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Gist-Based Conceptual Processing of Pictures Remains Intact in Patients With Amnestic Mild Cognitive Impairment

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Objective: The picture superiority effect, better memory for pictures compared to words, has been found in young adults, healthy older adults, and, most recently, in patients with Alzheimer's disease and mild cognitive impairment. Although the picture superiority effect is widely found, there is still debate over what drives this effect. One main question is whether it is enhanced perceptual or conceptual information that leads to the advantage for pictures over words. In this experiment, we examined the picture superiority effect in healthy older adults and patients with amnestic mild cognitive impairment (MCI) to better understand the role of gist-based conceptual processing. ***Method:*** We had participants study three exemplars of categories as either words or pictures. In the test phase, participants were again shown pictures or words and were asked to determine whether the item was in the same category as something they had studied earlier or whether it was from a new category. ***Results:*** We found that all participants demonstrated a robust picture superiority effect, better performance for pictures than for words. ***Conclusions:*** These results suggest that the gist-based conceptual processing of pictures is preserved in patients with MCI. While in healthy older adults preserved recollection for pictures could lead to the picture superiority effect, in patients with MCI it is most likely that the picture superiority effect is a result of spared conceptually based familiarity for pictures, perhaps combined with their intact ability to extract and use gist information.

Keywords: picture superiority effect, mild cognitive impairment, Alzheimer's disease, familiarity, recollection

Pictures are markedly better remembered than words on tests of recall and recognition; this picture superiority effect has been demonstrated in both healthy young and older adults (Ally et al., 2008; Mintzer & Snodgrass, 1999; Park, Puglisi, & Sovacool, 1983; Shepard, 1967; Winograd, Smith, & Simon, 1982). Clinical observations have also suggested that pictures are remembered better than words in patients with Alzheimer's disease (AD). Recent work inspired by these clinical observations was the first to demonstrate a preserved picture superiority effect in both patients with early AD and amnestic mild cognitive impairment (MCI; a precursor stage to AD; Ally, Gold, & Budson, 2009a). Unknown, however, is exactly how pictures improve memory in patients with AD and MCI, and whether these mechanisms are the same or different as those operating in healthy older adults. Investigating the preserved picture superiority effect in these patient groups has the potential to be relevant not only to help our understanding of the mechanisms of healthy memory processing, but also to create successful interventions to aid patients with AD and MCI.

There are three main theories proposed to explain the picture superiority effect: the dual coding hypothesis, the distinctiveness hypothesis, and the semantic processing hypothesis. The dual-coding hypothesis 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 (Paivio, 1971). 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. Another explanation is the distinctiveness hypothesis (or sensory-semantic account), which suggests that pictures provide more highly distinctive visual features at encoding than words, making them more memorable

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(Nelson, 1979). The third alternative is the semantic processing hypothesis, which proposes that the picture superiority effect is a result of pictures allowing for deeper and more elaborate conceptual processing than words (Weldon & Roediger, 1987; Weldon, Roediger, & Challis, 1989). The main difference between all three theories is the relative contribution of perceptual and conceptual information to the picture superiority effect.

Pictures obviously provide unparalleled perceptual information. For example, the perceptual information conveyed by a picture of a guitar includes the shape of its neck, the color of its body, and the orientation of its headstock and tuners, which likely makes this picture more memorable than the word “guitar.” This perceptual information would also make this picture discernible from other pictures of the same guitar and from pictures of other guitars (Nelson, 1979). More recent work has emphasized the enhanced contribution of conceptual information provided by pictures (Hamilton & Geraci, 2006). While the conceptual information provided by the word “guitar” likely revolves around the individual’s concept of guitar, a picture of a guitar may provide more detailed information to allow for deeper conceptual processing as well. For example, the conceptual information conveyed from a picture of a guitar might include “musical instrument,” “electric guitar,” “Jerry Garcia plays one just like it,” “I dig the Grateful Dead,” making the picture more memorable. Thus, perceptual and conceptual information may contribute in different ways to the picture superiority effect.

