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Using pictures and words to understand recognition memory deterioration in amnestic mild cognitive impairment and Alzheimer's disease: A review

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Abstract

Difficulty recognizing previously encountered stimuli is one of the earliest signs of incipient Alzheimer's disease (AD). Work over the last 10 years has focused on how patients with AD and those in the prodromal stage of amnestic mild cognitive impairment (aMCI) make recognition decisions for visual and verbal stimuli. Interestingly, both groups of patients demonstrate markedly better memory for pictures over words, to a degree that is significantly greater in magnitude than their healthy older counterparts. Understanding this phenomenon not only helps to conceptualize how memory breaks down in AD, but also potentially provides the basis for future interventions. The current review will critically examine recent recognition memory work using pictures and words in the context of the dual-process theory of recognition and current hypotheses of cognitive breakdown in the course of very early AD.

Keywords

object recognition; recollection; familiarity; episodic memory; semantic memory

Introduction

At its most fundamental level, everyday memory relies on our ability to identify and recall objects, people, and locations that we have previously encountered. In a number of situations, we are asked to discriminate between these previously encountered items and similar ones. Decades of research have investigated how these discrimination judgments (i.e., recognition decisions) are made in healthy and diseased populations. Alzheimer's disease (AD) is the most common memory disorder, currently affecting nearly 27 million individuals worldwide, with the projected number of cases expected to quadruple by 2050 [1]. Memory problems are among the most frequent reasons cited for admission to residential facilities [2] and delaying admission by only one month would result in saving the US healthcare system an estimated $4 billion annually [3]. While disease-modifying and curative therapies are being aggressively pursued, behavioral interventions to help manage or ameliorate episodic memory deficits are paramount in the interim. With this in mind, recent neuropsychology and cognitive neuroscience research has turned to identifying areas of memory and cognition that remain relatively intact in AD and its precursor, amnestic mild cognitive impairment (aMCI).

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To this end, one recent area of memory investigation in patients with aMCI and AD is the picture superiority effect [4]. The picture superiority effect refers to markedly better memory for pictures than for words, and our laboratory has been specifically interested in this phenomenon in the course of early AD. In fact, one recent study showed that the magnitude of the picture superiority effect is greater in patients than in healthy older adults [5••]. Understanding this phenomenon not only helps to conceptualize how memory breaks down in AD, but also potentially provides the basis for future interventions. The current paper will review recent work using pictures and words to understand how recognition memory breaks down during the course of aMCI and AD, as well as provide some clinical and diagnostic implications from this work.

Recognition Memory in amnestic mild cognitive impairment and Alzheimer's disease

To realize the potential of the picture superiority effect in patients, we must first review how recognition decisions are made. Though theories of a single recognition process continue to be advanced, most recognition literature suggests a two-process approach [see 6 for review]. This dual-process theory posits that recognition can occur on the basis of the independent processes of familiarity and recollection. The former is described as an acontextual, vague sense that an item, person, or location has been previously encountered, while the latter is described as the retrieval of specific, context-bound details of a previous item, person, or location. These two constructs are often commonly experienced in daily life. For example, the unexpected sight of a particular man on a crowded city street may elicit an immediate feeling of knowing him without being able to produce any specific details about who he is or how he is known. After some deliberation, details may come to mind regarding the man's identity—the salesman at the Apple store you visited one week earlier. In this example, that vague sense of familiarity is verified by detailed recollection of the man as the salesman that sold you an iPhone for your spouse's birthday present last week.

Over the last decade, memory researchers have focused on understanding how familiarity and recollection are involved in recognition decisions in patients with AD, with more recent focus on patients with aMCI. Alzheimer-related brain pathology typically begins in the medial temporal lobes (MTLs), even before clinical symptoms arise [7]. Braak and Braak (1991) [8] demonstrated that neurofibrillary tangle pathology typically develops first in perirhinal regions (Brodmann area 35), followed by entorhinal cortex, and then hippocampus proper. By the time a clinical diagnosis is made, there is dense neurofibrillary tangle involvement in the hippocampus and entorhinal, perirhinal, and parahippocampal cortices [9,10]. These MTL regions overlap heavily with those proposed to be involved in recollection. Although other regions, such as the frontal lobes [11] and parietal lobes [12], contribute to the process, the hippocampus has been extensively linked to recollection [13], and lesion studies have provided countless examples of patients with hippocampal lesions demonstrating impaired recollection [see 13]. Given the significant involvement of the hippocampus to recollection, it is not surprising that recollection is severely impaired in both aMCI and mild AD [14-16].

Although there is little debate as to whether recollection is impaired early in the course of AD, the consensus on familiarity is far less agreed upon. Familiarity appears to be a complex cognitive process based on the reactivation of perceptual (form-based) or conceptual (meaning-based) representations, which rely on numerous brain regions [17]. Like recollection, familiarity has been linked to MTL structures, particularly perirhinal and parahippocampal cortices [13,18,19]. However, lesion and neuroimaging studies have provided evidence that familiarity is far more diffuse, relying on other cortical and subcortical regions. For example, extended hippocampal system lesions appear to leave

familiarity intact [20-22], while lesions to the lateral prefrontal cortex do not [23]. A 2007 meta-analysis showed that recollection activated MTL regions to a far greater extent than familiarity [17]. Further, fMRI work has shown that as perceived strength of familiarity increased, activity in a number of brain regions increased linearly, while hippocampal activity was not modulated by changes in familiarity strength [24].

