Age Differences in Remembering "What" and "Where": A Comparison of Spatial Working Memory and Metacognition in Older and Younger Adults.

A thesis

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Bailey M. Bonura

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Advisers:

Ayanna K. Thomas
Holly A. Taylor

Abstract

Spatial memory involves remembering which object (identity) resides in which location. We examined memory for these elements individually and in combination. In Experiment 1, participants attended to either specific object identities, object locations, or both. When participants attended to specific grid information, location memory stayed constant with increasing array size, although younger adults were more accurate than older adults. Moreover, identity and identity-location combination performance decreased with increasing array size. In addition, older adults were impaired in their metacognitive monitoring compared to younger adults, especially for location information. In Experiment 2, participants did not know which information would be tested, thus the ability to use strategic processing was eliminated. When participants were unaware of to-be-tested material, both older and younger adults' performed similarly: Identity and combination accuracy decreased as array size increased, while location memory showed less impact of increasing items to remember. Moreover, older adults were able to use task difficulty cues to improve metacognitive accuracy when not strategically processing. Lastly, in Experiment 3, we examined the basis for poor combination trial performance. We found feature-binding failures constituted most of both age groups' combination errors; however, older adults' identity memory also contributed to their poor performance. Taken together, these results demonstrate age differences in identity and combination memory, as well as metacognitive monitoring, arising from encoding strategies. They also suggest location as a less effortful process compared to identity and combined information.

Age Differences in Remembering "What" and "Where": A Comparison of Spatial Working Memory and Metacognition in Older and Younger Adults.

It's Tuesday morning and you are running late for work. Just as you reach your car you realize you've left your lunch in the refrigerator. You rush back to the house, and head directly for the kitchen. Once in the kitchen, however you have no idea why you are there. You remember the item's general location, but have forgotten its identity. After several days of repeating this same series of events, you learn to write yourself a note: "Lunch" as a reminder to grab your lunch out of the refrigerator before leaving the house. This familiar scenario highlights that when we perceive objects, two forms of information are gleaned from our environment: identity and location (e.g., Baddeley, 1986; Simons, 1996; Ungerleider & Mishkin, 1982). Moreover, this scenario also demonstrates our ability to monitor our own cognitive processes (a concept known as metacognition) and implement appropriate strategies (e.g., see Hertzog and Hultsch, 1999).

Investigations into location and item memory have yielded conflicting results. For instance, studies testing whether or not memory for spatial location can be considered an automatic process are often at odds (e.g., Hasher & Zacks, 1979; Mandler, Seegmiller, & Day, 1977; Light & Zelinski, 1983; Naveh-Benjamin, 1987). The goal of the present research was to systematically study the relationship between location and identity memory using a visuospatial-working memory paradigm. We also investigated how this relationship changes with normal aging.

Is Memory for Spatial Location Automatic?

Previous research has shown that location memory is often superior to identity memory (e.g., Huang, Treisman, & Pashler, 2007; Postma & DeHaan, 1996; Wheeler & Treisman, 2002;

but see Chalfonte and Johnson, 1996; Kessels, Hobbel, & Postma, 2007). For instance, Postma and DeHaan (1996) demonstrated that participants made fewer errors when relocating objects after attending to location information alone. Moreover, unlike when attending to both identity and location together, location only error rates did not increase when display size (i.e., number of items) increased or after participants completed a secondary articulatory suppression task. Simons (1996) also found a benefit for location memory over identity memory. After studying arrays of object photographs or geometric shapes, participants were more accurate at detecting overall spatial configuration changes than object identity changes (Simons, 1996). Like Potsma and DeHaan (1996), this location memory benefit was unaffected by verbal interference at encoding. Previous research has also shown that when people read they can often effortlessly recall the approximate location of information within a given document (Rothkopf, 1971). Moreover, when individuals are instructed that they will be tested on passage information's location, memory is unaffected (Zechmeister, McKillip, Pasko, & Bespalec, 1975). This awareness of spatial location is thought to be important for readers because it aids in search and retrieval processes as well as increases reading comprehension (Lovelace, & Southall, 1983). Studies such as these support the idea that spatial location may be automatically processed (Hasher & Zacks, 1979).

According to Hasher and Zacks' (1979) framework, automatic processes require minimal attentional demands, co-occur with other cognitive processes (without interfering), and operate equivalently under both intentional and incidental learning conditions. Moreover, instructing individuals regarding their automatic processes should not affect memory performance. Likewise, compared to more effortful processes, automatic processes should be unaffected by practice, are likely to develop early and show minimal decline with advancing age, and exhibit little individual variability. Numerous studies have supported the idea that the extraction of location is an automatic process (e.g., Ellis, Katz, & Williams, 1987; Mandler et al., 1977; von Wright, Gebhard, & Karttunen, 1975). For instance, Mandler et al. (1977) found that both children and young adults recalled object locations equivalently after attending to either object identities alone (incidental instructions) or both identity and location (intentional instructions). Similarly, von Wright et al. (1975) found no differences between incidental and intentional learning when participants recalled the location of pictures. More specifically, participants recalled an equivalent number of picture locations when either aware or unaware of the upcoming recall test. Moreover, instructing participants to attend to picture locations had no benefit for recall performance. Ellis et al. (1987) also found evidence supporting location memory's automaticity when testing participants of differing ages and intelligence levels. With the exception of the youngest children (ages 3 - 4), participants (children, mentally challenged adults, younger adults, and older adults) performed equivalently when recalling picture locations. More recently, Köhler, Moscovich, and Melo (2001) found that recognition and recall performance for absolute spatial location was equivalent regardless of whether participants made encoding judgments about object identity or spatial relationships. Taken together, these results support the idea that memory for spatial location may be an automatic process.

Although there are numerous studies that support the idea of spatial location as automatic, other findings contradict this view (e.g., Light & Zelinski, 1983; Park, Puglisi & Lutz, 1982; Shulman, 1973). For instance, Schulman (1973) found that both word identity and location recognition was worse when participants intentionally attended to both identity and location in conjunction. Light and Zelinski (1983) also demonstrated that location learning might benefit from intentionality. After studying a map, older and younger adults located landmarks better after attending to both landmark identity and location than landmark identity alone. They also found that older adults' location memory was significantly worse than younger adults, another violation of Hasher and Zacks' (1979) criteria.

According to Naveh-Benjamin (1987), the literature on location automaticity is teeming with problems. For instance, many investigations lack a "true" incidental learning condition (e.g., Ellis et al., 1987; Light & Zelinski, 1983; von Wright et al. 1975), which is necessary to control strategy use (e.g., using spatial locations to better remember object identity). In addition, within much of the literature to-be-remembered objects appeared within a small number of recurring spatial locations over successive trials. This may have led to interference. Specifically, as limited locations reduce the number of distinctive combinations possible, confusion may have arisen regarding whether particular object-location combinations were actually studied. This could have impaired both identity and location memory. Lastly, the majority of research has only focused on three of Hasher and Zacks' (1979) criteria: intentionality, co-occurrence with other cognitive processes, and age invariability. Little research has been conducted on the other three criteria (practice effects, effortful training, and individual differences). In a series of four experiments, Naveh-Benjamin (1987) demonstrated that all six criteria influence location memory performance. Specifically, when participants were unaware of any upcoming memory test (i.e., "true" intentional encoding) their location memory was impaired compared to when they expected a test. Location memory was still quite good, however, even after incidental encoding. Moreover, practice and strategy use improved location memory. In addition, participants recruited from more "selective" academic programs remembered spatial location better than those from more "liberal" programs (within the same university). This suggests that individual differences may be an important factor for location memory. Secondary tasks were also shown to affect location memory; location memory declined with increasing secondary task difficulty. Lastly, older adults' location memory was found to be generally worse than younger adults.

Taken together, these findings suggest limitations to Hasher and Zacks' (1979) conceptualization of an automatic process; however, the procedure most commonly used to assess spatial location (e.g., Ellis, Katz, & Williams, 1987; Light & Zelinski, 1983; Mandler et al., 1977; Naveh-Benjamin, 1987) confounded object location and identity. Namely, the test for location memory involved participants replacing object photographs in their studied locations. Thus, location memory may have been dependent upon identity memory. In the current investigation, we wished to further test the "automaticity" possibility of spatial location with a novel working memory paradigm that separated object identity from object location. We predicted that if location information is automatically processed that both older and younger adults should perform better on location only trials, regardless of array size.

Metacognition and Cognitive Aging

Metacognitions, simply put, are cognitions about cognition (Wellman, 1983). As the opening scenario illustrates, one important function of metacognition is to monitor ongoing learning and apply appropriate learning strategies when necessary (Hertzog & Hultsch, 1999). In the current investigation, metacognition was examined in order to investigate the monitoring differences between identity and location information in older and younger adults. Research over the last 30 years has revealed a great deal about age-differences in episodic metacognitive monitoring. Metacognitive monitoring is evaluated in terms of absolute and relative accuracy. Absolute accuracy, or *calibration*, refers to the difference between predicted and actual recall performance (Hertzog & Hultsch, 1999). Absolute accuracy reflects how accurate or realistic metacognitive judgments are (Koriat, 2007). Relative accuracy, or *resolution*, on the other hand, refers to associations or correlations between predicted and actual performance (i.e. increases in predicted performance associated with increased actual performance; Hertzog & Hultsch, 1999). Relative accuracy reflects how well individuals can discriminate which items they will or will not remember (Koriat, 2007).