Several recent studies from our laboratory have demonstrated a robust picture superiority effect in patients with AD and MCI, and have begun the work to understand the mechanisms of this effect in these patient populations (Ally, Gold, & Budson, 2009a; Ally, McKeever, Waring, & Budson, 2009; O’Connor & Ally, 2010). The importance of conceptual processing to the picture superiority effect in patients with MCI was particularly supported by evidence examining the effect of form change (O’Connor & Ally, 2010). In form change experiments, items are studied in one form (e.g., pictures) and then are tested in a different form (e.g., words). Performance on these types of tasks is generally lower than when the study and test stimuli are matched on form and thus, sharing both conceptual *and* perceptual information. O’Connor and Ally (2010) found a preserved picture superiority effect in patients with MCI when only conceptual information could reliably be used. They found that patients with MCI showed a similar performance to healthy older adults when they studied pictures and were tested on words, whereas when subjects studied words and were tested with pictures, the patients were impaired. These findings suggested that pictures may provide greater, more detailed access to conceptual information at study than words.

One outstanding question is whether the picture superiority effect in patients with AD or MCI is due only to encoding or whether retrieval tasks might also play a part in the effect. Most of the studies examining the picture superiority effect have focused on encoding differences between pictures and words, but perhaps the conceptual information provided by pictures as the test cue enhances retrieval in patients. The picture superiority effect has been widely demonstrated with a number of different retrieval tasks (recall, recognition, associative recognition, form change, etc.). Previously, Weldon, Roediger, and Challis (1989) conducted an experiment in which healthy young participants studied a mixture of pictures and words. Participants were then cued by associated words (e.g., “emergency” to cue “ambulance”) to recall the studied items. A robust picture superiority effect was shown with recall of 72% for pictures and 56% for words. This finding suggested that pictures might allow for better conceptual processing than words in a recall task with young adults. An advantage for pictures in this task indicates that pictures allow privileged access to conceptual information in a way that words do not.

The current experiment examined whether a picture superiority effect would be present in a category-based retrieval task performed by healthy older adults and patients with MCI. This experiment will also further test the different competing hypotheses for explaining the picture superiority effect. Importantly, if our hypotheses are confirmed, this will confirm and extend the prior findings implicating conceptual processing in the picture superiority effect in young adults (Weldon et al., 1989) to older adults and patients with MCI offering more support for the semantic processing hypothesis. Potentially, determining that preserved conceptual processing underlies the picture superiority effect in patients with MCI could lead to better interventions that can be targeted to take advantage of the preserved processing.

In this experiment, healthy older adults and patients with amnestic MCI studied three exemplars from a category either as all words or as all pictures. In the test phase, participants were asked to determine whether a fourth exemplar (not seen in the study phase) belonged to a studied category or to a category that had not been seen before. If participants performed better with the exemplars that were shown as pictures (both at study and test) than those that were shown as words, this would demonstrate a picture superiority effect primarily based on conceptual and *not* perceptual processing supporting the semantic processing hypothesis.

Method

Participants

Twelve healthy older adults (five male/seven female, three run in Boston), and 12 patients (six male/six female, five run in Boston) with a clinical diagnosis of probable amnestic mild cognitive impairment (seven with single and five with multiple domain according to published criteria) were recruited for this study (Petersen et al., 2001). Patients were recruited from the Cognitive Disorders Clinic at Vanderbilt University and the Boston University Alzheimer’s disease Center (BU ADC). Healthy older adults were recruited through online postings on the Vanderbilt University Research Match Web site (www.researchmatch.org), online and community postings in the Boston, MA and Nashville, TN areas, and the BU ADC. Participants with a history of psychiatric illness, stroke or other focal brain injury, and/or substance abuse were excluded from participating. All participants were native English speakers and had normal or corrected to normal vision. The study was approved by the Behavioral Science Committee Division of the IRB at Vanderbilt University, Nashville, TN and the Human Subjects Committees at Edith Nourse Rogers Memorial Veterans Hospital, Bedford, MA, BU, Boston, MA, and VA Boston Health care System, Boston, MA. Written informed consents were obtained from all participants and from their caregivers when appropriate. Participants were paid $10/hour for their participation.