Given the rather diffuse and complex nature of familiarity, it is not surprising that results of investigations of familiarity in patients with aMCI and mild AD have been disparate, generally with findings showing intact familiarity for pictures but impaired familiarity for words [5••,14-16,25-30). Although the question remains as to whether the process of familiarity is impaired, studies using the remember/know paradigm suggest that patients with aMCI and AD subjectively experience familiarity in a similar manner as their healthy counterparts [27,29]. However, it has been proposed that in the face of impaired recollection, patients with AD become over-dependent on familiarity [31,32] and potentially misinterpret the strength or accuracy of the familiarity signal [33]. To understand how AD patients might face recognition decisions, imagine for a second that you were unable to experience recollection. In the example provided above about seeing a familiar man on a crowded city street, ultimately the flood of recollected information resolved the subjective sense of familiarity. Recollected details allowed you to place the man in context, and subsequently verify your feeling of familiarity. In contrast, patients with aMCI and AD likely experience familiarity in a similar manner, but do not have the benefit of recollection to support or inhibit their familiarity-based recognition [32,34]. This leads to poor discrimination, and this “unmonitored” familiarity has been linked with elevated false recognition and a liberal response bias in patients with AD [35-37]. Increased false recognition has been hypothesized to have a number of clinical consequences; perhaps misidentifying the above-mentioned man as a friend, or causing even more dangerous errors such as falsely remembering to have turned off the stove [33].

After initial recognition occurs based on familiarity and/or recollection, a final executive-based cognitive process occurs in the recognition decision process. Research has highlighted the need for post-retrieval monitoring and verification of the contents of memory [38]. It is likely that this post-retrieval process is not integrated specifically into models of recognition memory (i.e., single or dual process models) because it occurs with other types of decisions, such as semantic judgments [39]. In recognition memory studies, this post-retrieval processing is associated with right dorsolateral prefrontal regions and likely pertains to the accuracy and completeness of information retrieved from memory. Studies using event-related potentials (ERPs) and functional magnetic resonance imaging (fMRI) show that activity in right prefrontal regions increases when the contents of memory are evaluated for details and features, such as contextual information [40,41] or when the retrieved information is not sufficient for the task being performed [42]. In other words, this late frontal activity is associated with the ongoing evaluation and monitoring of the product of the retrieval attempt and perhaps initiates subsequent attempts.

In addition to the absence of recollection, it has been proposed that executive-based post-retrieval monitoring and verification is impaired in patients with AD [43,44]. One hypothesis is that diminished executive abilities do not allow patients with AD to properly monitor, verify, or inhibit responding based on familiarity alone [44]. Studies in patients using fMRI have shown diminished activity in prefrontal regions during the cognitive control of memory [45,46]. Further, a behavioral study found that patients with AD demonstrated diminished retrieval monitoring compared to healthy older adults [47]. However, behavioral work has also shown that, in some situations where recognition judgments need to be attributed to previous experience [48] or post-retrieval meta-memory

is required [49,50], patients with AD appear to be able to utilize some types of memorial post-retrieval processing.

The literature on post-retrieval processing in patients with aMCI has been sparse. Using standard neuropsychological tests of executive functioning, work has shown that performance on tasks of executive-based inhibition remains relatively intact in aMCI, while tasks that require planning and sequencing do not [51]. A subsequent study highlighted that the interaction between memory and executive functioning remained preserved in aMCI and suggested that memory-related executive functioning impairment was a potential marker of conversion from aMCI to clinical AD [52]. More recently, it has been reported that elevated false memory rates increased the diagnostic sensitivity and specificity for AD over aMCI and other dementias [53,54]. There have not been many studies directly investigating recognition memory post-retrieval monitoring and verification in patients with aMCI. One study from our laboratory found that the ERP late right prefrontal old/new positivity associated with post-retrieval monitoring and verification of the contents of memory was similar in patients with aMCI to healthy older adults for pictures, but not for words [15]. Interestingly, although patients with clinical AD in Gallo et al. (2007) [47] showed significantly diminished retrieval monitoring compared to their healthy peers, patients showed enhanced retrieval monitoring for pictures compared to words. Gallo et al. (2007) [47] speculated that the distinctive perceptual information provided by pictures might impel patients to engage in retrieval monitoring, which appears to remain intact in aMCI. Though the answer is far from clear, it appears as though pictures are a special class of stimuli that allow patients with aMCI, and potentially AD, to engage memory and cognitive processes that remain relatively intact.