Episodic metacognition research has shown that older adults demonstrate impaired absolute, but not relative accuracy. For instance, Connor, Dunlosky, and Hertzog (1997) found that older and younger adults' immediate Judgments of Learning (JOLs; a type of metacognitive measure) were equally as accurate using correlational measures (i.e., relative accuracy), but not when using difference scores (i.e., absolute accuracy). Two factors have been suggested to contribute to differences between absolute and relative metacognitive accuracy in older adults: 1) processing fluency, or accessibility, and 2) cue familiarity, or domain specific knowledge (Koriat & Levy-Sadot, 1999; Koriat, Bjork, Sheffer, & Bar, 2004). For instance, Matvey, Dunlosky, Shaw, Parks, and Hertzog (2002) found both age groups' gamma correlations (relative accuracy) increased as the experiment progressed, demonstrating knowledge updating based on cue-effectiveness. Only younger adults, however, improved their absolute metacognitive accuracy based on cue familiarity or effectiveness. Instead, older adults "globally" decreased their predictions across trials regardless of the cues (Matvey et al., 2002). Likewise, Bieman-Copland and Charness (1994) found that younger adults corrected their absolute accuracy according to cue effectiveness, while older adults used only their previous task performance to adjust their predictions. Taken together this research suggests age-related deficits in absolute metacognitive accuracy relating to cue-effectiveness or familiarity.

While many have investigated metacognition in verbal-episodic memory, little of this work has examined metacognition in spatial memory. To the best of our knowledge only one study has investigated spatial metacognition. Schwartz (2006) found that recall for both maps and spatial narratives were positively correlated with JOLs, demonstrating good relative accuracy. In addition, participants' JOLs were well calibrated with actual recall performance, demonstrating good absolute accuracy. This study however, was only conducted on young adults. As very little is known, we must borrow from our knowledge about aging's effect on episodic metacognition and apply it to spatial working memory research. Studying metacognition with the current paradigm allows us to determine how older and younger adults differ in their metacognitive monitoring of spatial material. We predicted that like previous research (e.g., Bieman-Copland & Charness, 1994; Matvey et al., 2002), older adults would demonstrate deficient absolute and intact relative spatial metacognitive accuracy compared to younger adults.

Present Research

The goal of the present research was to investigate the relationship between location and identity memory, aging, and metacognitive monitoring using a visuospatial-working memory paradigm. Specifically, we examined whether spatial location within our paradigm suggests an automatic process (Hasher & Zacks, 1979; Lovelace, & Southall, 1983; Rothkopf, 1971). We also investigated the role of strategies based on knowledge of to-be-tested material. In addition, we examined the basis for errors made on questions assessing both identity and location in combination. Specifically, are these errors driven by a failure to remember object features, or a failure to properly bind object identities and their respective locations? Lastly, we investigated age-differences in these areas. Age-related spatial memory and metacognitive differences (or lack there of) may inform strategies promoting spatial learning in later life.

As a secondary goal, we examined the role of metacognition on location and identity memory. As discussed above, we know relatively little about metacognition in spatial memory. We can, however, apply what is known about metacognitive monitoring in episodic memory and make spatial working memory predictions. For instance, research into verbal episodic metacognition has demonstrated that compared to younger adults, older adults are generally impaired in their absolute metacognitive accuracy. In contrast, older adults' relative metacognitive accuracy is generally spared. As such, we predicted older adults' absolute spatial metacognitive accuracy would be impaired (Bieman-Copland & Charness, 1994; Matvey et al., 2002). Specifically, older adults deficient use of cues when making metacognitive judgments may adversely affect their absolute metacognitive accuracy, especially for location information. As location information is hypothesized to be automatically processed, older adults may be unaware of the effectiveness of location based cues; thus impairing absolute metacognitive monitoring.

In three experiments older and younger adults studied objects in a 5x5 grid. After studying each grid, participants made Judgments of Learning (JOLs) and completed a yes-no recognition test assessing object identities, locations, or both in combination. In Experiment 1, participants attended to specific grid information (i.e., identities, locations, or both). In Experiment 2, we examined the role of strategies and prior knowledge by not informing participants of what information would be tested. From these experiments, we discuss whether spatial location within our paradigm suggests automatic processing. In Experiment 3, we examined whether errors made on questions assessing combined identity *and* location memory were driven by a feature binding deficit (i.e., bind identities to their respective locations) or simply a failure to remember individual object features (i.e., identity or location). Given the findings on location memory, combination errors seem unlikely to be based primarily on location memory failures. As all experiments collected metacognitive judgments, we were able to assess location and identity metamemory throughout the project‘s entirety.

In sum, this project sought to investigate five main research questions:

1. How does normal aging interact with memory for identity and location information?
2. What role do strategies and prior knowledge of to-be-tested material play in identity, location, and identity-location combination memory?
3. Does spatial location within our paradigm suggest automatic encoding?
4. Are errors made on questions assessing combined information (i.e., identity and location) driven by a feature memory failure or a binding failure? Moreover, is the basis of these errors the same for both age groups?
5. How does metacognitive accuracy interact with identity and location memory?

General Methods

We conducted three studies investigating how individuals process identity and location information. As all experiments use the same general methods, we begin by describing them.

Participants

The younger adults consisted of Tufts undergraduates (18 to 26 years) participating either to partially fulfill a course requirement, or for monetary compensation. The older adults (60+ years) consisted of volunteers recruited from a previously established older adult participant pool, and received monetary compensation. Every attempt was made to equally represent both genders and all major ethnic/racial backgrounds.

Apparatus & Laboratory

All experiments were conducted in either the Spatial Cognition Laboratory or the Cognitive Aging and Memory Laboratory at Tufts University. We administered the experiments on a standard personal computer running the Mac operating system (OSX) using the SuperLab (version 4.0.7b) software program.

Design

Unless otherwise noted, we used a 2 (Age: *Older adults, Younger adults*) X 3 (Question Type: *Identity*, *Location, Combination*) X 4 (Array Size: *2,3,4,5*) mixed factorial design, with question type and array size serving as within-participants variables, and age serving as a between-participant variable.

Materials

Grids. The to-be-studied spatial information consisted of 5x5 grids containing between two to five objects. Objects were drawn from a pool of twenty 2-D simple line drawings (Figure 1). Unless otherwise noted, 144 total grids were used: 36 2-object, 36 3-object, 36 4-object, and 36 5-object. We constructed grids so that the objects and corresponding locations were randomly chosen once certain constraints were imposed. For instance, the number of times we used an object or location was relatively equal. Out of 144 total grids (504 possible object identities and locations) each object was used between 24-28 times and each location was used between 18-21 times. In addition, any two objects could not be used together within the same grid more than five times. The same was true of locations. Moreover, an object could not be presented in the same location more than three times. Figure 2 displays a sample study grid.

Metacognitive Judgments. For each trial, participants were asked "How likely are you to remember _______ on this previous grid on an immediate test of memory?" Depending on the trial or experiment, the _____ was filled with either "the shapes", "the locations of shapes", or "the shapes and the locations of the shapes". We paired the question with a basic Likert scale ranging from 0 (*not likely at all*) to 9 (*extremely likely*).

Recognition Test. Unless otherwise noted, we assessed grid memory using a yes-no forced choice recognition test where 1/3 of the questions were previously studied (correct) and 2/3 were incorrect lures. In addition, 1/3 of the recognition questions assessed object identities (48), 1/3 assessed item locations (48), and 1/3 assessed both identities and locations (48). Items assessing object identities included the question "Was this shape presented in the previous grid?" paired with objects either studied (correct) or unstudied (incorrect lures) within the studied grid (Figure 2). Items assessing locations included the question "Was an object presented in this location in the previous grid?" The question was paired with an objectless grid with either a studied location (correct) or an unstudied location (incorrect lure) highlighted in red (Figure 2). Items assessing both identities and locations in combination included the question "Was this object presented in this location in the previous grid?" The question was paired with a grid containing either a studied object in a studied object location (correct) or the following incorrect lures: a studied object in an new unstudied location ("new-location/old-identity"), a studied object in a studied location ("old-location/old-identity"), a new unstudied object in an new unstudied location ("new-location/new-identity"), or a new unstudied object in a studied object location ("old-location/new-identity"; Figure 2).

Questionnaire. The questionnaire inquired about age, gender, amount of formal education, handedness, and immediate family member handedness. The questionnaire also asked whether participants prefer a verbal description or a map when getting travel directions. In addition, a 1 (*poor*) to 7 (*excellent*) Likert scale was included asking participants to rate their memories.

Procedure

During instruction, participants were told that they "will be presented with a series of displays containing various shapes in various locations within a grid. " We then asked participants to attend to either identities, locations, or both in combination depending on the condition or experiment. In addition, we told participants they would be asked to judge their ability to remember the grid information. Lastly, participants were instructed that they would be tested on the grid information. After instruction, participants completed a series of practice trials in which they studied practice grids of varying sizes, made corresponding JOLs, and answered recognition questions.