Healthy older adults and patients were administered a battery of neuropsychological tests in order to determine their eligibility for participation in the study. This battery included the MMSE (Folstein, Folstein, & McHugh, 1975), CERAD Word List Memory Test (Morris et al., 1989), Trail Making Test Part B (Adjutant General's Office, 1944), Verbal fluency to letters and categories (Monsch et al., 1992), and the short form Boston Naming Test (Mack, Freed, Williams, & Henderson, 1992). Table 1 presents demographic and neuropsychological data for the participants.

Materials

The stimuli used in this study were adapted from the Van Overschelde, Rawson, & Dunlosky (2004) updated Battig and Montague (1969) norms. Forty-eight specific categories (e.g., nuts) were chosen and randomly divided into two lists of 24 categories each. Each of the 24 categories had four distinct exemplars (e.g., pecans, cashews, almonds, hazelnuts). One list was used as studied categories and the other list used as new categories at test. For the list used as studied categories, 3 exemplars were presented in the study phase and the 4th only during the test. Each exemplar of the category was rotated throughout the counterbalancings so that across participants, all exemplars appeared as both studied and test items. For the new categories, one exemplar was presented in the test phase. Within each of the two lists, the 24 categories were randomly divided in half each so that 12 categories were presented as words and 12 categories were presented as pictures. Categories were presented in the same modality (pictures or words) at both study and test. The study was programmed using E-Prime 2.0 Professional software (Psychology Software Tools, Pittsburgh, PA) and run on PC laptops. The stimuli were presented in the center of the screen on a white background. Pictures were 450 pixels by 450 pixels (size). Words were presented in 32 point black Courier font.

Procedure

At study, participants were shown a total of 72 items: three exemplars from 12 word categories and three exemplars from 12 picture categories for a total of 24 categories studied (see Figure 1). Words and pictures were randomly intermixed throughout the study portion and were presented on the screen for 3 seconds, with a 500 ms fixation cross presented prior to each study item. Participants were instructed to look carefully at each word and picture and to try to remember them for a later memory test. After a few minutes delay (range of 2–5 minutes), all participants were instructed to indicate to the experimenter whether the item presented on the screen was similar to or in the same category as one of the items they previously studied. In order to ensure that the participants understood the test instructions, examples were given. A total of 48 test items were presented: 24 novel exemplars from the studied categories and 24 novel items from unstudied categories. For example, during the study portion, a participant might have seen a picture of a tulip, carnation, and daisy and then at test be presented with a picture of a rose, to which s/he should respond "yes" because all of these are in the category of "flowers." As in the study phase, test words and pictures were randomly intermixed.

Table 1
Demographic and Neuropsychological Data

	Healthy older adults	Patients with MCI
Test	Mean (*SD*)	Mean (*SD*)
Age	73.5 (7.54)	73.1 (8.6)
Years of Education	16.6 (2.15)	16.8 (2.33)
MMSE	29.2 (0.58)	28 (1.65)*
CERAD		
Immediate	21.7 (2.5)	16.3 (4.14)*
Delayed	7.6 (1.08)	3.2 (2.21)*
Recognition	9.7 (0.65)	8.5 (1.09)*
Trails-B	63.8 (10.76)	102.7 (39.9)*
FAS	45.2 (13.7)	43.4 (11.5)
CAT	47.8 (5.85)	36.8 (10.97)*
BNT-15	14.0 (0.85)	13.5 (1.24)

* Indicates a significant difference ($p < .05$) between the healthy older adults and the patients with MCI.

