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Ayanna K. Thomas [a] & Mark A. McDaniel [b]

[a] Psychology Department, Tufts University, Medford, MA, USA

[b] Psychology Department, Washington University, St. Louis, MO, USA

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The interaction between frontal functioning and encoding processes in reducing false memories

Ayanna K. Thomas[1] and Mark A. McDaniel[2]
[1]Psychology Department, Tufts University, Medford, MA, USA
[2]Psychology Department, Washington University, St. Louis, MO, USA

ABSTRACT

Studies suggest that age differences in false memories may be related to deficits in frontal lobe functioning (FLF; Butler, McDaniel, Dornburg, Price, & Roediger, 2004, *Psychonomic Bulletin & Review, 11*, 921). In addition, research has demonstrated that item-specific encoding can reduce false memories in younger adults (Arndt & Reder, 2003, *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*, 830). In the present study we examined whether younger and older adults who perform poorly on tests designed to assess frontal function would be less likely to benefit from item-specific encoding in a false memory paradigm. In three experiments, participants studied categorized word or picture lists. Encoding manipulations were designed to emphasize either item-specific or relational processing. Younger adults and high FLF older adults showed a reduction in false memories when item-specific processing was implemented. However, low FLF older adults showed a reduction in false memories only when relational processing was impoverished. Results suggest that frontal function directly influences the engagement in distinctive encoding processes.

Keywords: Frontal functioning; Encoding processes; False memories.

Research examining aging and memory has demonstrated age-related decrements in the ability to learn and remember (e.g., Craik, 1977; Craik & Jennings, 1992; Light, 1991; Zacks, Hasher, & Li, 2000). These age-related decrements in older adults' ability to accurately remember have applied consequences. From deceiving the elderly with false "I told you claims" (i.e.,

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Address correspondence to: Ayanna K. Thomas, Psychology Department, Tufts University, 490 Boston Ave, Medford, MA 02155, USA. E-mail: ayanna.thomas@tufts.edu

Jacoby, 1999) to an over-reliance on stereotyped schematic information (i.e., Mather, Johnson, & De Leonardis, 1999), the picture painted by research examining cognitive processes in older adults suggests that as we get older, we will be more easily misled (Mitchell, Mather, & Johnson, 2003), we will rely on general knowledge and relational information as compared to item-specific individuating information (Koutstaal et al., 2003; Koutstaal, Schacter, Galluccio, & Stofer, 1999; Mather et al., 1999; Thomas & Sommers, 2005), and we will be less able to subjectively assess the accuracy of our memories (Bulevich & Thomas, 2012; Dodson, 2005).

Though age seems to increase susceptibility to distortion in memory, more recent research suggests that older adults can reduce errors if they are given specific and detailed instructions as to how to make accurate memory judgments (Bulevich & Thomas, 2012; Thomas & Bulevich, 2006). In addition, several recent studies highlight the role of individual differences as they relate to memory accuracy in healthy older adults. Specifically, studies have demonstrated that frontal functioning may influence memory accuracy in such distortion paradigms as the Deese–Roediger–McDermott (DRM) paradigm (Butler et al., 2004), and misinformation paradigm (Roediger & Geraci, 2007). Specifically, older adults who scored low on measures assessing frontal function were more likely to falsely remember lures related to studied lists as compared to high scoring older adults.

Research has suggested that false memory susceptibility in the DRM may in part be a result of overreliance on relational processing (i.e., Thomas & Sommers, 2005). Thus, the goal of the present research is to examine whether high and low frontal lobe functioning (FLF) older adults effectively use item-specific and relational encoding processes. Item-specific processing is defined by the encoding of distinctive, non-overlapping attributes that provide a unique specification of the target and thus improves memory by making the target highly distinguishable (Lockhart, Craik, & Jacoby, 1976). Relational processing is defined by the encoding of representations concerning the relations of to-be-remembered items (Hunt & Einstein, 1981). The encoding of individuating and relational information may be facilitated by self-initiated processes or encouraged by the conditions of learning. In the context of the DRM paradigm, if individuals use primarily relational information at retrieval, they will more likely remember related but non-presented lures (cf. Thomas & Sommers, 2005).

Frontal Functioning and Older Adult Memory

Relative to low FLF older adults, those older adults characterized as high FLF have been shown to be less susceptible to distortions in memory (Butler et al., 2004; Butler, McDaniel, McCabe, & Dornburg, 2010; Chan & McDermott, 2007; La Voie, Willoughby, & Faulkner, 2006), have demonstrated better

source memory (Glisky, Polster, & Routhieaux, 1995; Glisky, Rubin, & Davidson, 2001), have demonstrated higher recall accuracy with the cognitive interview (Dornburg & McDaniel, 2006), have displayed more accurate monitoring of memory ability (Souchay, Isingrini, & Espagnet, 2000), have been found to be less susceptible to the misinformation effect (Roediger & Geraci, 2007), and have demonstrated better performance on prospective memory tasks (McFarland & Glisky, 2009). Particularly relevant to the present research is that frontal functioning in older adults has been reported to influence age related changes in false recall and recognition in various paradigms, with high FLF older adults showing levels of false memory that are more comparable to younger adults than to low FLF older adults (Bulter et al., 2004; Curran, Schacter, Norman, & Galluccio, 1997; La Voie et al., 2006; Schacter, Curran, Galluccio, Milberg, & Bates, 1996; see McDaniel, Einstein, & Jacoby, 2007; Roediger & McDaniel, 2008, for more detailed reviews). Similarly, neuroimaging studies have demonstrated that false recognition in healthy adults using the DRM paradigm is associated with activation of the frontal lobes (Schacter, Buckner, Koutstaal, Dale, & Rosen, 1997; Schacter, Reiman, et al., 1996).

One possible interpretation of this pattern is that high, but not low, FLF older adults, spontaneously and effectively engage source monitoring (cf. Dornburg & McDaniel, 2006; Glisky et al., 1995, 2001). In line with this interpretation, prior work has demonstrated a strong relationship between frontal functioning and older adults' source-monitoring abilities (e.g., McIntyre & Craik, 1987). For example, research has shown that lesions in frontal cortex disrupt the kind of self-initiated processes (Stuss & Benson, 1986) that are important to feature binding (e.g., by maintaining activation or generating organization or elaborations) and that are likely necessary for the encoding of individuating information and effective source monitoring (see Shimamura, 1994 for a review). Research also suggests that low FLF older adults may not integrate information from two different sources during encoding (Glisky et al., 2001). Glisky and Kong (2008) proposed that the deficit in source memory shown by low FLF participants could be attributable to a failure to initiate encoding and/or retrieval processes important for source monitoring. Moreover, performance on source tests is associated with activation in the frontal lobes, as revealed by event related potentials and functional magnetic resonance imaging (e.g., Nolde, Johnson, & D'Esposito, 1998; Trott, Friedman, Ritter, & Fabiani, 1997). We suggest that older adults characterized as low FLF are less able to take advantage of individuating item information acquired during encoding in order to effectively discriminate between studied items and non-studied but highly related items at test. That is, low FLF older adults may not effectively integrate individuating item information at encoding that could later be use for discrimination between studied items and lures at retrieval. We first describe the paradigm of interest here

and pertinent findings. We then present three experiments investigating the theoretical issues developed herein.