Every experimental trial used a similar 3-part procedure wherein after each grid was presented, the participant judged how well he or she thought they would remember the information. He or she then completed a yes-no recognition test. More specifically, for each trial a central fixation cross was presented for 500ms, followed by a study grid for a variable time period (500-3000ms) depending upon the age group or experiment. A mask and another fixation cross, both presented for 500ms, followed each grid. Next, we presented participants the Judgments of Learning (JOLs) where he or she judged how likely they were to remember the grid information on an immediate memory test. Lastly, participants completed the yes-no recognition test assessing their memories for specific studied grid features (i.e. identities, locations, or both in combination). After all grids were presented and subsequent testing was complete, we collected participants' general demographic information using the questionnaire.

Experiment 1a

How does normal aging interact with memory for identity and location information? How does metacognitive accuracy interact with identity and location memory? Does spatial location within our paradigm suggest automatic encoding?

Background and Predictions

Experiment 1a investigated whether spatial location is automatically encoded within the current paradigm. If spatial location automatically encoded (e.g., Hasher & Zacks, 1979; Lovelace, & Southall, 1983; Rothkopf, 1971), we would expect both older and younger adults to perform similarly for location, but not identity or combination trials. Specifically, we predicted both age groups would perform best when remembering location information alone, and that this benefit would not be affected by increasing array size.

In addition, Experiment 1a examined normal aging's effects on object feature memory. Numerous studies have demonstrated that older adults perform worse on working memory tasks compared to younger adults (e.g. see Craik & Jennings, 1992). For instance, age-related declines have been found in a variety of working memory tasks including those measuring computational (Salthouse, Mitchell, Skovronek, & Babcock, 1989; Salthouse & Babcock, 1991), verbal reasoning, and spatial (Salthouse et al., 1989) abilities. Accordingly, within our paradigm we predicted older adults' spatial working memory performance would suffer compared to younger adults. In particular, we expected age-differences in memory for more effortful material (i.e., identity and combination; Balota, Dolan, & Duchek, 2000; Rabinowitz, Craik, & Akerman, 1982). Lastly, as little research has been conducted examining spatial metacognitive monitoring, let alone the effects of age on spatial metacognitive judgments, we investigated the relationship between aging, spatial memory, and metacognitive accuracy in the current investigation. Similar to previous research (e.g., Bieman-Copland & Charness, 1994; Matvey et al., 2002), we predicted older adults would demonstrate deficient absolute and intact relative spatial metacognitive accuracy compared to younger adults, especially for automatically encoded location information. Moreover, like Schwartz (2006), we expected younger adults to demonstrate good absolute and relative accuracy for spatial material.

Methods

The methods were the same as the General Method with the following details:

Participants. Participants included 25 younger and 25 older adults. We dropped two participants' data, one younger and one older adult, from the analysis due to low recognition accuracy (i.e., more than 2 standard deviations below the mean). Fifteen female and 9 male younger adults (age range 18-26; $M = 21.3$, $SD = 2.2$) and 17 female and 7 male older adults (age range 66-84; $M = 74.0$, $SD = 6.3$) were included. Mean years of education were 15.2 ($SD = 1.6$) and 14.5 ($SD = 2.2$) for the younger and older adults respectively.

Design. We blocked trials by question type condition (i.e. identity, location, or combination), with trials randomized within each block. The order blocks were presented was counterbalanced. Dependent measures included recognition test accuracy, Judgments of Learning (JOLs), and prediction accuracy.

Procedure. Participants attended to either identities, locations, or both in combination depending on the experimental block they were completing. In addition, we also told participants they would make corresponding judgments about their ability to remember specific grid information (i.e. identities, locations, or both in combination). We also alerted them that they would be tested on the attended information. Lastly, participants were told that before each block they would be warned which trial type they were about to complete, in addition to being given trial specific instructions.

The study time for each grid differed between the two age groups in order to reduce floor and ceiling effects in older and younger adults respectively. Specifically, pilot testing revealed optimal performance levels with a presentation time of 500ms for younger adults and 3000ms for older adults. The metacognitive judgment (JOL) matched the attended information. For example, they judged their likelihood of remembering locations after paying attention to locations. The yes-no recognition test also matched the attended information (i.e. tested locations after attending to locations).

Results

Accuracy. Accuracy was evaluated by one 2 (Age: Older Adults, Younger Adults) X 3 (Question Type: Identity, Location, Combination) X 4 (Array Size: 2, 3, 4, 5) mixed-factor ANOVA. Table 1 displays older and younger adults' mean proportions of correctly recognized items). Sphericity was violated for the within-subjects interaction between question type and array size, thus the p values and degrees of freedom were adjusted in accordance with the Greenhouse–Geisser epsilon values. Analysis of recognition test accuracy yielded a main effect of array size, $F(3,138) = 60.02$, $MSe = .01$, $p < .001$; as the array size increased, participants made more recognition errors (*Means:* 2 = .90, 3 = .81, 4 = .77, & 5 = .76). We also found an interaction between age and array size, $F(3,138) = 2.88$, $MSe = .01$, $p < .05$. For the smallest and largest arrays (i.e., 2 and 5 items), younger adults (*Means:* 2 = .92, 5 = .79) were more accurate than older adults (*Means:* 2 = .88, 5 = .74). For the intermediate arrays (i.e., 3 and 4 items), younger adults recognition accuracy (*Means:* 3 = .81, 4 = .78) was equivalent to older adults (*Means:* 3 = .81, 4 = .76).

We also found a main effect of question type, $F(2,92) = 35.39$, $MSe = .01$, $p < .001$; participants made more errors on combination trials ($M = .76$) followed by identity trials ($M = .81$), and made the fewest errors on location trials ($M = .86$). An interaction between question type and age was also found, *F*(2,92) = 3.33, *MSe* = .01, p < .05. Older adults' combination trial recognition accuracy (*M* = .74) was worse than younger adults (*M* = .79). For identity and location trials however, older (*Means:* identity = .82, location = .84) and younger (*Means:* identity = .81, location = .87) adults produced statistically equivalent results, *t'*s < .1. In addition we found an interaction between question type and array size, *F*(4.83, 222.16) = 8.94, *MSe* = .01, p < .001, ε = .81; as the array size increased, participants made more errors on both identity (*Means:* 2 = .94, 3 = .80, 4 = .78, & 5 = .73) and combination trials (*Means:* 2 = .87, 3 = .77, 4 = .69, & 5 = .72). For location trials, errors remained relatively stable (*Means:* 2 = .89, 3 = .86, 4 = .84, & 5 = .84; Figure 3) as array size increased.

Judgments of Learning. Judgments of Learning (JOLs) were evaluated by one 2 (Age: Older Adults, Younger Adults) X 3 (Question Type: Identity, Location, Combination) X 4 (Array Size : 2, 3, 4, 5) mixed-factor ANOVA. Sphericity was violated for the within-subjects effects of question type, array size, and the interaction between array size and question type, thus we again adjusted p values and degrees of freedom in accordance with the Greenhouse–Geisser epsilon values. Table 2 displays older and younger adults' JOLs by question type and array size. Analysis of JOLs revealed a main effect of array size, *F*(1, 41, 64.64) = 158.30, *MSe* = 1.70, p < .001, ε = .47; participants' JOLs decreased as array size increased (*Means:* 2 = 6.95, 3 = 6.12, 4 = 5.34, & 5 = 4.81). An interaction between array size and age was also found, *F*(1, 41, 64.64) = 8.61, *MSe* = 1.70, p < .005, ε = .47. The difference between younger adults' JOLs (*Means:* 2 = 7.57, 3 = 6.50, 4 = 5.55, & 5 = 4.94) and older adults' JOLs (*Means:* 2 = 6.33, 3 = 5.75, 4 = 5.15, & 5 = 4.67) was greatest when array size was smaller (i.e., 2 or 3 items).

We also found a main effect of question type, *F*(1.7, 78.25) = 24.43, *MSe* = 2.24, p < .001, ε = .85; participants' JOLs were lowest for the combination trials (*M* = 5.24), and were highest for location and identity trials (*Means* =6.07 and 6.11 respectively). An interaction between question type and age was also found, $F(1, 7, 78.25) = 8.61$, $MSe = 2.24$, $p < .005$, $\varepsilon = .85$, whereby younger adults' JOLs were lowest for the combination trials ($M = 5.47$) followed by identity trials ($M = 6.21$), and were highest for location trials ($M = 6.74$). Older adults' JOLs on the other hand were lowest for the combination trials ($M = 5.00$) followed by location trials ($M = 5.41$), and were highest for identity trials ($M = 6.00$). We also found an interaction between question type and array size, $F(4.27, 196.38) = 21.84$, $MSe = .38$, $p < .001$, $\varepsilon = .71$. While identity (*Means:* 2 = 7.47, 3 = 6.60, 4 = 5.53, & 5 = 4.83) and combination (*Means:* 2 = 6.67, 3 = 5.42, 4 = 4.75, & 5 = 4.10) JOLs decreased steadily after 2 items, location JOLs (*Means:* 2 = 6.71, 3 = 6.35, 4 = 5.74, & 5 = 5.49) stayed relatively constant (Figure 4). Lastly, an interaction between question type, array size, and age was found, $F(4.27, 196.38) = 4.02$, $MSe = .38$, $p < .005$, $\varepsilon = .71$. Younger adults judged location trials higher than identity trials starting after 2 items. Conversely, older adults judged identity trials to be higher than location trials until 5 items where the judgments evened out.