Results

Hits and False Alarms

A repeated-measures ANOVA was conducted using a between-subjects factor of group (healthy older adults vs. patients with MCI) and a within-subjects factor of condition (pictures vs. words) examining hit rates (see Table 2). For all ANOVAs conducted, test site (Nashville vs. Boston) and gender were initially included as between-subjects variables; however, because no significant main effects or interactions were found, these variables were dropped from the analyses reported. Hit rates were higher for pictures than for words ($F(1, 22) = 29.44$, $p < .001$, $\eta^2 = .57$), and hit rate was greater for healthy older adults than for patients with MCI ($F(1, 22) = 9.40$, $p < .01$, $\eta^2 = .30$). There was a significant interaction between condition and group ($F(1, 22) = 6.22$, $p < .05$, $\eta^2 = .22$) because healthy older controls and patients with MCI showed no significant difference in picture hit rates, $t(1,22) = 1.08$, $p = .29$, but controls had a higher hit rate than the patients for words, $t(1,22) = 3.20$, $p < .01$.

Another repeated-measures ANOVA was conducted using a between-subjects factor of group (healthy older adults vs. patients with MCI) and a within-subjects factor of item condition (pictures vs. words) examining false alarm rates (see Table 2). There were no significant main effects (group: $F(1, 22) = 3.34$, $p = .08$; item condition: $F(1, 22) = 2.13$, $p = .16$) nor was there an interaction, $F(1, 22) = 2.46$, $p = .13$ with false alarm rates.

Discrimination and Response Bias

To examine discrimination, we calculated P_r (hit rate—false alarm rate; Snodgrass & Corwin, 1988). High values of P_r indicate greater discrimination, while a P_r value of zero indicates chance performance. A repeated-measures ANOVA was conducted using a between-subjects factor of group (older adults vs. patients with MCI) and a within-subjects factor of condition (pictures vs. words) examining discrimination (P_r; see Figure 2). Healthy older adults performed better than patients with MCI ($F(1, 22) = 25.21$, $p < .001$, $\eta^2 = .53$). All participants demonstrated a picture superiority effect ($F(1, 22) = 26.84$, $p < .001$, $\eta^2 = .55$) that did not interact

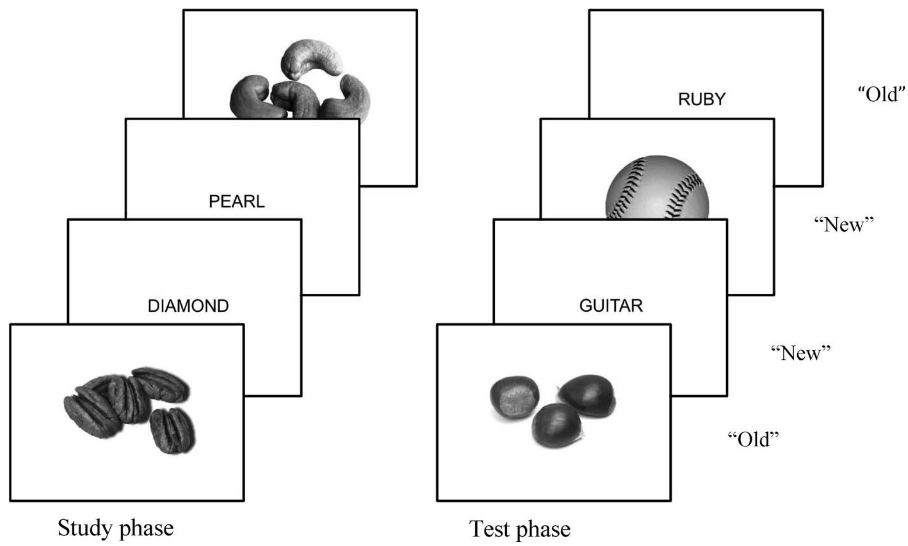

Figure 1. Visual depiction of the experimental method. First, participants study three exemplars of categories either as words or as pictures. In the test phase, participants decided whether items presented were from categories studied before or new categories.

with group ($F < 1$). The magnitude of change was numerically larger for the patients with MCI (average P_r difference between pictures and words = .31) than for the healthy older adults (average P_r difference between pictures and words = .21) but this numerical difference did not approach significance.