The DRM Paradigm, Aging, and False Recognition

In the DRM paradigm, participants are presented with associatively related words followed by recall and/or recognition testing. The typical finding is that people recall and recognize related but unstudied lures as having been previously presented (Balota et al., 1999; Deese, 1959; Mather, Henkel, & Johnson, 1997; Robinson & Roediger, 1997; Roediger & McDermott, 1995). Critically, older adults are generally more susceptible to these distortions in memory as compared to younger adults (Balota et al., 1999; Dehon & Bredart, 2004; La Voie & Faulkner, 2000; Kensinger & Schacter, 1999; Norman & Schacter, 1997; Tun, Wingfield, Rosen, & Blanchard, 1998).

A number of studies have introduced manipulations to enhance the encoding of item-specific information for the target words so as to reduce false recognition (and recall). For example, Kensinger and Schacter (1999) repeatedly presented and tested target lists (five study-test trials) to provide participants opportunities to accrue item-specific information about target words. Smith, Lozito, and Bayen (2005) presented target words visually to provide distinctive perceptual information (instead of a standard auditory presentation condition). Thomas and Sommers (2005) presented the DRM list items in the context of sentences to promote more individual item elaboration. The assumption in the above studies was that encoding item-specific features of target words would improve source discrimination between targets and critical lures (CLs) (which would not enjoy rich item-specific encoding) on recognition testing and thereby significantly reduce false recognition. The consistent finding for these studies was that younger adults less often endorsed CLs in the conditions that fostered item-specific processing than in the standard DRM conditions. In sharp contrast, older adults continued to display similar levels of false recognition for the item-specific enhanced and the standard DRM conditions. These patterns have been interpreted as establishing that older adults are less likely to encode or retrieve item-specific information that can be used to effectively monitor the source of activated information, thereby distinguishing presented targets from non-presented lures (e.g., Smith et al., 2005; Thomas & Sommers, 2005).

We propose a modification to this view. Based on the analysis and findings presented in the previous section (showing divergent false memory patterns between high and low FLF older adults), we suggest that frontal functioning in older adults will significantly influence the extent to which they can encode and use item-specific information to reduce false recognition (and more generally improve source monitoring). Specifically, our prediction is that high FLF older adults will reduce false recognition to CLs when

attention is drawn toward item-specific processing, as in the sentence presentation conditions of Thomas and Sommers (2005; see also the conditions in Kensinger & Schacter, 1999; Smith et al., 2005). By contrast, low FLF older adults will not show a reduction in these types of recognition errors under such conditions.

In some situations, individuating information between targets and CLs is extremely pronounced. For instance, in one condition in Thomas and Sommers (2005) the target items were presented in *divergent sentences*. Unlike the convergent-sentence condition, these sentences elicited meanings of list items that diverged from the meaning of the CLs. Under these relatively optimal conditions that augment individuating information of targets, older adults were able to more accurately discriminate targets from related lures. This pattern was noteworthy in light of unsuccessful previous attempts to reduce low-frontal older adults' memory illusions (as indexed by recall) in DRM by having them generate individuating semantic associates for each target (Butler et al., 2010) or by presenting items visually rather than aurally (Gallo, personal communication, April 2007). In the present study, we manipulated item-specific and relational encoding across three experiments. We hypothesized that younger and high FLF older adults would be similarly less susceptible to false memories when item-specific encoding was stressed. However, low FLF older adults would show reductions in false memory susceptibility only when relational processing was deemphasized *and* item-specific processing was emphasized.

Overview of Experiments

Across three experiments we investigated whether young adults, high FLF, and low FLF older adults could use item-specific information to improve memory performance when presented with DRM lists. We compared three conditions that were designed to differentially emphasize relational and item-specific encoding processes. In Experiment 1, the conditions were modeled after those used by Thomas and Sommers (2005). Specifically, we presented DRM list items in the context of convergent sentences, divergent sentences, or in isolation. In Experiment 2, attention was directed to item-specific processing by presenting items as pictures. Finally, in Experiment 3 participants engaged in relational, item-specific, or both relational and item-specific orientating tasks.

We hypothesized that when presented with DRM list items in isolation all groups would demonstrate the false memory effect. However, when presented with studied items in contexts that emphasized item-specific processing (i.e., sentences, pictures, and orientating instructions) young adults and high FLF older adults would show a reduction in false memories. However, low FLF older adults would only show reductions in false memories

when item-specific information was made more salient than relational information. To help clarify whether any effects associated with frontal status were related more generally to levels of cognitive functioning (instead of functioning associated primarily with the frontal system) we also assessed medial temporal lobe (MTL) status through neuropsychological testing. MTL functioning has also been shown to be important for source memory and processes that bind together features that co-occur during encoding and/or retrieval (Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, & D'Esposito, 2000; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Naveh-Benjamin, 2000; see also, Johnson & Chalfonte, 1994). However, the primary focus of the experiments reported here regards integrative processes at encoding. Based on previous neuropsychological findings concerning aging, source memory, and distinctive processing (see Mitchell & Johnson, 2009; Roediger & McDaniel, 2007 for reviews), we expected that levels of FL but not MTL functioning would be associated with the effects of distinctive feature encoding and integration. Therefore, we equated participants on medial temporal status. Both high and low FLF older adults were determined to be high MTL functioning (relative to normative data established by Glisky et al., 1995).

General Method

Participants

In each experiment we had a group of 24 young adults, 24 older adults classified as high FLF and 24 older adults classified as low FLF. Table 1 includes the demographic characteristics of all groups for each experiment. Across the three experiments 72 younger adults and 144 older

TABLE 1. Demographic information for all experiments

	Age	Male	Female	Education	Vocabulary	MMSE	FL score	MTL score
Experiment 1								
Young	19.4 (1.7)	5	19	13.9 (1.4)	28.1 (3.2)	30 (0)	–	–
High FLF	76.7 (4.1)	11	13	14.2 (2.1)	37.1 (3.1)	29 (1.2)	0.75 (0.25)	0.11 (0.75)
Low FLF	77.8 (3.5)	13	11	14.2 (2.5)	36.1 (2.1)	29 (1.5)	−0.82 (0.54)	0.09 (0.65)
Experiment 2								
Young	20.1 (1.1)	10	14	12.1 (2.4)	31.2 (4.1)	30 (0)	–	–
High FLF	78.5 (3.2)	15	13	13.9 (3.5)	37.5 (2.2)	28 (1.5)	0.81 (0.43)	0.05 (0.66)
Low FLF	79.2 (4.5)	8	16	14.5 (3.5)	37.1 (3.1)	29 (2.5)	−0.77 (0.34)	0.11 (0.35)
Experiment 3								
Young	19.2 (1.5)	9	15	13.4 (0.9)	29.5 (4.1)	30 (0)	–	–
High FLF	81.1 (4.2)	14	10	14.9 (3.8)	37.6 (3.5)	28 (1.8)	0.71 (0.53)	0.12 (0.46)
Low FLF	79.9 (5.1)	6	18	14.1 (4.5)	36.5 (2.4)	29 (1.5)	−0.89 (0.76)	0.14 (0.65)