Prediction Accuracy.

Relative Accuracy. We computed Goodman-Kruskal gamma correlations (Goodman and Kruskal 1954), a measure of relative metacognitive accuracy, between a participant's predictions (JOLs) and their actual recognition test performance. A gamma correlation was computed for each participant for each question type. These correlations were then averaged across participants. Gammas were evaluated by one 2 (Age: Older Adults, Younger Adults) X 3 (Question Type: Identity, Location, Combination) mixed-factor ANOVA. Table 3 displays older and younger adults' gamma correlations as a function of question type. As sphericity was violated for the within-subjects effect of question type, p values and degrees of freedom were adjusted in accordance with the Greenhouse–Geisser epsilon values. We found a main effect of question type, $F(1.74, 76.70) = 3.33$, $MSe = .14$, $p < .05$, $\varepsilon = .87$. Participants were better able to predict their future recognition performance on combination ($M = .39$) followed by identity ($M = .22$) trials. Participants were the least able to predict their recognition performance for location trials ($M = .19$). All gammas were significantly different than 0, *t*'s < .05. We found no other main effects or interactions, *Fs* < .1.

Absolute Accuracy. Calibration analyses were performed to evaluate participants' absolute metacognitive accuracy. Specifically, after converting JOLs to the same scale as recognition accuracy, both together were used as an additional repeated factor in a 2 (Age: Older Adults, Younger Adults) X 2 (Performance: Predicted Performance, Performance Accuracy) X 3 (Question Type: Identity, Location, Combination) mixed-factor ANOVA. Table 4 displays older and younger adults' scaled predicted and actual performance by question type. The analysis yielded a main effect of performance, $F(1, 46) = 3.84$, $MSe = .04$, $p < .001$; participants' predicted performance was lower overall ($M = .58$) than their actual performance ($M = .81$). We also found a main effect of question type, $F(2, 92) = 49.02$, $MSe = .01$, $p < .001$. Participants' average performance (collapsed across predicted and actual) was lower for combination ($M = .64$) and highest for identity ($M = .71$) and location ($M = .73$) trials. An interaction between question type and age quantified this finding, $F(2, 92) = 7.51$, $MSe = .01$, $p < .005$. Although both older and younger adults' performance was relatively equivalent for identity (*Means* = .71 and .72 respectively) and combination (*Means* = .62, and .67) trials, older adults' location performance ($M = .69$) was less than younger adults ($M = .77$; Figure 5).

We also found an interaction between question type and performance, $F(2, 92) = 4.29$, $MSe = .01$, $p < .05$; the difference between predicted and actual performance was the greatest for location (*Means:* predicted = .61, actual = .86) and combination (*Means:* predicted = .52, actual = .76) trials, and was least for identity trials (*Means:* predicted = .61, actual = .81). Moreover, a interaction between question type, performance, and age, $F(2, 92) = 5.46$, $MSe = .01$, $p < .01$, demonstrated that older adults were the most accurate at predicting future identity and combination performance, but were least accurate at predicting location performance. Younger adults on the other hand, were the most accurate for location and identity trials and least accurate for combination trials (Figure 5).

Discussion

Numerous studies have suggested spatial location may be automatically processed (e.g., Ellis, Katz, & Williams, 1987; Mandler et al., 1977; von Wright, Gebhard, & Karttunen, 1975). As such, in the current investigation we predicted participants would perform best when remembering only location information. We did indeed find an advantage for remembering location information alone for both older and younger adults. Further, while participants' identity and combined memory decreased with more objects to remember, location memory remained stable. Taken together these findings suggest that location information may be automatically encoded (Hasher & Zacks, 1979; Lovelace, & Southall, 1983; Rothkopf, 1971) within the current paradigm.

In addition, Experiment 1a investigated the effects of age on spatial metacognitive accuracy (relative and absolute), as no previous research has done so. We found no age-differences in relative metacognitive accuracy (Gammas). Specifically, both age groups were the most accurate at predicting future combination performance and least accurate at predicting location performance. When looking at absolute accuracy however, we see age-related changes in metacognitive monitoring. As predicted, older adults were best calibrated for identity and combination information, and least calibrated for location information (i.e., underestimating location). As location information is thought to be "automatic," older adults may have been unaware of location cues or their effectiveness; information important for absolute metacognitive accuracy. Younger adults' on the other hand, were better calibrated for location and identity and least calibrated for combination information (i.e., underestimating combination). Moreover, younger adults were better calibrated overall than older adults. Similar to previous research in verbal episodic memory (e.g., Bieman-Copland & Charness, 1994; Matvey et al., 2002), these results suggest that with spatial material younger adults have better overall absolute metacognitive accuracy than older adults. Unlike previous research, however, both groups are impaired in their relative metacognitive accuracy for spatial location.

While we found that younger adults remembered combination information better than older adults, we found no other age effects within the current paradigm. Specifically, we expected age-differences for both forms of effortful material (i.e., combination and identity), but found only older adults' combination memory to be deficient. These results are surprising as working memory deficits in older adults are well documented (e.g., see Craik & Jennings, 1992). The fact that older adults could view the grids longer than younger adults, may have contributed to this finding. We used different viewing times to avoid ceiling/floor effects, but this increased presentation may have attenuated any age effects. As such, Experiment 1b sought to address this possibility by matching grid study time between the two age groups.

Experiment 1b

Background and Predictions

Previous research has demonstrated that older adults generally perform worse on working memory tasks compared to younger adults (e.g., see Craik & Jennings, 1992). With the exception that younger adults performed better than older adults on the most difficult task of our working memory paradigm (i.e., combination trials), Experiment 1a's results did not support these previous findings (i.e., saw no effect of age on identity accuracy). One possible reason we did not find age effects may be due to the increased grid viewing time for older adults. Experiment 1b investigated this possibility by equating the grid presentation time between age groups. Experiment 1b also sought to replicate Experiment 1a accuracy and metacognitive findings to further support the idea of spatial location as being automatic.

Methods

The methods were the same as the General and Experiment 1a Methods with the following exceptions:

Participants. Participants included 25 young and 25 older adults. Two participants' data were dropped from the analysis, one younger and one older adult, due to low recognition accuracy (i.e., more than 2 standard deviations below the mean). Sixteen female and 8 male younger adults (age range 18-23; $M = 19.3$, $SD = 1.6$) and 18 female and 6 male older adults (age range 59-96; $M = 74.3$, $SD = 8.7$) were included. Mean years of education were 13.9 ($SD = 1.8$) and 15.0 ($SD = 2.5$) for the younger and older adults respectively.

Procedure. Experiment 1b's procedures were identical to Experiment 1a's procedures with the following exception: in Experiment 1b we presented each grid for 1500 ms for both younger and older adults.

Results

Accuracy. We analyzed recognition accuracy in the same manner as Experiment 1a (see Table 1 for older and younger adults' mean accuracy scores). Like Experiment 1a, the analysis of recognition accuracy in Experiment 1b yielded a main effect of array size, $F(3, 138) = 109.60$, *MSe* = .01, p < .001; participants made more recognition errors as the array size increased (*Means:* 2 = .89, 3 = .81, 4 = .77, & 5 = .72). We also found a main effect of question type, *F*(2, 92) = 52.82, *MSe* = .01, p < .001. Participants made more errors on combination trials (*M* = .73) followed by identity trials (*M* = .81), and made the fewest errors on location trials (*M* = .85). In addition we found an interaction between question type and array size, *F*(6, 276) = 11.75, *MSe* = .01, p < .001. Like Experiment 1a, Experiment 1b's participants made more errors on both identity (*Means:* 2 = .93, 3 = .79, 4 = .81, & 5 = .71) and combination trials (*Means:* 2 = .84, 3 = .79, 4 = .67, & 5 = .62) as the array size increased. For location trials on the other hand, participants error rate remained stable (*Means:* 2 = .90, 3 = .84, 4 = .83, & 5 = .84) with increasing array size.

Unlike Experiment 1a, we found a main effect of age in Experiment 1b, *F*(1,46) = 36.87, *MSe* = .01, p < .001; older adults made more recognition errors (*M* = .74) than younger adults (*M* = .86). We also found an interaction between question type, array size, and age, *F*(6, 276) = 5.04, *MSe* = .01, p < .001. While location and identity trials followed the same pattern for both older and younger adults, combination trial performance differed between the two age groups. In particular, younger and older adults' combination performance significantly differed for 2- [*t*(46) = -5.33, *p* < .001, critical alpha .0125], 3- [*t*(46) = -3.21, *p* < .005], and 4- [*t*(46) = -2.60, *p* = .012] item arrays, but not for 5-item arrays [*t*(46) = -1.35, *p* = .182]. We found no other main effects or interactions, *Fs* < .1.