The picture superiority effect in amnestic mild cognitive impairment and Alzheimer's disease

Over 50 years of research has focused on the picture superiority effect. To account for better memory for pictures than words, three basic theories have been advanced. First, the *dual-coding account* proposes that pictures are at an advantage over words because pictures evoke both a verbal code and an image code, while words only evoke a verbal code [55]. This dual encoding of pictures might allow them to be more easily remembered, as two stored representations potentially lead to a higher probability of retrieval success. A second explanation is the *distinctiveness account*, which suggests that pictures provide more highly distinctive visual features at encoding than words, making them more memorable [56]. The third alternative is the *semantic processing account*, which proposes that the picture superiority effect is a result of pictures allowing for deeper and more elaborate conceptual processing than words [57,58]. The main difference among all three theories is the relative contribution of perceptual and conceptual information to the picture superiority effect. Though the debate still exists as to the theory behind the picture superiority effect, cognitive psychology studies agree that pictures enhance recollection compared to words in healthy young and older adults [59-62]. However, this assertion likely does not explain the robust picture superiority effect in aMCI and AD. These patients have equally severe recollection impairment for pictures and words, leading to the hypothesis that enhanced familiarity for pictures must account for the picture superiority effect. Recently, Embree, Budson, and Ally (2012) [5••] confirmed this hypothesis by using receiver operating characteristic (ROC) curves to show that in patients with aMCI, estimates of familiarity were similar to healthy older adults for pictures but not for words.

Turning back to the main theories of the picture superiority effect, the distinctiveness account suggests that pictures provide more distinctive visual-perceptual representations at encoding, making them more memorable. As in healthy memory [63], perhaps the

distinctive visual information works to enhance familiarity of pictures over words in patients with aMCI and mild AD. Processing fluency, or the ease with which information is processed, is enhanced when a stimulus is re-processed in a subsequent encounter, regardless of whether the individual was aware of the original exposure. Fluency plays an essential role in familiarity-based recognition [64,65] and likely contributes to the *phenomenological* experience of familiarity [66-68]. Indeed, previous work in patients with aMCI and mild AD suggest that perceptual fluency remains intact and can contribute to increased recognition performance in these patients [25,69-71]. In this type of work, perceptual fluency refers to ease at which patients process only the physical characteristic of visual stimuli. Given that familiarity judgments have been strongly associated with fMRI activation of middle occipital gyri on recognition memory tasks [72], we have hypothesized that intact earlier visual processing areas within the ventral-visual-perirhinal pathway allow patients to utilize perceptual fluency or perceptually-based familiarity to enhance memory for pictures over words [5••]. This reliance on the posterior regions of the ventral-visual-perirhinal stream is likely responsible for the enhanced occipital activation seen in studies of patients with aMCI and those at genetic risk for AD compared to controls [73-76].

An alternative hypothesis is that pictures allow for deeper and more elaborate *conceptual* processing than words [57,63]. Although early studies of patients with AD using word generation tasks suggested that conceptual fluency was impaired [77], more recent work has shown that patients with aMCI and mild AD can successfully rely on conceptual fluency and extract conceptual meaning from pictures to enhance memory over words [28,78,79]. Further, the neural correlates thought to underlie conceptual processing of pictures remain intact in patients with aMCI [15,48]. It is likely that deterioration of the semantic network very early in the AD process [80] contributes to impaired conceptual processing, familiarity, and subsequent recognition of words. Indeed, aberrant semantic network activation has been proposed to contribute heavily to the pattern of memory loss associated with aMCI [81•,82]. Perhaps semantic network involvement signifies initial functional memory problems in the verbal domain that can be used as a marker of disease onset and progress. We propose that if a patient has forgotten conceptual information about a word [83], or degraded semantic networks prevent him or her from elaborately processing the meaning of a word [84], pictures can serve as this cue. Indeed, it has been hypothesized that pictures enhance semantic gist in patients and allow them to gain access more easily to the full meaning of words [85]. For example, if a patient is presented with the word “shoe” at study, he or she is left to generate an internal prototype of “shoe”; spread within the semantic network may result with only the concept of “foot.” In contrast, when a patient is shown a picture of a “shoe,” he or she may more easily be able to make the conceptual associations of “Converse,” “Chuck Taylors,” “hi-tops,” and “I used to wear Chuck Taylor hi-tops when I played basketball in high school.” This more elaborate conceptual processing of the picture might allow patients to utilize more effectively familiarity at test.

We have hypothesized that greater conceptual benefit from pictures, along with enhanced perceptual fluency, allows patients to better monitor their sense of familiarity [5••], which in turn leads to enhanced accuracy [4,30] and decreased false recognition [86] compared to words. In contrast, when studying words, patients are generally left to conceptual processing with very limited perceptual information to help generate and monitor familiarity at test [28], which is compounded by the fact that patients with mild AD have difficulty using mental imagery to enhance verbal encoding [84]. The difference in how patients with aMCI utilize familiarity and post-retrieval monitoring for pictures versus words is worthy of continued investigation. However, perhaps more importantly, what are the clinical considerations and implications of the picture superiority effect in patients with aMCI and mild AD?

Conclusions and clinical considerations

As outlined in the review of experimental work above, it appears as though disruption to the semantic network within the domain of memory might be the first signal of deteriorating recognition memory performance [82], which explains why verbal tests are most sensitive in picking up early deficits dissociating aMCI from healthy aging memory [87] and the robust picture superiority effect in patients with aMCI [5••]. Due to these aberrant semantic networks, patients with aMCI are unable to extract the gist from verbal information [81•], but do so without problem for pictures [78]. In addition to a standard verbal memory measure in a clinical evaluation, perhaps including a task examining one's abilities to extract gist information from words and pictures could help to diagnose patients with aMCI at a much earlier point, and possibly dissociate patients with aMCI owing to Alzheimer's pathology from other etiologies contributing to mild memory problems (e.g., depression, medication). Identifying these patients very early in the disease course is critical to implementing interventions and cognitive rehabilitation. In fact, work has shown that patients with aMCI can improve cognition and functional status when interventions are applied early in the disease course [88,89].