Note: Average age and performance on standard measures are included. Standard deviations are in parentheses. Number of male and female participants is also included. FL, frontal lobe; MTL, medial temporal lobe.

adults participated. For Experiment 1, younger adults were recruited from the participant pool at Washington University in St. Louis and older participants were recruited from the Older Adult Participant Pool at Washington University in St. Louis. For Experiments 2 and 3, younger adults were recruited from the participant pool at Tufts University, and older participants were recruited from the Older Adult Participant Pool at Tufts University. All younger adults were given course credit for their participation. Older adults were paid for their participation.

Neuropsychological Assessments

All older adults were first given a battery of neuropsychological tests designed to assess frontal and MTL functioning.[1] These tests were given no more than 6 months prior to experimental participation. Similar to Butler et al. (2004) we used five measures to calculate the composite FL function scores. Those were number of categories achieved on the modified Wisconsin Card Sorting Test (modified WCST; Hart, Kwentus, Wade, & Taylor, 1988); the total number of words generated for the letters F, A, and S, on the Controlled Oral Word Association Test (COWAT; Spreen & Benton, 1977) the Arithmetic score from the Wechsler Adult Intelligence Scale-Revised (WAIS-R; Wechsler, 1981); and the Mental Control and Backward Digit Span scores from the Wechsler Memory Scale-III (Wechsler, 1997). For each participant, a composite measure of FL function was calculated as the average of age-adjusted *z*-scores on each of the frontal measures. The FL function scores were calculated using an equation that was derived in the same way as has been reported previously (Glisky et al., 1995, 2001; McDaniel, Glisky, Guynn, & Routhieaux, 1999). The equations used were based on new normative sample tested in E. Glisky's lab (personal communication, March 2005; Glisky & Kong, 2008). Participants designated as high FLF were those who received age-adjusted *z*-score that were greater than zero. Those designated as low FLF received *z*-scores that were less than zero.

In addition to assessments of FL functioning, older adults were given a group of tests thought to measure MTL functioning. The tests contributing to the MTL factor included Logical Memory I, Verbal Paired Associates I and

[1] The present study did not assess frontal functioning in younger adults. To our knowledge, only one study has examined the relationship between frontal lobe functioning and false memories in young adults using the battery of tests employed in this study (Chan & McDermott, 2007). Chan and McDermott did find that higher frontal functioning in young adults was associated with lower levels of false recall. This finding suggests that like older adults, younger adults' susceptibility to false memories may be driven by level of frontal functioning. As it relates to the present study, these findings suggest that frontal functioning in young adults may play a role in the successful engagement of item-specific processing to reduce false memory susceptibility. Attempts were made to assess frontal functioning in young adults in order to examine this question; however, these attempts were thwarted. The challenge of finding young adults who qualified as low FL and good to high ML functioning was too great.

Visual Paired Associates II (all from the WMS-R), and the Long Delay Cued Recall test from the California Verbal Learning Test (Delis, Kramer, Kaplin, & Ober, 1987). High FLF and Low FLF older adults did not differ when MTL functioning was compared ($t < 1$; see Table 1 for means). The composite measure of MTL function was an age-adjusted z-score. Only older adults who received z-scores that were greater than zero participated in this study. Older adults were also screened for depression and dementia. Anyone scoring 10 or above on the Geriatric Depression Scale was excluded for possible depression (Brink et al., 1982). Anyone scoring 25 or below on the Mini-Mental State Examination (MMSE) was excluded for possible dementia (Folstein, Folstein, & McHugh, 1975).

The neuropsychological tests used in the present study have previously been submitted to an exploratory principal components analysis (Glisky et al., 1995, 2001). The use of a composite measure provides a more reliable and stable measure of both FL and MTL function than any single measure (cf. Glisky & Kong, 2008; Salthouse, Atkinson, & Berish, 2003). Importantly, the FLF tests are not tests of long-term memory, but rather are thought to tap executive control processes. That is, the FL factor has been shown to reflect a component of working memory the enables the integration of information across a variety of cognitive and perceptual domains (cf. Glisky & Kong, 2008).

In all three experiments, both high and low FL older adults had significantly more years of education than younger adults, and both high and low FL older adults performed better on the Shipley Vocabulary test than younger adults [Education Experiment 1: $t(46) = 2.9$, $SE = 0.61$; $t(46) = 1.3$, $SE = 0.54$; Education Experiment 2: $t(46) = 3.3$; $SE = 0.54$, $t(46) = 2.3$, $SE = 0.74$; Education Experiment 3: $t(46) = 4.7$, $SE = 0.58$, $t(46) = 5.2$, $SE = 0.60$; Vocabulary Experiment 1: $t(46) = 5.5$, $SE = 0.23$; $t(46) = 4.8$, $SE = 0.87$; Vocabulary Experiment 2: $t(46) = 4.3$, $SE = 0.43$; $t(46) = 5.5$, $SE = 0.67$; Vocabulary Experiment 3: $t(46) = 4.8$, $SE = 0.55$; $t(46) = 3.9$, $SE = 0.47$]. Across the three experiments the two groups of older adults did not differ on years of education or vocabulary performance.

Design and Procedure

A similar design and procedure was used across the three experiments. All experiments used a 3 × 3 mixed design. The between subjects variable was age (younger, high-FLF older, low-FLF older), and the within subjects variable was type of presentation/instructions. The experiment consisted of an encoding and retrieval phase. At encoding participants were presented with sentences, words, or pictures via computer. Presentation was blocked by non-presented related theme word or words. Blocks were randomly presented to participants. Within each block items were presented in a fixed order, from highest associate with the non-presented theme word to lowest

associate. In Experiments 1 and 2, after each block, participants worked on arithmetic problems for 60 seconds. A 5-minute distractor task followed the last block. Participants then completed a final yes/no recognition task consisting of 64 items. Participants were told to press the 'Y' key if they remembered having studied the item in the first part of the experiment. They were told to press the 'N' key if the item had not been presented in the first part of the experiment. Participants were encouraged to be as accurate as possible.

Experiment 1

In Experiment 1, DRM list items were presented in the context of convergent or divergent sentences. We compared three conditions that were designed to differentially emphasize relational and item-specific encoding processes. The conditions were modeled after those used by Thomas and Sommers (2005). Specifically, we presented DRM list items in the context of convergent sentences, divergent sentences, or in isolation. We hypothesized that when presented with DRM list items in isolation all groups would demonstrate the false memory effect. However, when presented with DRM items in the context of either convergent or divergent sentences younger adults and high FLF older adults would demonstrate dramatic reductions in the false memory effect. Low FLF older adults would only show reductions in distortions when item-specific information was made more salient that relational information, as in the divergent sentences condition.