Judgments of Learning. We analyzed JOLs in the same manner as Experiment 1a (see Table 2 for older and younger adults' mean JOLs). Sphericity was violated for the within-subjects effect of array size and the interaction between array size and question type, thus the p values and degrees of freedom were again adjusted using Greenhouse–Geisser epsilon values.

Like Experiment 1a, we found a main effect of array size, *F*(1.53,70.55) = 165.88, *MSe* = 1.46, p < .001, ε = .51; as array size increased, participants' JOLs decreased (*Means:* 2 = 7.05, 3 = 6.19, 4 = 5.22, & 5 = 5.06). We also found a marginally significant interaction between array size and age, *F*(1.53,70.55) = 3.01, *MSe* = 1.46, p = .069, ε = .51. Like Experiment 1a, the difference between younger adults (*Means:* 2 = 7.81, 3 = 6.87, 4 = 5.74, & 5 = 5.56) and older adults' JOLs (*Means:* 2 = 6.28, 3 = 5.52, 4 = 4.69, & 5 = 4.56) in Experiment 1b was greatest when array size was small (i.e., 2 or 3 items).

A main effect of question type was also found, *F*(2, 92) = 4.67, *MSe* = 1.98, p < .001; participants' JOLs were highest for identity and location trials (*Means* = 6.35 and 6.14 respectively) and lowest for combination trials (*M* = 5.14). We also found an interaction between question type and age, *F*(2,92) = 4.66, *MSe* = 1.98, p < .05. Younger adults' JOLs were highest for identity (*M* = 7.07) and location trials (*M* = 6.91), and lowest for combination trials (*M* = 5.51). Older adults' JOLs were highest for identity trials (*M* = 5.64) followed by location trials (*M* = 5.37), and lowest for the combination trials (*M* = 4.78). We also found an interaction between question type and array size, *F*(4.54, 208.62) = 22.56, *MSe* = .39, p < .005, ε = .75. Identity (*Means:* 2 = 7.66, 3 = 6.81, 4 = 5.83, & 5 = 5.12) and combination (*Means:* 2 = 6.60, 3 = 5.39, 4 = 4.08, & 5 = 4.51) JOLs decreased linearly after 2 items. Location JOLs (*Means:* 2 = 6.88, 3 = 6.39, 4 = 5.74, & 5 = 5.55) linearly decreased up until 4 items (all p's < .001), where they leveled off [*t*(47) = 2.31, *p* = .025, critical alpha .006]. In addition, we found an interaction among question type, array size, and age, *F*(4.54, 208.62) = 4.71, *MSe* = . 39, p < .005, ε = .75. Up until 5 items, both younger and older adults judged location and identity trials to be relatively equivalent. At 5 items however, younger adults' JOLs were higher for location than for identity trials [*t*(23) = -3.07, *p* < .01, critical alpha .025], while older adults continued to judge them equivalently [$t(23) = -.42$, $p = .68$, critical alpha .025]. Lastly, unlike Experiment 1a we found a main effect of age in Experiment 1b, $F(1, 46) = 8.01$, $MSe = 2.26$, $p < .01$; younger adults' JOLs ($M = 6.49$) were higher than older adults ($M = 5.26$).

Prediction Accuracy.

Relative Accuracy. We analyzed relative prediction accuracy in the same manner as Experiment 1a (See table 3 for mean gamma correlations). The analysis of relative accuracy (gamma correlations) yielded a main effect of question type, $F(2, 90) = 3.37$, $MSe = .11$, $p < .05$. Participants were better able to predict future identity recognition performance ($M = .41$), and were least able to predict location ($M = .26$) and combination ($M = .25$) performance. We also found main effect of age, $F(1, 45) = 8.69$, $MSe = .04$, $p < .01$; younger adults ($M = .39$) were more accurate in their predictions than older adults ($M = .23$). An interaction between question type and age was also found, $F(2, 90) = 3.79$, $MSe = .11$, $p < .05$. Older adults were the most accurate in their identity trial predictions ($M = .41$) followed by combination trials ($M = .18$), and were least accurate for location trials ($M = .08$). The location trial gamma however was not significantly different than 0 [$t(23) = 1.06$, $p = .31$]. Younger adults' relative prediction accuracy on the other hand was relatively equivalent for all question types (*Means:* identity = .41, location = .45, combination = .33)

Absolute Accuracy. We evaluated absolute metacognitive accuracy (calibration) in the same way as Experiment 1a (See Table 4 for mean predicted and actual performance). The analysis showed a main effect of performance, $F(1, 46) = 3.15$, $MSe = .04$, $p < .001$; both older and younger adults' predicted performance was lower ($M = .59$) than their actual recognition performance ($M = .80$) overall. We also found a main effect of age, $F(1, 46) = 27.73$, $MSe = .01$, $p < .001$; younger adults' collapsed average performance ($M = .75$) was better overall than older adults (*M* = .63). In addition, a main effect of question type was found, $F(2, 92) = 78.53$, MSe = .01, $p < .001$. Participants' collapsed combination trial performance was lower (*M* = .62) compared to identity (*M* = .72) and location (*M* = .73) . Moreover, an interaction between question type and age, $F(2, 92) = 7.51$, MSe = .01, $p < .005$, was found. Younger adults' collapsed identity and location trial performance (*Means* = .79 and .80 respectively) was higher than older adults (*Means* = .65, and .67); however, younger adults' combination trial performance (*M* = .67) was similar to older adults (*M* = .58; Figure 6).

We also found an interaction between performance and question type, $F(2, 92) = 5.95$, MSe = .01, $p < .005$. The difference between participants' actual and predicted recognition performance was the greatest for location (*Means:* predicted = .61, actual = .85) followed by combination (*Means:* predicted = .51, actual = .73) trials, and was least for identity trials (*Means:* predicted = .64, actual = .81). Lastly, a marginally significant interaction between question type, performance, and age was found, $F(2, 92) = 2.69$, MSe = .01, $p < .01$. Older adults' were least calibrated for location trials and best calibrated for identity and combination trials. Younger adults were the least calibrated for location and combination trials and the best calibrated for identity trials (Figure 6).

Discussion

Compared to younger adults, older adults are generally impaired on tasks requiring effortful processing (Balota, Dolan, & Duchek, 2000; Rabinowitz, Craik, & Akerman, 1982). Although Experiment 1a found that younger adults performed better on combination trials than older adults, it showed no age effects on identity recognition accuracy, most likely due to different grid viewing times. In Experiment 1b, we found that older adults performed worse than younger adults for identity, location, and combination trials. The fact that older adults performed worse than younger adults on location trials disputes Hasher and Zack's (1979) age-invariability criterion of an automatic process. Although, both older and younger adults made the fewest errors when recognizing location alone. Moreover, like Experiment 1a, increases in array size did not adversely affect participants' location performance. These latter findings support Hasher and Zack's (1979) conceptualization of an automatic process. Like the multitude of research on the automaticity of spatial location (e.g., Hasher & Zacks, 1979; Light & Zelinski, 1983; Mandler et al., 1977; Naveh-Benjamin, 1987), our results are mixed. They both support as well as refute the idea of spatial location as automatic. This suggests that location information may be less effortful (as opposed to automatic) compared to identity and combination information. This possibility will be discussed in greater detail within the General Discussion.

Equating grid viewing time also affected metacognitive accuracy. Specifically, in Experiment 1a, both age groups' relative location accuracy was impaired compared to identity and combination. When given additional study time in Experiment 1b (compared to Experiment 1a), younger adults' relative predictions were statistically equivalent for all information. Conversely, decreasing older adults' gird-viewing time did not affect their already impaired relative accuracy for location information. Specifically, like Experiment 1a, older adults' relative accuracy was best for identity and combination trials and worst for location trials. This suggests younger adults' relative metacognitive accuracy may be more sensitive to encoding time than older adults. Younger adults' absolute metacognitive accuracy was also affected by changes in grid study time. In Experiment 1a, we found that younger adults were best calibrated for location and identity information, while older adults were least calibrated for location. In Experiment 1b, both age groups were least calibrated for location information. Taken together, these results suggest that younger adults' relative and absolute accuracy for spatial location was sensitive to encoding time. Conversely, changes in study time did not affect older adults' already impaired absolute and relative location monitoring. These findings will be discussed in more detail in the General Discussion.

In Experiment 2, we investigate whether participants' strategies based on the knowledge of to-be- tested information affects predicted and actual recognition performance. Specifically, we examined whether eliminating the ability to strategically attend to specific grid information (i.e., identity, location, or both) influences the learning and metacognitive monitoring of spatial material.

Experiment 2

What role do strategies and prior knowledge of to-be-tested material play in identity, location, and identity-location combination memory?

Background/Predictions

Learning goals and strategies influence learning by changing the information people process. They activate relevant schemas (Pichert & Anderson, 1977), guide attention (e.g., Britton, Meyer, Simpson, Holdredge, & Curry, 1979; Brunyé & Taylor, 2009; LaBerge, 1995), and act as retrieval cues (Anderson & Pichert, 1978) during learning. Experiment 2 examined the role of strategies and prior knowledge of to-be-tested material on older and younger adults' visuospatial working memory. If location is automatically processed, as Experiment1 and previous research suggest (e.g., Hasher & Zacks, 1979; Lovelace, & Southall, 1983; Rothkopf, 1971; but see Naveh-Benjamin, 1987) then being unaware of when location information will be tested should not affect location memory. In contrast, more incidental encoding should adversely affect memory for the more effortfully processed identity and combination information (e.g., Hasher & Zacks, 1979). As such, we predicted that compared to identity and combination information, both older and younger adults would perform best on location only trials and that this benefit would be unaffected by array size.