As the disease progresses, more cognitive domains are affected. Typically, patients with aMCI have some type of executive dysfunction related to cognitive flexibility and planning, but monitoring and inhibition processes tend to remain intact [15,51]. In contrast, patients with AD have impaired post-retrieval processing, likely owing to frontal lobe pathology, that is thought to get worse as the disease state becomes more severe [90]. It has been proposed that the interplay between memory and executive function may serve as a potential marker of conversion from aMCI to clinical AD [52]. Clinically, false recognition has been used as a putative marker of impaired executive post-retrieval monitoring of memory. Patients with AD demonstrate elevated false recognition to both semantically related and, more importantly, non-related test items [35, 54]. Clinicians are encouraged to examine the type of errors made on neuropsychological tests of memory, which may be indicative of disease state or functional status.

Experimentally, pictures have been shown to reduce false recognition significantly in patients with AD (Beth et al., 2009). However, to our knowledge this has never been examined as a way to reduce false memory in a real world or clinical trial setting. With respect to improving overall memory performance, there has been relatively little work published on cognitive rehabilitation in patients with clinical AD, and in general those results have been mixed [91]. Most work has been focused on learning novel face-name pairs, but recent work has examined re-learning of previously held information (e.g., object names). Using techniques such as errorless learning and cognitive stimulation therapy, a handful of studies have shown improvement in memory and cognitive functioning in patients with AD [92, and see 93 for earlier review]. In the future, intervention and cognitive rehabilitation with AD patients may benefit from the use of pictures. For example, reminder systems can use pictures rather than word lists for reminders and medication management. Additionally, recent work has shown that patients with AD demonstrate relatively intact discrimination when forced to rely on global characteristics of visual objects rather than specific perceptual details [71]. Perhaps working with patients to focus on the gist or conceptual information rather than specific details can help with new learning. Moreover, helping them to discard ineffective strategies, such as focusing on item-specific details that require recollection, can be just as effective for improving memory.

As a final note, when conceptualizing episodic memory in clinical evaluations, the influence of other cognitive domains on memory should not be neglected. This is complicated by the fact that standard neuropsychological measures tend to not be "process pure." For example,

measures of visual memory often require a planned visuomotor response (typically drawing), which relies heavily on intact visuospatial skills and executive functioning [94]. The patient needs to approach the copy of these complex figures with an organized and systematic plan to perform well on the subsequent recall and recognition portions of the test. Given that healthy older adults and patients with aMCI likely have decrements in the executive ability to plan ahead and sequence [51,95], we are potentially *over-estimating* their visual memory impairment. In contrast, verbal memory tests, such at the Hopkins Verbal Learning Testing or the California Verbal Learning Test, which allow for semantic clustering and categorical cues, can provide an artificial boost in memory performance for those with relatively intact executive skills. In this situation, we may be *under-estimating* verbal memory impairment in patients who are purely amnestic. In addition to these practical clinical considerations, future clinical test development is encouraged to incorporate novel experimental methods and analyses. Some more recent experimental tests of memory and executive functioning are thought to be highly sensitive and specific to many disorders of aging, which could potentially provide improved acumen and assessment in the clinical domain [see 96•]. These sensitive and specific tests are more likely to readily reveal subtle deficits, leading to earlier diagnosis and providing a potential window for nonpharmacological and disease modifying therapies.

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References

1). Brookmeyer R, Johnson E, Ziegler-Graham K, Arrighi HM. Forecasting the global burden of Alzheimer's disease. Alzheimer's & Dementia. 2007; 3:186–191.

2). Andel R, Hyer K, Slack A. Risk factors for nursing home placement in older adults with and without dementia. J Aging Health. 2007; 19:213–228. [PubMed: 17413132]

3). Clipp, E. US Department of Veteran's Affairs HSR&D Study NRI 95-218, Informal Caregivers of Veterans and Dementia: Cost, QOL, and Service Use. 2005.

4). Ally BA, Gold CA, Budson AE. The picture superiority effect in patients with Alzheimer's disease and Mild Cognitive Impairment. Neuropsychologia. 2009a; 47:595–598. [PubMed: 18992266]

5)••. Embree LM, Budson AE, Ally BA. Memorial familiarity remains intact for pictures but not for words in amnestic mild cognitive impairment. Neuropsychologia. 2012; 50:2333–2340. [PubMed: 22705441] For nearly 5 years, there has been debate in the literature as to whether memorial familiarity remains intact in patients with aMCI. Conflicting evidence appeared to be resolved when stimulus type was taken into consideration. This study provided convincing evidence that familiarity remains intact for pictures but not for words in patients with amnestic mild cognitive impairment. Further, this study also provided solid evidence that the picture superiority effect is greater in magnitude compared to healthy older adults.