Method

Materials. The experimental materials were identical to those used by Thomas and Sommers (2005) and consisted of 16 lists of either eight words or eight sentences each. Thomas and Sommers used list items that were taken from the Stadler, Roediger, and McDermott (1999) norms. Convergent and divergent sentences were generated with the list item serving as the sentences' final word. The context of convergent sentences was constrained to elicit the meaning of the list item that converged on the meaning of the critical lure (CL). Convergent: Kim took a nap in her bed. The context of divergent sentences was constrained to elicit the meaning of the list item that *did not* converge on the meaning of the CL. Divergent: Kim skipped rocks near the river bed.

Design and Procedure. The experiment used a 3 × 3 mixed design. The between subjects variable was age (younger, high-FLF older, low-FLF older), and the within subjects variable was type of presentation (convergent sentences, divergent sentences, or words only). During encoding participants were presented with either sentences or words via computer. A block of eight sentences or eight words were presented one at a time for 2.5 seconds each. Pretesting of a separate group of 24 older adult participants ensured

that 2.5 seconds allotted a sufficient amount of time for sentence processing. Presentation of sentences and words were blocked by non-presented CL. Participants were instructed to read the sentences or words out loud. Blocks were randomly presented to participants. Within each block, sentences, or words, were presented in a fixed order, from highest semantic association with the non-presented lure to lowest semantic associates. Associative strength was based on the Stadler et al. (1999) norms.

The experiment was counterbalanced so that all list items were presented in the word-only, convergent sentences, and divergent sentences condition. After each block, participants worked on arithmetic problems for 60 seconds. A 5-minute distractor task followed the last block of sentences or words. Participants then completed a final yes/no recognition task consisting of 64 items. Three words from each study list were presented as targets on the recognition test. Thus, 24 of the items on the recognition test had been studied previously in the context of sentences or words in isolation. For distractors, 24 were words from non-studied lists, and 16 were CLs (8 associated with studied lists and 8 associated with non-studied lists).

Results

As Table 2 demonstrates when DRM list items were presented in isolation, all groups were highly likely to erroneously recognize non-presented CLs. However, when context was embellished the pattern of results changed, with younger adults and high FLF older adults showing a reduction in false alarming to CLs in both the convergent and divergent sentence conditions, and low FLF older adults showing a reduction in CL false alarms in the divergent condition but not the convergent condition. False alarms to CLs were statistically compared using a mixed design 3 (group: younger, high FLF older, low FLF older) × 3 (presentation: word, convergent sentence, divergent sentence)

TABLE 2. Average recognition hits to studied items and false alarms to related lures associated with Experiment 1

	Words *M* (*SD*)	Convergent *M* (*SD*)	Divergent *M* (*SD*)
Young			
Hits	0.73 (0.24)	0.69 (0.19)	0.65 (0.18)
False alarms	0.63 (0.32)	0.31 (0.24)	0.21 (0.19)
High FLF			
Hits	0.65 (0.38)	0.56 (0.25)	0.55 (0.16)
False alarms	0.65 (0.37)	0.40 (0.24)	0.27 (0.27)
Low FLF			
Hits	0.61 (0.18)	0.57 (0.17)	0.56 (0.12)
False alarms	0.70 (0.31)	0.74 (0.30)	0.31 (0.33)

Note: Standard deviations are in parentheses.

ANOVA. We found a main effect of group, $F(2, 69) = 6.29$, $p < .01$, $MSE = 0.12$, and a main effect of presentation, $F(2, 138) = 43.32$, $p < .01$ $MSE = 0.07$. Pair-wise comparisons with a Bonferroni correction, revealed that low FLF older adults ($M = 0.58$) were more likely to falsely remember CLs than high FLF older adults ($M = 0.44$), $t(46) = 2.23$, $d = .63$. The difference between high FLF older adults and younger adults was not significant, $t < 1$. In addition, participants were more susceptible to false memories when they studied word lists ($M = 0.66$) as compared to when they studied convergent sentences ($M = 0.32$), $t(71) = 4.41$, $d = .55$, or divergent sentences, $t(71) = 8.54$, $d = 1.32$. False memories were greater in the convergent sentences condition as compared to the divergent sentences condition ($M = 0.27$), $t(71) = 4.91$, $d = .76$. Finally, the interaction between group and presentation was significant, $F(4, 138) = 4.34$, $p < .01$, $MSE = 0.12$. Younger adults and high FLF older adults were similarly likely to falsely remember CLs across the presentation conditions. That is, both groups were less likely to falsely remember CLs when studied words were presented in the context of either divergent or convergent sentences than when presented in isolation. However, low FLF older adults were as likely to falsely remember lures when studied items were studied in isolation and when studied in convergent sentences.

Also evident is the difference among groups in correctly recognizing studied items. On average, younger adults ($M = 0.69$) recognized more studied items than high FLF older adults ($M = 0.59$) and low FLF older adults ($M = 0.58$). The difference in 'hit' rates was statistically confirmed through a 3 (group: younger, high FLF, low FLF) $\times$ 3 (type of presentation: words, convergent, divergent) mixed design ANOVA performed on 'yes' responses to studied items. A main effect of type of presentation was found, $F(2, 138) = 3.42$, $p < .01$, $MSE = 0.03$. As Table 2 demonstrates, participants recognized more studied items when presented as words in isolation than in the context of sentences. Planned comparisons with a Bonferroni correction reveal a significant difference in average hit rates between the divergent sentences and words in isolation conditions, $t(71) = 2.62$, $d = .40$. A main effect of group was also found, $F(2, 69) = 5.06$, $p < .01$, $MSE = 0.06$. Younger adults recognized more studied items than both groups of older adults [young-low FLF: $t(46) = 2.91$, $d = .86$; young-high FLF: $t(46) = 2.42$, $d = .71$]. No other effects were significant, $F < 1$. Finally, we compared false alarms to lures that were not related to studied items using a 3 (type of presentation: convergent sentences, divergent sentences, words-only) $\times$ 3 (group: young, high FLF, low FLF) ANOVA. No comparisons were significant, Fs < 1.

Discussion

Whereas younger adults and high FLF older adults were similarly likely to false alarm to CLs across all conditions, low FLF older adults were more likely than both groups to false alarm when DRM list items were presented in

the context of convergent sentences. Put another way, convergent sentences did not reduce false memory susceptibility in low FLF older adults. However, divergent sentences did. As in Thomas and Sommers (2005), the present study demonstrated that divergent sentences were less likely to elicit false memories than convergent sentences in populations hypothesized to have general cognitive deficits. Divergent sentences may be particularly effective because they enhance item-specific processing and concurrently impoverished relational information linking the targets and the CL. This possibility leads to the hypothesis that in order for low FLF older adults to effectively use cues generated from item-specific processing, relational processing needs to be somehow impoverished.

