

Knight, R. G. (1998). Controlled and automatic memory process in Alzheimer's disease. *Cortex*, *34*, 427–435.

Koivisto, M., Portin, R., Seinela, A., & Rinne, J. (1998). Automatic influences of memory in Alzheimer's disease. *Cortex*, *34*, 209–219.

Koriat, A., Goldsmith, M., & Pansky, A. (2000). Toward a psychology of memory accuracy. *Annual Review of Psychology*, *51*, 481–537.

Koutstaal, W., Reddy, C., Jackson, E. M., Prince, S., Cendan, D. L., & Schacter, D. L. (2003). False recognition of abstract versus common objects in older and younger adults: Testing the semantic categorization account. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *29*, 499–510.

Koutstaal, W., & Schacter, D. L. (1997). Gist-based false recognition of pictures in older and younger adults. *Journal of Memory and Language*, *37*, 555–583.

Koutstaal, W., & Schacter, D. L. (2001). Memory distortion and aging. In M. Naveh-Benjamin, M. Moscovitch, & H. L. Roediger III (Eds.), *Perspectives on human memory and cognitive aging: Essays in honour of Fergus Craik* (pp. 362–383). Philadelphia, PA: Psychology Press.

Koutstaal, W., Schacter, D. L., & Brenner, C. (2001). Dual task demands and gist-based false recognition of pictures in younger and older adults. *Journal of Memory and Language*, *44*, 399–426.

Koutstaal, W., Schacter, D. L., Galluccio, L., & Stofer, K. A. (1999). Reducing gist-based false recognition in older adults: Encoding and retrieval manipulations. *Psychology and Aging*, *14*, 220–237.

Lee, Y. S., Iao, L. S., & Lin, C. W. (2006). False memory and schizophrenia: Evidence for gist memory impairment. *Psychological Medicine*, 1–9.

Lidstrom, A. M., Bogdanovic, N., Hesse, C., Volkman, I., Davidsson, P., & Blennow, K. (1998). Clusterin (apolipoprotein J) protein levels are increased in hippocampus and in frontal cortex in Alzheimer's disease. *Experimental Neurology*, *154*, 511–521.

MacMillan, N. A., & Creelman, C. D. (2005). *Detection theory: A user's guide*. New Jersey: Lawrence Erlbaum Associates.

Macromedia Inc. (1996). *Aldus FreeHand 7. 0 [Computer software]*. San Francisco, CA: Macromedia, Inc..

McKhann, G., Drachman, D., Folstein, M., Katzman, R., & Price, D. (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.

Mountjoy, C. Q., Roth, M., Evans, N. J., & Evans, H. M. (1983). Cortical neuronal counts in normal elderly controls and demented patients. *Neurobiology of Aging*, *4*, 1–11.

Nessler, D., Mecklinger, A., & Penney, T. B. (2001). Event related brain potentials and illusory memories: The effects of differential encoding. *Cognitive Brain Research*, *10*, 283–301.

Parkin, A. J., Bindschaedler, C., Harsent, L., & Metzler, C. (1996). Pathological false alarm rates following damage to the left frontal cortex. *Brain and Cognition*, *32*, 14–27.

Pierce, B. H., Sullivan, A. L., Schacter, D. L., & Budson, A. E. (2005). Comparing source-based and gist-based false recognition in aging and Alzheimer's disease. *Neuropsychology*, *19*, 411–419.

Price, J. L., & Morris, J. C. (1999). Tangles and plaques in nondemented aging and "preclinical" Alzheimer's disease. *Annals of Neurology*, *45*, 358–368.

Rajaram, S., & Geraci, L. (2000). Conceptual fluency selectively influences knowledge. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 1070–1074.

Raven, J. C. (1941). Standardization of progressive matrices, 1938. *British Journal of Medical Psychology*, *19*, 137–150.

Ries, M., & Marks, W. (2006). Heightened false memory: A long-term sequela of severe closed head injury. *Neuropsychologia*, *44*, 2233–2240.

Rugg, M. D., Walla, P., Schloerscheidt, A. M., Fletcher, P. C., Frith, C. D., & Dolan, R. J. (1998). Neural correlates of depth of processing effects on recollection: Evidence from brain potentials and positron emission tomography. *Experimental Brain Research*, *123*, 18–23.

Schacter, D. L., Israel, L., & Racine, C. (1999). Suppressing false recognition in younger and older adults: The distinctiveness heuristic. *Journal of Memory and Language*, *40*, 1–24.

Schacter, D. L., Norman, K. A., & Koutstaal, W. (1998). The cognitive neuroscience of constructive memory. *Annual Review of Psychology*, *49*, 289–318.

Schacter, D. L., & Slotnick, S. D. (2004). The cognitive neuroscience of memory distortion. *Neuron*, *44*, 149–160.

Schacter, D. L., Verfaellie, M., Anes, M. D., & Racine, C. (1998). When true recognition suppresses false recognition: Evidence from amnesic patients. *Journal of Cognitive Neuroscience*, *10*, 668–679.

Schacter, D. L., Wig, G. S., & Stevens, W. D. (2007). Reductions in cortical activity during priming. *Current Opinion in Neurobiology*, *17*.

Smith, J. A., & Knight, R. G. (2002). Memory processing in Alzheimer's disease. *Neuropsychologia*, *40*, 666–682.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*, 34–50.

Sommers, M. S., & Huff, L. M. (2003). The effects of age and dementia of the Alzheimer's type on phonological false memories. *Psychology and Aging*, *18*, 791–806.

Verfaellie, M., & Cermak, L. S. (1999). Perceptual fluency as a cue for recognition judgments in amnesia. *Neuropsychology*, *13*, 198–205.

Voss, J. L., & Paller, K. A. (2006). Fluent conceptual processing and explicit memory for faces are electrophysiologically distinct. *Journal of Neuroscience*, *26*, 926–933.

Waldie, B. D., & Kwong See, S. T. (2003). Remembering words never presented: False memory effects in dementia of the Alzheimer type. *Aging, Neuropsychology, and Cognition*, *10*, 281–297.

Whittlesea, B. W. A. (1993). Illusions of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 1235–1253.

Whittlesea, B. W. A., Jacoby, L. L., & Girard, K. (1990). Illusions of immediate memory: Evidence of an attributional basis for feelings of familiarity and perceptual quality. *Journal of Memory and Language*, *29*, 716–732.

Whittlesea, B. W., & Williams, L. D. (2000). The source of feelings of familiarity: The discrepancy-attribution hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *26*, 547–565.

Whittlesea, B. W. A., & Williams, L. D. (2001). The discrepancy-attribution hypothesis. I. The heuristic basis of feelings of familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *27*, 3–13.

Wilding, E. L., & Rugg, M. D. (1996). An event-related potential study of recognition memory with and without retrieval of source. *Brain*, *119*, 889–905.

Wixted, J. T. (2007). Dual-process theory and signal-detection theory of recognition memory. *Psychological Review*, *114*, 152–176.

Wolk, D. A., Schacter, D. L., Berman, A. R., Holcomb, P. J., Daffner, K. R., & Budson, A. E. (2004). An electrophysiological investigation of the relationship between conceptual fluency and familiarity. *Neuroscience Letters*, *369*, 150–155.

Wolk, D. A., Schacter, D. L., Berman, A. R., Holcomb, P. J., Daffner, K. R., & Budson, A. E. (2005). Patients with mild Alzheimer's disease attribute conceptual fluency to prior experience. *Neuropsychologia*, *43*, 1662–1672.

Yonelinas, A. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, *46*, 441–517.