6). Yonelinas AP. The Nature of Recollection and Familiarity: A Review of 30 Years of Research. Journal of Memory and Language. 2002; 46:441–517.

7). Hyman BT, Van Horsen GW, Damasio AR, Barnes CL. Alzheimer's disease: cell-specific pathology isolates the hippocampal formation. Science. 1984; 225:1168–1170. [PubMed: 6474172]

8). Braak H, Braak E. Neuropathological stageing of Alzheimer-related changes. Acta Neuropathol. 1991; 82:239–259. [PubMed: 1759558]

9). Gomez-Isla T, West HL, Rebeck GW, et al. Clinical and pathological correlates of Apolipoprotein E epsilon 4 in Alzheimer's disease. Ann Neurol. 1996; 39:62–70. [PubMed: 8572669]

10). Mesulam MM. A plasticity-based theory of the pathogenesis of Alzheimer's disease. Ann N Y Acad Sci. 2000; 924:42–52. [PubMed: 11193801]

11). Simons JS, Owen AM, Fletcher PC, Burgess PW. Anterior prefrontal cortex and the recollection of contextual information. Neuropsychologia. 2005; 43:1774–17. 83. [PubMed: 16154453]

12). Ally BA, Simons JS, McKeever JD, Peers PV, Budson AE. Parietal contributions to recollection: electrophysiological evidence from aging and patients with parietal lesions. Neuropsychologia. 2008; 46:1800–1812. [PubMed: 18402990]

13). Eichenbaum H, Yonelinas AP, Ranganath C. The medial temporal lobe and recognition memory. Annu Rev Neurosci. 2007; 30:123–152. [PubMed: 17417939]

14). Ally BA, Gold CA, Budson AE. An evaluation of recollection and familiarity in Alzheimer's disease and mild cognitive impairment using receiver operating characteristics. Brain Cogn. 2009; 69:504–513. [PubMed: 19101064]

15). Ally BA, McKeever JD, Waring JD, Budson AE. Preserved frontal memorial processing for pictures in patients with mild cognitive impairment. Neuropsychologia. 2009; 47:2044–55. [PubMed: 19467355]

16). Wolk DA, Signoff ED, DeKosky ST. Recollection and familiarity in amnestic mild cognitive impairment: A global decline in recognition memory. Neuropsychologia. 2008; 46:1965–1978. [PubMed: 18328509]

17). Skinner EI, Fernandes MA. Neural correlated of recollection and familiarity: a review of neuroimaging and patient data. Neuropsychologia. 2007; 45:2163–2179. [PubMed: 17445844]

18). Brown MW, Aggleton JP. Recognition memory: what are the roles of the perirhinal cortex and hippocampus. Nat Rev Neurosci. 2001; 2:51–61. [PubMed: 11253359]

19). Henson RN, Cansino S, Herron JE, Robb WG, Rugg MD. A familiarity signal in human anterior medial temporal cortex? Hippocampus. 2003; 13:301–304. [PubMed: 12699337]

20). Gilboa A, Winocur G, Rosenbaum RS, et al. Hippocampal contributions to recollection in retrograde and anterograde amnesia. Hippocampus. 2006; 16:966–980. [PubMed: 17039487]

21). Vann SD, Tsivilis D, Denby CE, et al. Impaired recollection but spared familiarity in patients with extended hippocampal system damage revealed by 3 convergent methods. Proc Natl Acad Sci. 2009; 31:5442–5447. [PubMed: 19289844]

22). Yonelinas AP, Kroll NE, Dobbins I, Lazzara M, Knight RT. Recollection and familiarity deficits in amnesia: convergence of remember-know, process dissociation, and receiver operating characteristic data. Neuropsychology. 1998; 12:323–339. [PubMed: 9673991]

23). Aly M, Yonelinas AP, Kishiyama MM, Knight RT. Damage to the lateral prefrontal cortex impairs familiarity but not recollection. Behav Brain Res. 2011; 225:297–304. [PubMed: 21827792]

24). Montaldi D, Spencer TJ, Roberts N, Mayes AR. The neural system that mediates familiarity memory. Hippocampus. 2006; 16:504–520. [PubMed: 16634088]

25). Algarabel S, Escudero J, Mazon JF, et al. Familiarity-based recognition in the young, healthy elderly, mild cognitive impaired, and Alzheimer's patients. Neuropsychologia. 2009; 47:2056–2064. [PubMed: 19467356]

26). Anderson ND, Ebert PL, Jennings JM, et al. Recollection- and familiarity-based memory in healthy aging and amnestic mild cognitive impairment. Neuropsychology. 2008; 22:177–187. [PubMed: 18331160]

27). Hudon C, Belleville S, Gauthier S. The assessment of recognition memory using the Remember/Know procedure in amnestic mild cognitive impairment and probable Alzheimer's disease. Brain and Cognition. 2009; 70:171–179. [PubMed: 19250730]

28). O'Connor MK, Ally BA. Using stimulus form change to understand memorial familiarity for pictures and words in patients with mild cognitive impairment and Alzheimer's disease. Neuropsychologia. 2010; 48:2068–2074. [PubMed: 20362596]

29). Serra L, Bozzali M, Cercignani M, et al. Recollection and familiarity in mold cognitive impairment. Neuropsychology. 2010; 24:316–26. [PubMed: 20438209]