Methods

The methods were the same as those previously described with the following exceptions:

Participants. Participants included 25 younger and 25 older adults. We dropped two participants' data, one younger and one older adult, from the analysis due to low recognition accuracy (i.e., more than 2 standard deviations below the mean). Twelve female and 12 male younger adults (age range 18-22; M = 19.9, SD = 1.2) and 14 female and 10 male older adults (age range 63-82; M = 74.1, SD = 5.6) were included. Mean years of education were 14.0 (SD =1.7) and 16.1 (SD =3.2) for the younger and older adults respectively.

Design. All experimental trials were randomized within 3 blocks. The presentation order of the randomized blocks was counterbalanced.

Procedure. Participants attended to both identity and location in combination for all trials. In addition, we also told participants to make judgments about their ability to remember the combination grid information (i.e. identity and location). Lastly, they were alerted that they would be tested on specific grid information (i.e. identities, locations, or both in combination). For Experiment 2, both age groups studied each grid for 1500ms. Like Experiment 1a and b, participants were tested on identity, location, and identity/location combined information; however, participants did not know when a specific question type would be tested. So as not to hint at the test question type, the metacognitive judgment always asked about both identity and location information.

Results

Accuracy. Recognition accuracy was analyzed in the same manner as Experiment 1 (see Table 1 for older and younger adults' mean accuracy scores). Sphericity was violated for within-subjects interaction between question type and array size, thus the p values and degrees of freedom were again adjusted using Greenhouse–Geisser epsilon values. Analysis of recognition accuracy yielded a main effect of array size, $F(3, 138) = 72.63$, $MSe = .01$, $p < .001$; as the array size increased, participants made more recognition errors (*Means:* 2 = .82, 3 = .74, 4 = .70, & 5 = .64). In addition, we found a main effect of question type, $F(2, 92) = 3.60$, $MSe = .03$, $p < .001$. Participants made the least errors on identity ($M = .74$) and location trials ($M = .74$), and made the most errors on combination trials ($M = .70$). We also found a main effect of age, $F(1,46) = 55.33$, $MSe = .04$, $p < .001$; older adults made more recognition errors ($M = .66$) than younger adults ($M = .78$). The analysis also yielded an interaction between question type and array size, $F(4.63,212.90) = 6.31$, $MSe = .02$, $p < .001, \varepsilon = .77$. Like the previous Experiments, as the array size increased participants made more errors on both identity (*Means:* 2 = .88, 3 = .73, 4 = .71, & 5 = .62) and combination trials (*Means:* 2 = .77, 3 = .76, 4 = .65, & 5 = .60; Figure 7). Conversely, after an initial dip in performance after 2 items, participants' location trial accuracy remained constant (*Means:* 2 = .83, 3 = .71, 4 = .74, & 5 = .69) as array size increased (t's < .1; Figure 5). We found no other main effects or interactions, *Fs* < .1.

Judgments of Learning. JOLs in Experiment 2 were evaluated by one 2 (Age: Older Adults, Younger Adults) X 4 (Array Size: 2, 3, 4, 5) mixed-factor ANOVA. As the JOLs in Experiment 2 inquired about combination information for all recognition question types (i.e., identity, location, and combination), question type was not used as a within-subjects factor in the analysis. Sphericity was violated for within-subjects effects of array size, thus we again adjusted p values and degrees of freedom using Greenhouse–Geisser epsilon values. The analysis yielded a main effect of array size, $F(1.25,57.57) = 64.31$, $MSe = 1.86$, $p < .001$, $\varepsilon = .42$. Participants' JOLs decreased (*Means:* 2 = 5.89, 3 = 4.87, 4 = 4.08, & 5 = 3.75) as the array size increased. A main effect of age was also found, $F(1,46) = 22.10$, $MSe = 7.73$, $p < .001$; older adults' JOLs ($M = 4.04$) were lower than younger adults ($M = 5.26$). We also found an interaction between array size and age, $F(1.25,57.57) = 4.15$, $MSe = 1.86$, $p < .05$, $\varepsilon = .42$. When array size was small (i.e., 2 or 3 items) the difference between younger adults (*Means:* 2 = 6.72, 3 = 5.57, 4 = 4.56, & 5 = 4.17) and older adults' JOLs (*Means:* 2 = 5.06, 3 = 4.17, 4 = 3.60, & 5 = 3.33) was greatest.

Prediction Accuracy.

Relative Accuracy. For Experiment 2, relative metacognitive accuracy was evaluated by computing an inter-participant gamma correlation for each array size condition. Gammas were then averaged across participants and evaluated by one 2 (Age: Older Adults, Younger Adults) X 4 (Array Size : 2, 3, 4, 5) mixed-factor ANOVA. Table 5 displays older and younger adults' mean Gamma correlations by array size. A main effect of array size was found, $F(3, 132) = 3.13$, $MSe = .17$, $p < .05$. Participants were better able to predict their future recognition performance for 3-Item arrays ($M = .27$), compared to 5- ($M = .03$) 4- ($M = .09$), and 2- ($M = .09$) item arrays. However, the gammas for 5-, 4-, and 2-item arrays were statistically equivalent to 0, *t*'s > .1. We found no other main effects or interactions, *Fs* < .1.

Absolute Accuracy. In Experiment 2, absolute metacognitive accuracy (calibration) was evaluated by using converted JOLs and recognition accuracy as an additional repeated factor in a 2 (Age: Older Adults, Younger Adults) X 2 (Performance: Predicted Performance, Performance Accuracy) X 4 (Array Size: 2, 3, 4, 5) mixed-factor ANOVA. Table 6 displays older and younger adults' scaled predicted and actual performance by array size. Sphericity was violated for within-subjects effects of array size as well as the interaction between array size and performance. Hence, we again adjusted p values and degrees of freedom using Greenhouse–Geisser epsilon values. We found a main effect of performance, $F(1, 46) = 4.92$, $MSe = .04$, $p < .001$;

participants' predicted performance was lower ($M = .50$) than their actual recognition performance ($M = .72$). A main effect of age was also found, $F(1, 46) = 49.06$, $MSe = .01$, $p < .001$; younger adults' collapsed performance ($M = .69$) was higher than older adults ($M = .53$). The analysis also yielded a main effect of array size, $F(1.60, 73.36) = 128.97$, $MSe = .01$, $p < .001$, $\varepsilon = .53$. Collapsed performance decreased with increasing array size (*Means: 2* =.73, =.63, *4* =.57, *5* =.52). This finding was quantified by a marginally significant interaction between array size and age, $F(1.60, 73.36) = 2.90$, $MSe = .01$, $p = .07$, $\varepsilon = .53$. The difference between younger (*Means:* 2 = .82, 3 = .71, 4 = .64, 5 = .58) and older adults' (*Means:* 2 = .64, 3 = .55, 4 = .50, 5 = .46) collapsed performance decreased as array size increased. We also found an interaction between performance and array size, $F(1.84, 84.85) = 3.55$, $MSe = .01$, $p < .05$, $\varepsilon = .62$. The difference between participants' actual (*Means:* 2 = .82, 3 = .74, 4 = .70, 5 = .64) and predicted (*Means:* 2 = .63, 3 = .52, 4 = .44, 5 = .40) recognition performance increased as array size increased. A marginally significant interaction between array size, performance, and age was also found, $F(1.84, 84.85) = 2.82$, $MSe = .01$, $p = .07$, $\varepsilon = .62$, demonstrating that the difference between older adults' predicted and actual performance predictions stayed relatively constant, while the difference between younger adults' predicted and actual performance increased as array size increased.

Discussion

Experiment 2 sought to test the possibility that strategic encoding influenced Experiment 1's results. Specifically, we sought to rule out the possibility that participants' knowledge of to-be-tested information contributed to the recognition and metacognitive accuracy. Participants still found combination trials the most difficult, showing the worst performance. Notably, we found that location memory was not overall superior to identity memory for either age group, unlike the previous experiments. We did see that like Experiment 1, location memory was less sensitive to array size, as after two items performance stayed relatively stable. Identity and combination memory on the other hand decreased as array size increased. Like Experiment 1b and previous research (e.g., Hasher & Zacks, 1979; Light & Zelinski, 1983; Mandler et al., 1977; Naveh-Benjamin, 1987), our results both support and refute the idea of spatial location as an automatic process. This further suggests spatial location may be less effortful as opposed to automatic.

Strategic processing also seemed to affect metacognitive accuracy. This is evident in that, unlike Experiment 1b, no age-differences were found in relative metacognitive accuracy. Specifically, older and younger adults did not differ in their relative predictions of future recognition performance. Conversely, younger adults were better calibrated (absolute accuracy) than older adults overall. Interestingly, younger adults' absolute accuracy decreased with increasing array size while older adults' remained constant. This suggests that although younger adults were overall better calibrated, older adults may have been more sensitive to cues for task difficulty, such as array size, when unable to strategically process grid information. This possibility will be discussed in greater detail within the General Discussion.