Research has indicated that when attention is drawn to item-specific processing, impoverished relational processing is a consequence (i.e., Hege & Dodson, 2004). However, response latency results from Thomas and Sommers (2005) suggest that even in the divergent sentences condition, where relational processing was deemphasized, CLs were internally activated. These results suggest that some relational processing may be occurring even in the divergent condition. In Experiments 2 we test further whether impoverished relational processing is required for low FLF older adults to demonstrate reductions in false memories. Specifically, in Experiment 2, we examined whether low FLF would be able to benefit from item-specific processing in situations where both relational and individuating information was highly salient and accessible.

Experiment 2

To provide a competitive test of the hypotheses outlined above, Experiment 2 used non-DRM categorized lists presented in the form of pictures, words, or pictures + words. Previous research suggests that pictures should engender more useful item-specific information than verbal labels (Shepard, 1967; Snodgrass, Volvovitz, & Walfish, 1972; Standing, 1973). Picture presentation was employed to increase access to item specific information. That being said, the meaning attribute associated with specific pictures should also support relational processing for a list of pictures with conceptually similar referents. Thus, the picture presentation format was presumed to increase access to item-specific information, but not necessarily divert attention away from relational processing. We hypothesized that low FLF older adults would not be able to extract and use item-specific information when presented with pictures, because they would be captured by the more easily extracted relational information. However, high FLF older adults, similar to younger adults, would effectively use item-specific information in the 'pictures' condition to discriminate between studied items and lures.

Finally, Experiment 1 demonstrated that high FLF older adults were able to reduce false memories in the convergent sentences condition. These

data suggest that high FLF older adults can effectively use item-specific information in situations where relational information is salient and accessible. To test the boundaries of effective item-specific information use, we included a 'pictures + words' condition in Experiment 2. This condition made highly accessible relational and item-specific information. We predicted that whereas low FLF older adults would demonstrate high levels of false memories in this condition, high FLF older adults would effectively use individuating information extracted from pictures and effectively discriminate between studied items and lures.

Method

Materials. The experimental materials were 12 lists taken from the Battig and Montague (1969) category production norms. Battig and Montague lists were used in Experiment 2 because we could present participants with more items within a given block/category. In addition, research has demonstrated that people are susceptible to false memory errors when presented with categorized lists that are not DRM lists (i.e., Henkel & Rajaram, 2011; Meade & Roediger, 2009). Finally, we were interested in extending the findings beyond the narrow realm of DRM materials. Participants were presented with 18 items from each list. The first two items of each category were used as CLs, and thus not presented during study. For each item, a picture was created to represent that item (Snodgrass & Vanderwart, 1980). Pictures were tested on a separate group of 24 younger adult participants to determine whether participants would self-generate the same labels for each picture that have been experimentally derived. During study, participants were presented with blocked categorized lists as pictures, words, or pictures and words.

Design and Procedure. The design was a 3 × 3 mixed factorial, with group (younger, high-FLF older, low-FLF older) as the between subjects variable and type of presentation (words, pictures, or pictures + words) as the within subjects variable. During encoding, lists were presented in blocked form, blocked by category, and by mode of presentation. Participants were presented with six categorized lists comprised of 18 items. Each item was presented for 2.5 seconds each. Blocks of items were randomly presented to participants. Within each block, pictures, words, or pictures and words were presented in a fixed order, from highest category association (excluding the first two associates). The experiment was counterbalanced so that all list items were presented in the pictures, pictures and words, or words alone. After each block, participants worked on arithmetic problems for 60 seconds. A 5-minute distractor task followed the last block of items. Participants then completed a final recognition task consisting of 78 items. Thirty-six of those items had been studied previously as words, pictures, or pictures and words.

For distractors, 30 were words from non-studied lists, and 12 were CLs or the two highest associates to each category.

Results

As Table 3 demonstrates, younger adults and high FLF older adults were less likely to claim that non-presented highly related lures were presented at study if items were studied as pictures (young $M = 0.28$; high FLF old $M = 0.27$) or pictures and words (young $M = 0.24$; high FLF old $M = 0.27$), than if items were studies as words alone (young $M = 0.49$; high FLF old $M = 0.52$). However, low FLF older adults did not show a difference in false alarms to critical related lures as a function of list presentation. In addition, younger adults and high FLF older adults were more likely to correctly recognize studied items if those items had been presented as pictures or pictures and words as compared to words alone. This same pattern was not present for low FLF older adults, who demonstrated similar responding for studied items in all presentation conditions.

A 3 (type of presentation: words, pictures, pictures + words) × 3 (group: young, high FLF, low FLF) mixed ANOVA with average false alarms to non-presented related lures as the dependent variable found a main effect of presentation, $F(2, 138) = 11.60$, $p < .01$, $MSE = 0.05$, and a main effect of group, $F(2, 69) = 12.18$, $p < .01$, $MSE = 0.06$. Planned comparisons using a Bonferroni correction revealed that false memories were greater in the 'words' condition ($M = 0.51$) as compared to the 'pictures' condition ($M = 0.36$), $t(71) = 4.37$, $d = .67$. Similarly, false alarms were greater in the 'words' condition than in the 'pictures + words' condition ($M = 0.34$), $t(71) = 3.93$, $d = .66$. Further, as in Experiment 1, we found that low FLF older adults were more susceptible to these kinds of memory errors than high FLF older adults ($M = 0.35$), $t(46) = .3.49$, $d = 1.09$. Similarly, low

TABLE 3. Average recognition hits to studied items and false alarms to related lures associated with Experiment 2

	Words *M* (*SD*)	Pictures *M* (*SD*)	Pictures + Words *M* (*SD*)
Young			
Hits	0.60 (0.19)	0.82 (0.17)	0.77 (0.19)
False alarms	0.49 (0.19)	0.28 (0.19)	0.24 (0.19)
High FLF			
Hits	0.58 (0.22)	0.76 (0.25)	0.80 (0.16)
False alarms	0.52 (0.27)	0.27 (0.19)	0.27 (0.25)
Low FLF			
Hits	0.56 (0.17)	0.56 (0.18)	0.57 (0.13)
False alarms	0.51 (0.16)	0.53 (0.22)	0.52 (0.36)

Note: Standard deviations are in parentheses.

FLF older adults ($M = 0.52$) were more susceptible to false memories than younger adults ($M = 0.33$), $t(46) = 4.68$, $d = 1.49$. There was no difference between high FLF older adults and younger adults, $t < 1$. Finally, the interaction between group and presentation was significant, $F(4, 138) = 3.44$, $p < .01$, $MSE = 0.18$. Both younger adults and high FLF older adults were less likely to incorrectly recognize related lures when list items were studied as pictures or pictures and words, as compared to when list items were studies as words. However, low FLF older adults were similarly likely to falsely recognize lures across all presentation conditions.