30). Westerberg CE, Paller KA, Weintraub S, et al. When memory does not fail: Familiarity-based recognition in mild cognitive impairment and Alzheimer's disease. Neuropsychology. 2006; 20:193–205. [PubMed: 16594780]

31). Gallo DA, Shahid KR, Olson MA, et al. Overdependence on degraded gist memory in Alzheimer's disease. Neuropsychology. 2006; 20:625–632. [PubMed: 17100507]

32). Pierce BH, Sullivan AL, Schacter DL, Budson AE. Comparing source-based and gist-based false recognition in aging and Alzheimer's disease. Neuropsychology. 2005; 19:411–419. [PubMed: 16060815]

33). Gold CA, Budson AE. Memory loss in Alzheimer's disease: implications for development of therapeutics. Expert Rev Neurother. 2008; 8:1879–1891. [PubMed: 19086882]

34). Mitchell JP, Sullivan AL, Schacter DL, Budson AE. Misattribution errors in Alzheimer's disease: The illusory truth effect. Neuropsychology. 2006; 20:185–192. [PubMed: 16594779]

35). Budson AE, Wolk DA, Chong H, Waring JD. Episodic memory in Alzheimer's disease: Separating response bias from discrimination. Neuropsychologia. 2006; 44:2222–2232. [PubMed: 16820179]

36). Deason RG, Hussey EP, Ally BA, Budson AE. Changes in response bias with different study-test delays: Evidence from young adults, older adults, and patients with Alzheimer's disease. Neuropsychology. 2012; 1:119–126. [PubMed: 22409339]

37). Gallo DA, Sullivan AL, Daffner KR, Schacter DL, Budson AE. Associative recognition in Alzheimer's disease: Evidence for impaired recall-to-reject. Neuropsychology. 2004; 18:556–563. [PubMed: 15291733]

38). Henson RN, Shallice T, Dolan RJ. Right prefrontal cortex and episodic memory retrieval: A functional MRI test of the monitoring hypothesis. Brain. 1999; 122:1367–1381. [PubMed: 10388802]

39). Hayama HR, Johnson JD, Rugg MD. The relationship between the right frontal old/new ERP effect and post-retrieval monitoring: specific or non-specific? Neuropsychologia. 2008; 46:1211–23. [PubMed: 18234241]

40). Allan K, Wilding EL, Rugg MD. Electrophysiological evidence for dissociable processes contributing to recollection. Acta Psychol. 1998; 98:231–252.

41). Wilding EL, Rugg MD. An event-related potential study of recognition memory with and without retrieval of source. Brain. 1996; 119:889–905. [PubMed: 8673500]

42). Shallice T, Fletcher P, Frith CD, et al. Brain regions associated with acquisition and retrieval of verbal episodic memory. Nature. 1994; 368:633–635. [PubMed: 8145849]

43). Budson AE, Michalska KJ, Sullivan AL, et al. False recognition in Alzheimer's disease: Evidence from categorized pictures. Cognitive and Behavioral Neurology. 2003; 16:16–27. [PubMed: 14764998]

44). Dodson CS, Spaniol M, O'Connor MK, et al. Alzheimer's disease and memory-monitoring impairment: Alzheimer's patients show a monitoring deficit that is greater than their accuracy deficit. Neuropsychologia. 2011; 49:2609–2618. [PubMed: 21620877]

45). Schwindt GC, Black SE. Functional imaging studies of episodic memory in Alzheimer's disease: a quantitative meta-analysis. Neuroimage. 2009; 45:181–190. [PubMed: 19103293]

46). Sperling RA, Dickerson BC, Pihlajamaki M, et al. Functional alterations in memory networks in early Alzheimer's disease. Neuromolecular Med. 2010; 12:27–43. [PubMed: 20069392]

47). Gallo DA, Chen JM, Wiseman AL, Schacter DL, Budson AE. Retrieval monitoring and anosognosia in Alzheimer's disease: Evidence from the criterial recollection task. Neuropsychology. 2007; 21:559–568. [PubMed: 17784804]

48). Wolk DA, Schacter DL, Berman AR, et al. Patients with Alzheimer's disease attribute conceptual fluency to prior experience. Neuropsychologia. 2005; 43:1662–1672. [PubMed: 16009248]

49). Budson AE, Dodson CS, Daffner KR, Schacter DL. Metacognition and false recognition in Alzheimer's disease: Further exploration of the distinctiveness heuristic. Neuropsychology. 2005; 19:253–258. [PubMed: 15769209]

50). Waring JD, Chong H, Wolk DA, Budson AE. Preserved metamemorial ability in patients with mild Alzheimer's disease: Shifting response bias. Brain and Cognition. 2008; 66:32–39. [PubMed: 17576033]

51). Zhang Y, Han B, Verhaeghen P, Nilsson LG. Executive functioning in older adults with mild cognitive impairment: MCI has effects on planning, but not on inhibition. Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2007; 14:557–570. [PubMed: 18038355]

52). Bisiacchi PS, Borella E, Bergamaschi S, Carretti B, Mondini S. Interplay between memory and executive functions in normal and pathological aging. J Clin Exp Neuropsychol. 2008; 30:723–733. [PubMed: 18608665]

53). Hildebrandt H, Haldenwanger A, Eling P. False recognition helps to distinguish patients with Alzheimer's disease and amnestic MCI from patients with other kinds of dementia. Dement Geriatr Cogn Disord. 2009; 28:159–167. [PubMed: 19696484]

54). Zhang F, Geng H. What can false memory tell us about memory impairments in Alzheimer's disease? Chinese Science Bulletin. 2010; 35:3989–3997.