Experiment 3

Are errors made on questions assessing combined information (i.e., identity and location) driven by a feature memory failure or a binding failure? Moreover, is the basis of these errors the same for both age groups?

Background/Predictions

As the opening scenario highlights, one possible explanation proposed for episodic memory declines is a failure to combine elements into cohesive episodes. However, research investigating binding object features into cohesive episodes has produced contradictory findings; some investigations demonstrate general age related binding deficits (e.g., Chalfonte & Johnson, 1996; Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Cowan, Naveh-Benjamin, Kilib, & Saults, 2006) while others do not (e.g., Brockmole, Parra, Della Sala, & Logie, 2008). For instance, Chalfonte and Johnson (1996) found that after studying complex object arrays, older adults' memories for object location, as well as feature combinations (e.g., identity and location) were impaired compared to younger adults. Likewise, Naveh-Benjamin (2000) found older adults' performed worse on tests assessing both individual items (i.e., non-words) and item combinations (i.e., which items were studied together) after they studied unrelated word, non-word pairs. Naveh- Benjamin, Guez, Kilb, and Reedy (2004) also found that older adults performed worse on tests assessing item combinations using different stimuli (i.e., face-name pairs) and memory tests. Taken together, these findings demonstrate an age-related decline in remembering feature combinations in episodic memory.

Similar age-related deficits have also been investigated within working memory. For instance, Cowan et al. (2006) found older adults' performed significantly worse than younger adults when detecting whether two objects' colors had been swapped between study and test. Mitchell et al. (2000) also found similar results when comparing older and younger adults' memory for both individual features (i.e., object identities or locations) and feature combinations (i.e. object identity and locations). Specifically, older and younger adults attended to either object identities, locations, or both in combination while viewing a series of sequentially presented visual displays. They found that older adults were no worse than younger adults at recognizing individual features, but were impaired when recognizing feature combinations.

These results suggest that older adults are deficient in remembering object features in combination. The cause of these deficits however is unclear. Mitchell et al.'s (2000) investigation (discussed above) also found that when combination trial lures were composed of one studied and one unstudied feature (old-new), older adults performed better than when the lures were two studied features (old-old), suggesting a general binding deficit at encoding. Brockmole et al. (2008) however, found that older adults' change detection performance on combination trials may have been dependent upon identity memory and not on binding. Specifically, older adults' performance for object color was superior to object identity. Older adults' identity-color combination performance, however, was equivalent to their identity performance, suggesting an identity memory failure. Although identity memory was overall superior to combination memory in the current investigation, similar recognition patterns were seen for both identity and combination trials. Namely, with increasing array size, both identity and combination recognition performance decreased while location memory did not. These findings suggest that identity memory may contribute to combination performance.

Experiment 3 furthered this research by examining whether the decreased combination trial performance in Experiments 1 and 2 was driven by impaired identity memory or a failure to correctly bind identities to their respective locations. Furthermore, we investigated whether this decrement's basis was the same for both age groups. In particular, in a similar manner as Mitchell et al. (2000), we used different lure types to examine whether errors are truly due to a binding deficit or an identity memory deficit. We examined binding failures by comparing false alarms on "old-location/old–identity" lures with "new–location/old-identity" as well as "old–location/new-identity" lures. Increased "old–location/old–identity" false alarms would demonstrate that participants have both identity and location memory, but did not properly bind them.

Unlike Mitchell et al. (2000), we also included a lure condition where both the object identity and the location were unstudied or new (i.e., "new-location/new-identity"). Hence, we were able to examine the role of object identity or location alone on combination trial performance. Increased "old/new" lure ("new-location/old-identity", "old-location/new-identity") false alarms compared to "new/new" trials would signify a feature memory breakdown, as participants would be unable to distinguish a studied "old" identity or location from an unstudied "new" one. For instance, increased "new-location/old-identity" lure false alarms would suggest participants remember a presented identity, but are unsure about the corresponding location. Likewise, increased "old-location/new-identity" lure false alarms would suggest participants remember a presented location, but are unsure about the corresponding identity. Like Brockmole et al. (2008), we predicted that older adults' performance would be dependent on feature memory and not feature binding.

Methods

The methods were identical to the General and previous experiment's methods with the following exceptions:

Participants. Participants included 25 Young and 25 older adults. Three participants' data were dropped from the analysis, one younger and two older adults, due to high or low recognition accuracy (i.e., more than 2 standard deviations above or below the mean). Twelve female and 12 male younger adults (age range 19-24; M = 20/4, SD = 1.4) and 16 female and 7 male older adults (age range 67-90; M = 75.7, SD = 3.0) were included. Mean years of education were 15.0 (SD =1.4) and 15.5 (SD =3.0) for the younger and older adults respectively.

Materials.

Grids. 156 total grids were used: 39 2-object, 39 3-object, 39 4-object, and 39 5-object. Grids were constructed very similarly to those outlined in the General Methods section. For instance, the number of times we used an object or location was relatively equal. Out of 156 total grids (546 possible object identities and locations) each object was used between 24-31 times and each location was used between 20-24 times. Like previous grids, any two objects or locations could not be used together within the same grid more than five times. Likewise, an object could not be presented in the same location more than three times.

Recognition Test. Twenty-four of the recognition questions assessed object identities, 24 assessed item locations, and 108 assessed both identities and locations in combination. Half of the identity recognition questions were previously studied (correct) items (12), and 1/2 were incorrect lures (12). The same was true for location recognition questions. For combination questions, 1/3 were previously studied (correct; 36) and 2/3 were incorrect lures (72).

Design. We only evaluated combination trial performance. Specifically, combination accuracy was evaluated with one 2 (Age: Older Adults, Younger Adults) X 4 (Array Size: 2, 3, 4, 5) mixed repeated measures ANOVA. Combination errors were evaluated with a 2 (Age: Older Adults, Younger Adults) X 4 (Lure type: “Old-Location/Old-Identity”, “Old-Location-New-Identity”, “New-Location/Old-Identity”, “New-Location/New-Identity”) mixed repeated measures ANOVA.

Procedure. The procedures for Experiment 3 were identical as Experiment 2.

Results

Accuracy. Experiment 3’s methods outline how combination trial recognition accuracy was evaluated. Sphericity was violated for the within-subjects effect of array size, thus we adjusted p values and degrees of freedom using Greenhouse–Geisser epsilon values. Analysis of combination recognition accuracy yielded a main effect of array size, $F(2.16, 97.34) = 64.99$, $MSe = .01$, $p < .001$, $\varepsilon = .72$; as the array size increased, participants made more combination errors (*Means:* 2 = .80, 3 = .74, 4 = .68, & 5 = .56). We also found a main effect of age, $F(1,45) = 38.36$, $MSe = .01$, $p < .001$; older adults ($M = .64$) made more combination errors than younger adults ($M = .75$). In addition, an interaction between age and array size was also found, $F(2.16, 97.34) = 5.89$, $MSe = .01$, $p < .005$, $\varepsilon = .72$. The difference between younger adults' combination performance (*Means:* 2 = .88, 3 = .81, 4 = .71, 5 = .58) and older adults' performance (*Means:* 2 = .71, 3 = .66, 4 = .64, 5 = .54) was greatest when array size was smaller (i.e., 2 and 3 items).

Combination Trial Errors. Experiment 3's methods describe how combination errors were evaluated. Sphericity was violated for the within-subjects effect of lure type, thus the p values and degrees of freedom were again adjusted in accordance with the Greenhouse–Geisser epsilon values. Table 7 displays older and younger adults' mean error rates for the four lure types. Analysis of combination trial errors revealed a main effect of age, $F(1,45) = 42.80$, $MSe = .01$, $p < .001$; older adults made more combination errors ($M = .29$) than younger adults ($M = .13$). We also found a main effect of lure type, $F(2.36, 106.12) = 66.82$, $MSe = .02$, $p < .001$, $\varepsilon = .79$; participants made the most combination errors on "old-location/old-identity" trials ($M = .35$) followed by "new-location/old-identity" trials ($M = .27$) and "old-location/new-identity" trials ($M = .15$), and made the least errors on "new-location/new-identity" trials ($M = .07$). Simple contrasts demonstrate that participants made more errors on "old-location/old-identity" trials than "new-location/old-identity trials" [$F(1, 45) = 11.10$, $MSe = .03$, $p < .005$], "old-location/new-identity" trials [$F(1, 45) = 58.90$, $MSe = .03$, $p < .001$], and "new-location/new-identity" trials [$F(1, 45) = 167.37$, $MSe = .02$, $p < .001$]. In addition, an interaction between age and lure type was found, $F(2.36,106.12) = 4.08$, $MSe = .01$, $p < .05$, $\varepsilon = .79$. This interaction was supported through several paired sample t-tests using the Bonferroni correction (2 tests, critical alpha .025). Older adults made more errors on "old-location/new-identity" compared to "new-location/new-identity" trials [$t(22) = 4.85$, $p < .001$] while younger adults did not [$t(22) = 2.10$, $p = .047$].