The design of Experiment 2 also allowed us to examine the picture superiority effect as a function of frontal functioning. Researchers have demonstrated this effect in older adults; however the effect has been shown to decline with age (Rissenberg & Glanzer, 1986). We examined whether this reported decline could be explained in terms of frontal functioning. A 3 (group: younger, high FLF, low FLF) × 3 (type of presentation: words, pictures, pictures + words) mixed design ANOVA was performed on 'yes' responses to studied items. A main effect of type of presentation was found, $F(2, 138) = 12.45$, $p < .01$, $MSE = 0.03$. A main effect of group was also found, $F(2, 69) = 15.24$, $p < .01$, $MSE = 0.04$. Finally, the interaction between type of presentation and group was significant, $F(4, 138) = 3.46$, $p < .01$, $MSE = 0.03$.

To explore the nature of this interaction, simple-effects tests were performed for each presentation context. No significant differences between the groups were found when lists items were presented as words. When list items were presented as pictures, a main effect for group emerged, $F(2, 69) = 11.03$, $p < .01$, $MSE = 0.04$. Pair-wise comparisons with a Bonferroni correction revealed that younger adults and high FLF older adults were significantly better at recognizing previously presented items in this condition compared to low FLF older adults, $t(46) = 5.23$, $d = 1.32$ and $t(46) = 3.23$, $d = .76$, respectively. No significant difference was found between high FLF older adults and younger adults. When hit rates were compared in the pictures + words condition, a similar pattern was found. Younger adults and high FLF older adults were significantly better at recognizing previously studied items as compared to low FLF older adults, $t(46) = 4.31$, $d = .89$ and $t(46) = 5.47$, $d = .97$, respectively, and no difference was found between younger adults and high FLF older adults. These results suggest that low FLF older adults may be less likely to demonstrate standard picture superiority effects as compared to high FLF older adults and younger adults.

Discussion

Unlike in Experiment 1, low FLF older adults were not able to reduce false memories even in conditions designed to emphasize item-specific encoding. However, the results do suggest that picture presentation facilitated

item-specific processing in younger adults and high FLF older adults. That is, recognition performance in these groups was greater after picture presentation than after word presentation. Further, fewer false memories resulted in these groups after the study of pictures than after the study of words. The virtually identical recognition patterns for young and high FLF older adults suggests that older adults with relatively good FLF have spared item-specific processing and use item-specific information in source monitoring (at least as required for recognition decisions). Alternatively, low FLF older adults may have more difficulty encoding or retrieving useful item-specific information. Experiment 3 examined whether item-specific encoding could be enhanced in the low FLF population through an encoding manipulation designed to directly facilitate the extraction of individuating information.

Experiment 3

Experiment 3 was developed to further test the boundaries of low FLF older adults' encoding and use of item-specific information. The results of Experiments 1 and 2 suggest that relational processing does not need to be impoverished for younger adults and high FLF older adults to reduce false memories, contrary to previous explanations of distinctive effects on false memories (Arndt & Reder, 2003; Hege & Dodson, 2004). However, low FLF older adults only showed reductions in false memories when attention was diverted away from relational processing (i.e., divergent sentences). An extensive literature has indicated that orienting tasks successfully focus learners' processing on the dimension targeted by the particular orienting task (e.g., see; Craik & Tulving, 1975; McDaniel, Freidman, & Bourne, 1978; Thomas & Millar, 2011; Till & Jenkins, 1973). Therefore, in Experiment 3 we examined whether we could support item-specific processing through a direct encoding task, and thereby reduce false memory susceptibility even in conditions where relational information remained accessible.

Finally, we examined recall output to further assess the likelihood that participants engaged in relational processing. Instead of a final recognition test, participants were given free recall tests after each encoding block. This allowed us not only to examine false memory susceptibility using a different test of memory, but also to examine the kinds of processes participants may use when retrieving information. We hypothesized that when relational processing was deemphasized participants would be less likely to cluster recall output as a function of semantic category.

Method

Materials. The materials used in Experiment 2 were again used, with the addition of six categories taken from Battig and Montague (1969). The first two items of each list were not presented for study and considered the critical words of interest at test. In Experiment 3 all items were presented as words.

Design and Procedure. A 3 × 3 mixed factorial design was used, with group (younger, high-FLF older, low-FLF older) as the between subjects variable, and type of encoding orientation (item specific, relational, both) as the within subjects variable. The presentation of studied items in Experiment 3 was similar to Experiment 2, with the following exceptions. All items were presented as words. In addition, before each block, instructions were presented in order to orient participants to a specific type of processing mode. For item specific orientation, participants were told to study each item and try to determine a specific use for the studied item. Below the presented item participants were also presented with the following question: "How useful is this object?" For the relational condition, participants were asked to think of how each item in the particular block of items related to one another. As each item was presented so was the following question: "How related is this object to others in this block?" Responses to both relational and item-specific orienting questions were recorded on a scale from 1 to 7. In the condition in which participants were directed to engage in both item specific and relational processing, participants were told before those blocks that they would answer both questions for a given object, but the order of the questions would be random. Therefore, for some items, the item-specific orienting question would be presented first and for other items, the relational question would be presented first. All orienting questions were presented after the item had been studied for 2.5 seconds. In addition, participants were told to make their judgments as quickly as possible. After an encoding block consisting of two lists had been present, participants engaged in a free recall task. They were asked to write down as many studied words from the previous block they could remember. Participants were given 5 minutes to perform the recall task and encouraged to try to use the entire time to remember words.

Results

Free Recall. As Table 4 demonstrates, average false recall, or intrusions, of critical words was lowest when participants were given item-specific orienting instructions. Further, all three groups produced similar levels of false recall in the item-specific orienting condition ($M = 0.15$). However, in the combined relational—item-specific condition, low FLF older adults displayed high levels of false recall ($M = 0.45$), whereas the other two groups were far less likely to falsely recall critical theme words ($M = 0.20$). To confirm the reliability of these patterns, a 3 (encoding orientation: item-specific, relational, both) × 3 (group: young, high FLF, low FLF) mixed design ANOVA was performed on average false recall. A main effect of type of orienting task was found, $F(2, 138) = 9.17$ $p < .01$, $MSE = 0.03$. When participants engaged in relational encoding ($M = .27$), intrusions associated with critical items were greater than when they engaged in item-specific encoding ($M = 0.15$), $t(71) = 3.62$, $d = .82$. Similarly, intrusions were greater when

TABLE 4. Average correct recall, false recall, and ARC scores associated with Experiment 3

	Studied *M* (*SE*)	Critical *M* (*SE*)	ARC score *M* (*SE*)
Relational orienting			
Young	0.27 (0.03)	0.25 (0.04)	0.52 (0.18)
High FL	0.29 (0.04)	0.24 (0.05)	0.49 (0.17)
Low FL	0.31 (0.04)	0.32 (0.05)	0.44 (0.17)
Item-specific orienting			
Young	0.27 (0.03)	0.13 (0.03)	0.45(0.18)
High	0.30 (0.03)	0.13 (0.02)	0.43 (0.16)
Low	0.31 (0.04)	0.19 (0.04)	0.10 (0.13)
Combined orienting			
Young	0.39 (0.04)	0.18 (0.04)	0.50 (0.15)
High	0.42 (0.04)	0.22 (0.05)	0.52 (0.17)
Low	0.38 (0.04)	0.45 (0.05)	0.50 (0.12)