55). Paivio, A. Imagery and verbal processes. Holt, Rinehart, and Winston; New York: 1971.

56). Nelson DL, Reed US, Walling JR. Picture superiority effect. Journal of Experimental Psychology: Human Learning & Memory. 1976; 2:523–528. [PubMed: 1003125]

57). Weldon MS, Roediger HL 3rd. Altering retrieval demands reverses the picture superiority effect. Memory and Cognition. 1987; 15:269–280.

58). Weldon MS, Roediger HL 3rd, Challis BH. The properties of retrieval cues constrain the picture superiority effect. Memory and Cognition. 1989; 17:95–105.

59). Ally BA, Budson AE. The worth of pictures: Using high density event-related potentials to understand the memorial power of pictures and the dynamics of recognition memory. NeuroImage. 2007; 35:378–395. [PubMed: 17207639]

60). Ally BA, Waring JD, Beth EH, et al. Aging memory for pictures: Using high-density event-related potentials to understand the effect of aging on the picture superiority effect. Neuropsychologia. 2008; 46:287–297.

61). Curran T, Doyle J. Picture superiority doubly dissociates the ERP correlates of recollection and familiarity. Journal of Cognitive Neuroscience. 2011; 23:1247–1262. [PubMed: 20350169]

62). Rajaram S. Perceptual effects on remembering: Recollective processes in picture recognition memory. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1996; 22:365–377.

63). Hamilton M, Geraci L. The Picture Superiority Effect in Conceptual Implicit Memory: A Conceptual Distinctiveness Hypothesis. The American Journal of Psychology. 2006; 119:1–20. [PubMed: 16550852]

64). Rajaram S, Geraci L. Conceptual fluency selectively influences knowing. Journal of Experimental Psychology: Learning, Memory, and Cognition. 2000; 26:1070–1074.

65). Whittlesea BWA, Williams LD. Why do strangers feel familiar, but friends don't? A discrepancy-attribution account of feelings of familiarity. Acta Psychologica. 1998; 98:141–165. [PubMed: 9621828]

66). Jacoby LL, Whitehouse K. An illusion of memory: False recognition influenced by unconscious perception. Journal of Experimental Psychology: General. 1989; 118:126–135.

67). Lindsay DS, Kelley CM. Creating Illusions of Familiarity in a Cued Recall Remember/Know Paradigm. Journal of Memory and Language. 1996; 35:197–211.

68). Roediger HL, McDermott KB. Creating false memories: Remembering words not presented in lists. Journal of Experimental Psychology: Learning, Memory, and Cognition. 1995; 21:803–814.

69). Ballesteros S, Reales JM, Mayas J. Picture priming in normal aging and Alzheimer's disease. Psicothema. 2007; 19:239–244. [PubMed: 17425893]

70). Fleischman DA, Wilson RS, Gabrieli JD, et al. Implicit memory and Alzheimer's disease neuropathology. Brain. 2005; 128:2006–2015. [PubMed: 15975947]

71). Willems S, Salmon E, Van der Linden M. Implicit/explicit memory dissociation in Alzheimer's disease: The consequence of inappropriate processing? Neuropsychology. 2008; 22:710–717. [PubMed: 18999344]

72). Yonelinas AP, Hopfinger JB, Buonocore MH, Kroll NE, Baynes K. Hippocampal, parahippocampal and occipital-temporal contributions to associative and item recognition memory: an fMRI study. Neuroreport. 2001; 12:359–363. [PubMed: 11209950]

73). Golby A, Silverberg G, Race E, et al. Memory encoding in Alzheimer's disease: an fMRI study of explicit and implicit memory. Brain. 2005; 128:773–787. [PubMed: 15705615]

74). Koenig P, Smith EE, Troiani V, et al. Medial temproal lobe involement in an implicit memory task: evidence of collaborating implicit and explicit memory systems from fMRI and Alzheimer's disease. Cerebral Cortex. 2008; 18:2831–2843. [PubMed: 18400793]

75). Quiroz YT, Ally BA, Celone K, et al. Event-related potential markers of brain changes in preclinical familial Alzheimer's disease. Neurology. 2011; 77:469–475. [PubMed: 21775732]

76). Troller JN, Sachdev PS, Haindl W, et al. A high-resolution single photon emission computer tomography study of verbal recognition memory in Alzheimer's disease. Dementia and Geriatric Cognitive Disorders. 2006; 21:267–274. [PubMed: 16479105]

77). Fleischman DA, Gabrieli JD. Repetition priming in normal aging and Alzheimer's disease: a review of findings and theories. Psychol Aging. 1998; 13:88–119. [PubMed: 9533193]