We also examined response bias as measured by B_r (false alarm rate/1- P_r; Snodgrass & Corwin, 1988). For B_r, 0.5 is considered a neutral bias (equally likely to respond "old" or "new"), while higher values indicate a liberal bias (more likely to respond "old") and lower values indicate a conservative bias (more likely to respond "new"). A repeated-measures ANOVA was conducted using a between-subjects factor of group (older adults vs. patients with MCI) and within-subjects factor of condition (pictures vs. words) examining response bias. All participants showed a more liberal bias for pictures ($B_r = .61$) than for words ($B_r = .44$; $F(1, 22) = 10.63$, $p < .01$, $\eta^2 = .27$), which did not interact with group ($F < 1$).

Discussion

Both the healthy older adults and patients with MCI demonstrated a robust picture superiority effect in this category-based retrieval task. Overall, as expected, the patients with MCI showed lower discrimination for both words and pictures compared with the healthy older adult controls. The patients showed similar hit rates for pictures, but lower hit rates for words compared to controls. False alarm rates showed no statistical differences between conditions or groups. For all participants, response bias was more liberal for pictures than for words, similar to prior findings (Beth, Budson, Waring, & Ally, 2009). To begin to understand these patterns of performance in the patients with MCI and the healthy older adults, it will be helpful to review the dichotomy of recollection versus familiarity in these groups and in studies of pictures versus words.

Table 2
Proportion of Hits and False Alarms In Healthy Older Adults and Patients With MCI

	Hits		False alarms	
	Pictures	Words	Pictures	Words
OC (*SD*)	.91 (0.08)	.79 (0.11)	.12 (0.08)	.21 (0.11)
MCI (*SD*)	.86 (0.13)	.55 (0.24)	.23 (0.14)	.22 (0.12)

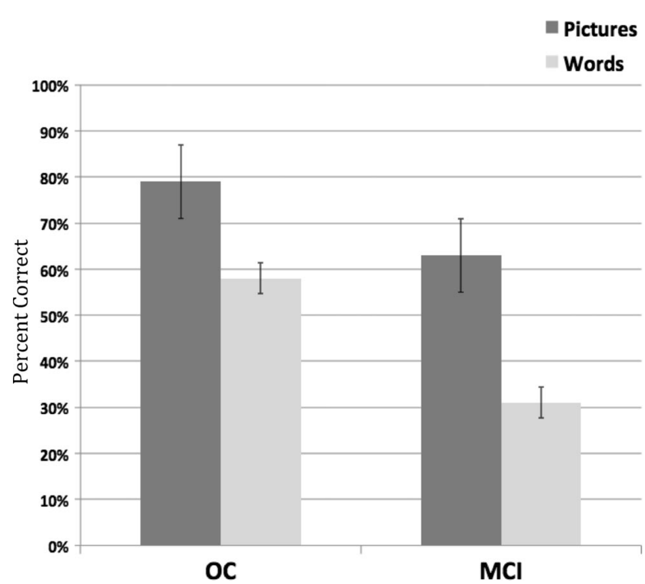

Figure 2. Discrimination (P_r) for healthy older adults (OC) and patients with MCI for both pictures and words (error bars reflect the standard error of the mean).

Dual process theories of recognition memory suggest that two independent processes contribute to accurate recognition decisions: *recollection* and *familiarity* (Yonelinas, 2002). Recollection is specific recall of an event/item that brings to mind particular details. Familiarity is a more general sense of having encountered an event or item before without recall of the specific context.