Note: Standard deviations are in parentheses.

participants engaged in combined encoding ($M = .28$) as compared to item-specific encoding, $t(71) = 3.93$, $d = .49$. There was no difference in false memories between the relational and combined conditions, $t < 1$. In addition, we found a main effect of group, $F(2, 69) = 7.08$, $p < .01$, $MSE = 0.05$. Low FLF older adults ($M = 0.32$) had a greater proportion of critical intrusions than high FLF older adults ($M = 0.20$), $t(46) = 2.96$, $d = .92$. There was no difference in false recall between younger adults and high FLF older adults, $t < 1$. No other effects were significant; however the interaction between group and presentation was marginal, $F(4, 138) = 2.27$, $p = .06$, $MSE = 0.03$.

We also performed an analysis on correct recall. A main effect of type of presentation was found, $F(2, 138) = 7.80$, $p < .01$, $MSE = 0.03$. Recall of studied items was significantly better when participants engaged in combined item-specific and relational encoding ($M = 0.40$), than when they engaged in item-specific ($M = 0.29$) or relational encoding alone ($M = 0.29$) [combined with item-specific: $t(71) = 3.38$, $d = .52$; combined with relational: $t(71) = 3.44$, $d = .58$. There were no other significant effects, $F < 1$. Finally, an analysis of false recall of unrelated lures did not yield any significant effects, F's < 1.

Recall Clustering. Experimental studies on clustering and recall quantify the use of relational encoding by computing clustering indices associated with different organizing properties (e.g., Adjusted Ratio Clustering, ARC, Roenker, Thompson, & Brown, 1971). The ARC score assumes chance clustering to be 0 and perfect clustering to be 1 and is computed according to the following formula: ARC = [R – E(R)/[maxR – E(R)], where R is the total

number of category repetitions, maxR is the maximum possible number of category repetitions, and E(R) is the expected (chance) number of category repetitions (Roenker et al., 1971, p. 46). It adjusts for differences in the total number of items recalled, which is important considering that younger adults may recall more than older adults.

An ARC score was computed for each participant in each condition. Subsequently, we performed a 3 (encoding orientation: item-specific, relational, both) × 3 (group: young, high FLF, low FLF) mixed design ANOVA on average ARC scores. To begin with, we found a main effect of processing, $F(2, 138) = 49.66$, $p < .01$, $MSE = 0.01$. Participants were more likely to cluster responses after engaging in relational encoding ($M = 0.43$) than after engaging in item-specific encoding ($M = 0.29$), $t(71) = 6.29$, $d = 1.06$. Cluster scores were not significantly different between the relational and relational + item-specific ($M = 0.44$) encoding conditions, $t < 1$. In addition, we found a main effect of group, $F(2, 69) = 7.69$, $p < .01$, $MSE = 0.02$. Finally, the interaction between group and type of processing was significant, $F(4, 138) = 14.13$, $MSE = 0.01$. Younger and high FLF older adults were similarly likely to cluster output. However, low FLF older adults were significantly less likely to cluster output after engaging in item specific encoding, as compared to the other two encoding conditions.

Discussion

The present experiment sought to affect type of processing through orienting questions on an item-by-item basis. When item specific processing was accentuated (through the 'use' question) all groups of participants were unlikely to report critical theme words on the free recall test. When given both orienting questions, low FLF older adults had more intrusions of theme words than high FLF older adults and younger adults. The results of the present experiment clearly demonstrate that high FLF older adults and younger adults do not need to have relational processing impoverished in order to benefit from item-specific processing. However, low FLF older adults may only be able to reduce false memory susceptibility when relational processing is impoverished. To directly index relational processing we also examined recall clustering output. We found that low FLF older adults were significantly less likely to cluster recall output by category in the item-specific encoding condition as compared to younger adults and high FLF older adults. In sum, the results demonstrate that relational processing does not need to be compromised for younger adults and high FLF older adults to effectively use item-specific elaboration to reduce memory false memories. However, for low FLF older adults to use item-specific information optimally, disruption of focus on relational information during encoding appears to be necessary.

General Discussion

The present set of experiments demonstrated that the effective use of item-specific and relational information was associated with FLF. In three experiments, we demonstrated that low FLF older adults were unable to use item-specific information to reduce false memory susceptibility if relational processing was also engaged. However, low FLF older adults were able to reduce false memories in certain conditions. Specifically, reductions were found when relational processing was likely impoverished. These results suggest that low FLF older adults are impaired in their ability to use item specific information when relational information (or shared cues) has been jointly encoded.

Several theories that account for false memories in related lists paradigms make use of item-specific and relational information. For example, according to the activation-monitoring theory, incorrectly recalling or recognizing non-presented related lures is due to: (1) internal activation of the lure presumably stimulated by relational or associative processing and (2) an inability to effectively discriminate between that internal activation and external presentation (Balota et al., 1999). Based on these assumptions, there are at least two ways to reduce these kinds of memory errors: (1) reduce internal activation or (2) provide individuating cues that can be used to improve source discrimination.

In order to reduce internal activation, Arndt and Reder (2003) varied the font in which DRM list items were presented. List items studied in the same font were more likely to elicit false memories of related lures than list items studied in different fonts. Arndt and Reder suggested that by presenting items in different fonts item-specific processing was enhanced and relational processing was reduced. Reducing relational processing thereby reduced the probability that CLs were activated during encoding. Importantly, this early selection model is qualitatively different from late-correction models, such as those that use the distinctiveness heuristic (Schacter, Israel, & Racine, 1999). Specifically, the distinctiveness heuristic is a strategy that is adopted at the time of test. Information deemed distinctive is used to guide responding. The absence of distinctive accompanying information would be evidence for the absence of the item in the original experience.

Variations in Older Adults' Use of Distinctive Processing to Reduce False Memory

One possible reason why older adults have been shown to not be able to reduce false memories even after attention is directed to item-specific information, is that they may not encode contextual and perceptual cues that individuate items within a given list (i.e., Glisky et al., 1995; Park,

Puglisi, & Sovacool, 1983; Trahan, Larrabee, & Levin, 1986). Deficits in encoding of individuating information would likely result in source memory confusions (Mather et al., 1997). Older adults are less likely to benefit from contextual reinstatement at retrieval (Rabinowitz, Craik, & Ackerman, 1982). Additionally, older adults are less likely to remember the source of information (McIntyre & Craik, 1987). Although these findings suggest that a deficit in the encoding of contextual cues develops as we age, more recent research and the present findings suggest that older adults do encode, but may have difficulty using contextual or item-specific information (i.e., Bulevich & Thomas, 2012; Koutstaal et al., 2003; Naveh-Benjamin & Craik, 1995; Thomas & Sommers, 2005). Further, the present study suggests that difficulty in effectively using item-specific information may be related to frontal functioning.