78). Deason RG, Hussey EP, Budson AE, Ally BA. Gist-based conceptual processing of pictures remains intact in patients with amnestic mild cognitive impairment. Neuropsychology. 2012; 2:202–208. [PubMed: 22229341]

79). Martins CA, Lloyd-Jones TJ. Preserved conceptual priming in Alzheimer's disease. Cortex. 2006; 42:995–1004. [PubMed: 17172179]

80). Goudour A, Samson S, Bakchine S, Ehrle N. Agnosic or semantic impairment in very mild Alzheimer's disease? Neuropsychol Dev Cogn B Aging Neuropsychol Cogn. 2011; 18:230–53. [PubMed: 21360357]

81)•. Price SE, Kinsella GJ, Ong B, et al. Semantic verbal fluency strategies in amnestic mild cognitive impairment. Neuropsychology. 2012; 26:490–497. [PubMed: 22746308] This study used multiple methods to examine cognitive strategies in semantic fluency in patients with aMCI. Patients not only had worse overall performance on the fluency task, but they produced smaller semantic cluster sizes and fewer subcategories of items. Further, patients with aMCI had an overall reduction in word production. These results demonstrate the aberrant spread within the semantic network that likely underlies diminished conceptual processing of words in these patients.

82). Wierenga CE, Stricker NH, McCauley A, et al. Altered brain response for semantic knowledge in Alzheimer's disease. Neuropsychologia. 2011; 49:392–404. [PubMed: 21163275]

83). Chertkow H, Bub D. Semantic memory loss in dementia of Alzheimer's type. What do various measures measure? Brain. 1990; 113:397–417. [PubMed: 2328410]

84). Hussey EP, Smolinsky JG, Piryatinsky I, Budson AE, Ally BA. Using mental imagery to improve memory in patients with Alzheimer disease: trouble generating or remembering the mind's eye? Alzheimer Dis Assoc Disord. 2012; 26:124–34. [PubMed: 21946012]

85). Budson AE, Sitarski J, Daffner KR, Schacter DL. False recognition of pictures versus words in Alzheimer's disease: The distinctiveness heuristic. Neuropsychology. 2002; 16:163–173. [PubMed: 11949708]

86). Beth EH, Budson AE, Waring JD, Ally BA. Response Bias for Picture Recognition in Patients with Alzheimer Disease. Cognitive and Behavioral Neurology. 2009; 22:229–235. [PubMed: 19996875]

87). Dierckx E, Engelborghs S, De Raedt R, et al. Verbal cued recall as a predictor of conversion to Alzheimer's disease in Mild Cognitive Impairment. Int J Geriatr Psychiatry. 2009; 24:1094–100. [PubMed: 19280679]

88). Greenaway MC, Duncan NL, Smith GE. The memory support system for mild cognitive impairment: randomized trial of a cognitive rehabilitation intervention. Int J Geriatr Psychiatry. Jun 7.2012 doi: 10.1002/gps.3838. [Epub ahead of print].

89). Sugano K, Yokogawa M, Yuki S, et al. Effect of cognitive and aerobic training intervention on older adults with mild or no cognitive impairment: a derivative study of the nakajima project. Dement Geriatr Cogn Dis Extra. 2012; 2:69–80. [PubMed: 22619662]

90). Macduffie KE, Atkins AS, Flegal KE, Clark CM, Reuter-Lorenz PA. Memory distortion in Alzheimer's disease: Deficient monitoring of short- and long-term memory. Neuropsychology. 2012; 26:509–516. [PubMed: 22746309]

91). Noonan KA, Pryer LR, Jones RW, Burns AS, Lambon Ralph MA. A direct comparison of errorless and errorful therapy for object name relearning in Alzheimer's disease. Neuropsychol Rehabil. 2012; 22:215–34. [PubMed: 22376314]

92). Clare L, Linden DE, Woods RT, et al. Goal-oriented cognitive rehabilitation for people with early-stage Alzheimer disease: a single-blind randomized controlled trial of clinical efficacy. Am J Geriatr Psychiatry. 2010; 18:928–39. [PubMed: 20808145]

93). Clare L, Jones RS. Errorless learning in the rehabilitation of memory impairment: a critical review. Neuropsychol Rev. 2008; 18:1–23. [PubMed: 18247118]

94). Lezak, MD.; Howieson, DB.; Loring, DW. Neuropsychological Assessment. Fourth Edition. Oxford University Press; New York: 2004. Memory I: Tests; p. 414-479.

95). Sanders C, Schmitter-Edgecombe M. Identifying the nature of impairment in planning ability with normal aging. J Clin Exp Neuropsychol. Apr 16.2012 [Epub ahead of print].

96)•. Johns EK, Phillips NA, Belleville S, et al. The Profile of Executive Functioning in Amnestic Mild Cognitive Impairment: Disproportionate Deficits in Inhibitory Control. J Int Neuropsychol Soc. 2012; 18:541–55. [PubMed: 22370245] This study highlighted the need for more sensitive and detailed measures in clinical assessment. These authors found that 100% of 40 MCI patients in there data set demonstrated executive dysfunction in at least one of the five established subdomains of executive function, 96% in at least two subdomains, and 43% in all five subdomains. These results are not only important when conceptualizing clinical evaluations, but raise important questions about the potential implications of executive functioning inefficiencies on memory.