We have previously shown that when recognizing pictures as compared to words, young adults showed an increased parietal old/new effect, which has been purported to be the event-related potential (ERP) correlate of recollection (Ally & Budson, 2007). This finding suggested that young adults experienced an increase in recollection that led to their picture superiority effect. Curran and Doyle (2011) also showed a similar pattern with an enhanced parietal old/new ERP effect whenever pictures were studied as compared to when words were studied. Curran and Doyle found that an earlier ERP component thought to reflect familiarity (FN400) was enhanced whenever there was study-test congruency (picture-picture or word-word), but the parietal old/new effect was increased only when pictures were studied regardless of test stimuli presentation (picture-picture or picture-word). The authors took their findings as support for the distinctiveness hypothesis suggesting that pictures have distinctive features that lead to better encoding and, thus, the picture superiority effect.

Whereas recollection is enhanced for pictures compared to words in young adults, a different mechanism may explain the picture superiority effect in older adults. Although a robust picture superiority effect has been demonstrated in healthy older adults (Ally et al., 2008; Cherry et al., 2008; Park, Puglisi, & Sovacool, 1983; Winograd, Smith, & Simon, 1982), many studies have suggested that recollection is impaired in the course of healthy aging (Craik & Jennings, 1992; Light, 1991). To better understand the picture superiority effect in older adults, Ally et al. (2008) performed a recognition memory ERP study comparing pictures and words. Behaviorally, they found that older adults benefited even more strongly than younger adults from pictures. In terms of ERP effects, the early frontal component (reflecting familiarity), the parietal old/new effect (reflecting recollection), and the late frontal effect (reflecting postretrieval processing) for older adults were indistinguishable from young adults for pictures. For words, however, the older adults showed diminished early frontal and parietal old/new effects when compared to the young adults. These findings suggest that in healthy aging, although both familiarity and recollection might be impaired for words, these processes are relatively intact for pictures.

Using ERPs to investigate the picture superiority effect in patients with MCI, Ally, McKeever et al. (2009) found that the early frontal effect, reflecting familiarity, remained intact for pictures, but not for words, in patients with MCI when compared with healthy older adults. The parietal effect, reflecting recollection, was diminished for both words and pictures in the patient group. These results are consistent with prior research suggesting that because recollection is severely impaired in patients with AD and MCI, these patients are forced to rely on familiarity (Ally, Gold, & Budson, 2009b; Ally, McKeever et al., 2009; Balota, Burgess, Cortese, & Adams, 2002; Budson, Daffner, Desikan, & Schacter, 2000; Gallo, Sullivan, Daffner, Schacter, & Budson, 2004; Knight, 1998; Koivisto, Portin, Seinela, & Rinne, 1998; Smith & Knight, 2002; Westerberg et al., 2006; Wolk et al., 2005). Ally, McKeever et al. (2009) therefore proposed that the intact picture superiority effect in patients with MCI might be related to relatively preserved memorial familiarity in these patients.

In brief, the picture superiority effect may be related to better recollection of pictures versus words in healthy older adults, and better preserved familiarity for pictures versus words in both healthy older adults and patients with MCI. These explanations discussed thus far using recollection and familiarity explain why studying and being tested on a particular item (such as peanut) as a picture should lead to better memory than when the item is studied and tested as a word. In the current paradigm, however, none of the test items had been previously seen: instead groups of three category exemplars were studied (peanut, walnut, cashew) and a different exemplar was shown at test (pecan). In order to perform well on this paradigm, subjects must therefore extract the conceptual meaning of the items (peanut: nut, food, snack), form a representation of the general idea, meaning, or *gist* of the categorically related items (peanut, walnut, hazelnut: nuts), retain that gist-based representation (nuts) throughout the experiment, and apply it as appropriate to test items (pecan: yes, a nut). To understand the picture superiority effect in this paradigm, we must therefore also understand the role of conceptual and gist-based processes in pictures versus words, and how these processes relate to those of recollection and familiarity.