While previous research implies false memories in the older adult population may be driven by an inability to effectively use item-specific information (or contextual cues), the present study qualifies those findings. In three experiments, we demonstrated that there is systematic variability in the non-demented older adult population. Older adults designated as high FLF do not show deficits in encoding or using item-specific information. Further, the results of all three experiments suggest that relational processing does not need to be impoverished in order for younger and high FLF older adults to effectively encoding and use individuating item-information. We will return to this point later. First we address the performance of low FLF older adults. These older adults effectively used item specific processing (supported by features of the stimulus presentation or by orienting tasks) to reduce false memory only when relational processing was presumably impoverished. Direct evidence for the reduction of relational processing was garnered though recall-clustering analyses. When recall cluster output was minimal, low FLF older adults were less likely to falsely recall related lures. The question raised by this finding is why do low FLF older adults demonstrate an inability to rely on individuating item information when relational information remains accessible? Several potential answers exist.

Trade-Offs Between Item-Specific and Relational Processing

To begin with, low FLF older adults may be less likely to encode individuating item information as compared to high FLF older adults (cf. Smith et al., 2005), and therefore may require specific orienting instructions to effectively do so (e.g., Glisky et al., 2001). The combined patterns across the present experiments are consistent with this explanation. Deficient item encoding was indicated in Experiment 2, in which low FLF older adults produced significantly lower hit rates in the ‘pictures’ and ‘pictures + words’ conditions as

compared to high FLF older adults and younger adults.[2] In addition, high FLF older adults and younger adults, but not low FLF older adults produced higher hit rates in these conditions as compared to the 'words-only' condition. By contrast, in Experiment 3, when participants were encouraged to encode item-specific information on an item-by-item basis, low FLF older adults produced correct recall rates similar to those displayed by the other groups. This pattern indicates that the encoding deficit that may impact low FLF older adults' ability to use item-specific information may be ameliorated by item-by-item explicit orienting questions.

Another possibility is that relational processing may distract low FLF older adults from item-specific elaboration. Consistent with this idea, low FLF older adults only showed reductions in errors of commission when they were directed away from relational processing (divergent sentences of Experiment 1 and the 'utility question' of Experiment 3). In the presence of relational processing, low FLF older adults may have needed a continuous reminder as to how to encode item-specific information. Results from Experiments 2 and 3 support this hypothesis. Specifically, the same materials were used in both experiments. What differed between the two was how item-specific information was highlighted. In Experiment 2, categorized lists were presented as pictures to facilitate the encoding of individual item information. In Experiment 3, categorized lists were presented as words that were encoded through specific orienting questions. In Experiment 2, item information had to be extracted spontaneously, whereas in Experiment 3, participants were directed as to how to extract item information on an item-by-item basis. It is possible that low FLF older adults may require this constant explicit reminding to engage in item-specific processing, when lists are relationally structured.

Finally, relational processing may need to be impoverished in low FLF older adults, because these individuals may over-rely on relational information during retrieval. Research has demonstrated that the frontal lobes function as filtering mechanisms that gate irrelevant memory associations (Shimamura, 1994). This view would suggest that low FLF older adults encode individuating information, but have difficulty efficiently using this information because of an over-reliance on relational associations that are also encoded. Consistent with this view, Butler et al. (2010, Experiment 1) reported that low FLF older adults' false recall in DRM lists was not diminished even when instructed with an orienting task that required generation of individuating information. Thomas and Bulevich (2006) demonstrated that

[2] Both high and low FLF produce lower hit rates in Experiment 1. This pattern is similar to one observed by Thomas and Sommers (2005). Rather than an encoding deficit, Thomas and Sommers (2005) attributed this difference to deficits in working memory. The task was such that participants had to read a sentence and remember the last word of the sentence. This task is similar to the working memory task developed by Daneman and Carpenter (1980).

it was more difficult for older adults to use contextual detail extracted from distinctive processing as compared to younger adults. Similarly, Tun et al. (1998) suggested that older adults over-rely on gist processing. Again, we now qualify these findings by demonstrating that high FLF older adults may not over-rely on this type of processing.

Researchers have suggested that relational and item-specific processing may compete for finite resources (e.g., DeLosh & McDaniel, 1996; Serra & Nairne, 1993). Specifically, the extent to which study items promote attention to, and the encoding of, item-specific information determines how much relational information is encoded. Thus, conditions that are conducive to the encoding of relational information should diminish the encoding of item-specific information relative to conditions that do not promote the encoding of relational information. If low FLF older adults operate with fewer resources, then they may over-rely on the less effortful relational process.

Distinctive Processing in Younger and High FLF Older Adults

Interestingly, the present study does call into question the assumption of resource competition, at least in younger adults and high FLF older adults. In three experiments participants were presented with relationally structured lists; however, in conditions where participants were explicitly encouraged to engage in both item-specific and relational processing, high FLF older adults and younger adults demonstrated the efficient use of item-specific information (Experiment 3, 'both' questions condition). For these participants, item-specific and relational processing worked in concert, resulting in a combined distinctive processing that reduced false memories (i.e., Hunt & Einstein, 1981). Low FLF, however, still produced false memories when directed to engage in item-specific and relational processing. Only when directed to encode only item-specific information did low FLF older adults demonstrate comparable reductions in false memories. By directing attention only to item-specific processing, low FLF older adults may have used all available resources to encode this information, and thus, may not have encoded relational information. Thus, presenting participants with DRM list items in the context of sentences, presenting related lists as pictures as opposed to words, or requiring participants to answer an orienting question designed to accentuate item-specific processing, may have facilitated a trade-off in the resources required for relational processing.

CONCLUSIONS

An important contribution from the present study is the evidence that frontal functioning influences distinctive processing. Our findings suggest that low FLF older adults can effectively use distinctive information, but they may

need additional support in order to do so. Specifically, these participants can encode distinctive information with supporting elaboration or with orienting tasks focused on item-specific information, but use of that information appears to depend on minimizing the accessibility of relational information. In addition, the present study demonstrates that item-specific and relational processing may be performed in parallel, at least in younger adults and high FLF older adults.

From a practical standpoint, our results are the first to demonstrate that the success of memory improvement techniques for older adults will be contingent on frontal functioning. Older adults designated as low FLF may show improvements in source discrimination only when techniques are employed that force these participants to maximally utilize individuating information, and reduce reliance on relational information. Healthy non-demented high FLF older adults have access to and effectively use encoded individuating information, and thus effectively rely on distinctive processing. Low FLF older adults, however, may be better served with memory improvement techniques that modify decision strategies towards more conservative responding (i.e., distinctiveness heuristic, Schacter et al., 1999), or on techniques that implement constant reminders of effective item-encoding and minimal activation of relational information.

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