Finding a picture superiority effect in our conceptual task supports the semantic processing explanation of the picture superiority effect (Weldon & Roediger, 1987; Weldon, Roediger, & Challis, 1989). This theory proposes that pictures potentially access more detailed conceptual information than words. Pictures in both the study and test phase allowed for more detailed access to conceptual information, and this conceptual information led to the increased recognition of the categorically related items in the test phase (pecan: yes, a nut). Since perceptual information was not the same between study and test phases, it is likely that conceptual information contributed more to the picture superiority effect in this task.

Although research has suggested that enhanced perceptual processing of test stimuli may provide the basis for the sense of memorial familiarity (see Yonelinas, 2002 for review), and prior work has reported that perceptual priming and perceptual fluency remain intact even in moderate AD (Fleischman, 2007), other work has suggested that enhanced conceptual processing of test stimuli may also play a significant role in familiarity (Parks & Toth, 2006). Whereas conceptual processing of words has been investigated in patients with AD, there has been less work examining the conceptual processing of pictures in this population. The results of this experiment, and our prior work (Ally, McKeever et al., 2009; O'Connor & Ally, 2010), indicate that conceptual processing plays an important role in the preserved picture superiority effect in patients with MCI.

Once the conceptual information of items has been extracted, a gist-based representation must be formed, retained, and applied correctly. Using word-based false memory paradigms, several studies have demonstrated impaired item-specific recollection in patients with AD, while showing relatively intact gist-based memory (Budson et al., 2000; Budson, Sullivan, et al., 2002; Gallo et al., 2006). Similar findings have been shown for picture stimuli with gist-based memory for pictures relatively spared compared to impaired item-specific recollection in patients with AD and MCI (Budson et al., 2001; Budson, Sitarski, Daffner, & Schacter, 2002;

Budson, Michalska, et al., 2003; Budson, Todman, & Schacter, 2006; Westerberg et al., 2006). When compared to words, pictures have also been found to increase gist-based false memory in patients with AD at encoding (Budson, Sitarski, et al., 2002). In the current experiment, patients with MCI could successfully rely on their relatively intact gist-based memory since the paradigm does not require—and in fact does not even allow—item-specific recollection because studied items do not appear at test. As the previous work has shown, gist-based memory is greatly enhanced by pictures, which could contribute to the picture superiority effect in patients.

The picture superiority effect has been theorized to be a result of more detailed perceptual and/or conceptual information for pictures than for words. The results of the current experiment suggest that conceptual information plays an important role in the picture superiority effect for both healthy older adults and patients with MCI. Prior ERP studies indicated that both familiarity and recollection for pictures are intact as compared to words for healthy older adults. For patients with MCI, familiarity and gist-based memory are more preserved for pictures than words (recollection is impaired for both). This study in combination with prior ERP studies suggest that while in healthy older adults preserved recollection for pictures could lead to the picture superiority effect, in patients with MCI it is most likely that the picture superiority effect is a result of spared conceptually based familiarity for pictures, perhaps combined with their intact ability to extract and use gist information. Future ERP or fMRI studies might be able to confirm or refute this conclusion.

This experiment has helped to better understand the robust picture superiority effect in healthy older adults and patients with MCI. Understanding the mechanisms of the picture superiority effect may lead to the development of successful picture-based strategies for improving daily memory functioning in these populations. An important extension of this experiment would be to examine the picture superiority effect and its relation to conceptual processing in patients with AD. As the AD pathophysiologic process progresses from MCI to AD dementia, patients are more likely to have disrupted conceptual processing. If conceptual processing plays a large role in the picture superiority effect, a diminished effect might, therefore, be expected in patients with AD. Better understanding the relative contribution of perceptual and conceptual components to the memorial benefit of pictures will help clinicians to tailor interventions for greater success. For example, a patient with MCI may remember a picture schedule of her day more readily if the pictures emphasize the conceptual rather than perceptual aspects of the pictures. Also, new learning techniques, such as errorless learning (which has shown modest benefit using words), can use pictures and be tailored to emphasize either perceptual or conceptual details of the picture, depending upon which aspect is found to be most important.

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