Judgments of Learning. Combination trial JOLs in Experiment 3 were evaluated by one 2 (Age: Older Adults, Younger Adults) X 4 (Array Size: 2, 3, 4, 5) mixed-factor ANOVA. Sphericity was violated for the within-subjects effect of array size; hence we again adjusted p values and degrees of freedom using Greenhouse–Geisser epsilon values. We found a main effect of array size, $F(1.65,74.18) = 81.48$, $MSe = 1.05$, $p < .001$, $\varepsilon = .55$. As the array size increased, participants' JOLs decreased from 2 to 4 Item arrays (*Means:* 2 = 6.08, 3 = 5.19, & 4 = 3.81), but then increased at 5-Items (5 = 4.28). A main effect of age was also found, $F(1,45) = 20.30$, $MSe = 2.67$, $p < .001$; older adults' combination JOLs ($M = 3.74$) were lower than younger adults ($M = 5.89$). We also found an interaction between array size and age, $F(1.65,74.18) = 5.58$, $MSe = 1.05$, $p < .001$, $\varepsilon = .55$. The difference between younger (*Means:* 2 = 7.35, 3 = 6.40, 4 = 4.52, & 5 = 5.30) and older adults' (*Means:* 2 = 4.75, 3 = 3.93, 4 = 3.06, & 5 = 3.23) JOLs was greatest when array size was small (i.e., 2 or 3 items).

Prediction Accuracy.

Relative Accuracy. For Experiment 3, an inter-participant gamma correlation was computed for each array size condition for combination trials only. Gammas were then averaged across participants and evaluated by one 2 (Age: Older Adults, Younger Adults) X 4 (Array Size: 2, 3, 4, 5) mixed-factor ANOVA (See table 5 for older and younger adults' mean gamma correlations by array size). Sphericity was violated for the within-subjects effect of array size, thus p values and degrees of freedom were adjusted. We found an interaction between array size and age, $F(2.15, 96.9) = 3.59$, $MSe = .26$, $p < .05$, $\varepsilon = .72$. Younger adults predictions were only accurate for 4-item arrays, as the gamma for other array sizes (i.e., 2, 3, and 5) were not significantly different from 0. In addition, none of the older adults' gamma correlations significantly differed from 0. We found no other main effects or interactions, *Fs* $< .1$.

Absolute Accuracy. Absolute metacognitive accuracy (combination trials only) was evaluated in the same manner as Experiment 2 (See Table 6 for predicted and actual recognition performance). Sphericity was violated for the interaction between array size and performance; thus, we adjusted p values and degrees of freedom using Greenhouse–Geisser epsilon values. The analysis yielded a main effect of performance, $F(1, 45) = 111.29$, $MSe = .05$, $p < .001$; participants' predicted performance was lower ($M = .47$) than their actual recognition performance ($M = .71$) on combination trials. We also found a main effect of age, $F(1, 45) = 64.78$, $MSe = .01$, $p < .001$; younger adults' collapsed performance ($M = .68$) was higher on combination trials than older adults ($M = .49$). Moreover an interaction between age and performance was found, $F(1, 45) = 4.24$, $MSe = .05$, $p < .05$. The difference between predicted and actual recognition performance was greater in older (*Means:* predicted = .34, actual = .64) than younger (*Means:* predicted = .58, actual = .78) adults. The analysis also yielded a main effect of array size, $F(3,135) = 111.80$, $MSe = .01$, $p < .001$. Participants' collapsed combination trial performance decreased with increasing array size (*Means: 2* =.71, *3* =.61, *4* =.53, *5* =.50).

An interaction between array size and age was also found, $F(3, 135) = 8.54$, $MSe = .01$, $p < .001$; the difference between younger (*Means:* 2 = .84, 3 = .71, 4 = .62, 5 = .57) and older adults (*Means:* 2 = .58, 3 = .51, 4 = .43, 5 = .43) collapsed performance decreased as array size increased. The analysis also showed an interaction between performance and array size, $F(2.21, 99.64) = 8.90$, $MSe = .01$, $p < .001$, $\varepsilon = .74$. The difference between participants' actual (*Means:*

2 = .82, 3 = .74, 4 = .70, 5 = .64) and predicted (*Means:* 2 = .63, 3 = .52, 4 = .44, 5 = .40) recognition performance was greatest at larger array sizes (i.e., 4 and 5 items). Lastly, an interaction between array size, performance, and age was found, $F(2.21, 99.64) = 5.10$, $MSe = .01$, $p < .01$, $\varepsilon = .74$. The difference between older adults' predicted and actual performance predictions stayed relatively constant across array size. The difference between younger adults' predicted and actual performance on the other hand, was lower for smaller arrays (i.e., 2 and 4 items) and greater for larger arrays (i.e., 4 and 5 items).

Discussion

Research investigating the cause of impaired feature combination memory is often at odds. Some investigations have attributed these errors to age-related deficits in binding (e.g., Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Cowan, Naveh-Benjamin, Kilib, & Saults, 2006), while others have implicated feature memory failures in erroneous combination performance (e.g., Brockmole, Parra, Della Sala, & Logie, 2008). In Experiment 3, we furthered this research by examining the basis of decreased recognition performance on identity-location combinations when participants were not strategically attending to specific grid information. Like Mitchell et al. (2000), we found that older adults had difficulty binding identity and location information into cohesive wholes. Specifically, older adults made more combination errors on "old-location/old-identity" trials. Increased "old-location/old-identity" false alarms suggest that older adults had both identity and location memory, but had difficulty properly binding them.

Although less likely to make combination errors than older adults, younger adults also demonstrated a deficit in binding object features. Specifically, like older adults, younger adults made the most errors on "old-location/old-identity" trials. In addition, compared to "new-new" trials, older adults made significantly more errors on "old-location/new-identity" trials. Older adults' increased "old-location/new-identity" false alarms suggest they remembered a presented location, but failed to remember the corresponding identity. Taken together these findings demonstrate that older adults' combination memory was disrupted by failures in feature binding (e.g., Mitchell et al., 2000) and to a lesser extent identity memory (e.g., Brockmole et al., 2008).

In addition, both older and younger adults were impaired in their relative metacognitive accuracy for combination information. In terms of absolute accuracy, younger adults were overall better calibrated than older adults. Moreover, like Experiment 2, older adults' absolute accuracy stayed constant with increasing array size, while younger adults' accuracy decreased. These results add further support for the idea that the absence of strategic processing may lead to greater sensitivity for cues of task difficulty in older adults.

General Discussion

Location as Automatic

Previous research has suggested that spatial location may be automatically encoded (e.g., Ellis, Katz, & Williams, 1987; Mandler et al., 1977; von Wright, Gebhard, & Karttunen, 1975). This project examined whether spatial location could be considered "automatic" within a novel visuo-spatial working memory task where spatial location and identity memory were separated. This included examining the use of strategies based on the knowledge of to-be-tested information. Ideally, if location information is automatically encoded, it should be unaffected by changes in learning intentionality. Specifically, location performance should be equivalent whether or not participants specifically attend to location during encoding. As such, we predicted that if location information were automatically processed, both older and younger adults would perform best on location only trials, regardless of array size or encoding strategies. Our results, however, were mixed. When instructed to strategically attend to specific grid information

(Experiment 1), we found location memory to be overall superior to identity and combined memory. Moreover, spatial location was less sensitive to array size compared to identity and combined information for both age groups (Experiments 1 and 2). These results support the idea that location information may be automatically encoded (Hasher & Zacks, 1979; Lovelace, & Southall, 1983; Rothkopf, 1971). In contrast with Hasher and Zacks' (1979) conceptualization of an automatic process, we also found that younger adults outperformed older adults overall when study time was equated (Experiment 1b and 2) regardless of encoding strategy. According to Hasher and Zacks' (1979) criteria, age should not affect automatic processing; however, our results suggest older adults may need more time than younger adults to successfully process spatial information, including location. In addition, when participants attended to all grid information simultaneously (Experiment 2), location memory was no better overall than identity memory. This suggests that different encoding strategies affect location memory, disputing its classification as automatic.

In an effort to unite the contrasting research on the topic (e.g., Ellis, Katz, & Williams, 1987; Light & Zelinski, 1983; Mandler et al., 1977; Naveh-Benjamin, 1987), Naveh-Benjamin (1987) suggested that spatial location might fall within a continuum between "automatic" and "effortful" processing, as opposed to within a discrete "automatic" category. Compared to more effortful material, spatial location may be considered less-effortfully processed instead of "automatic." A second potential explanation for these contradictory findings (including our own) is that spatial location learning may involve multiple processes, only some of which are automatic (Naveh-Benjamin, 1987). A manipulation such as encoding strategy may only affect location-based processes that are more effortful. Moreover, tasks assessing location performance, may measure all of location's processes, regardless of automaticity. Further research is needed to differentiate between these two hypotheses. In addition, future research is needed to rule out the possibility that participants attended to specific grid features despite instruction to learn all information. Attending to all grid information is inevitably a more difficult task than attending to specific features. As such, participants may have engaged knowingly or unknowingly in strategies aimed at remembering specific features as opposed to feature combinations. If this were the case however, we would have expected to obtain similar results to Experiment 1 in Experiment 2, when participants were told to attend to grid features. Nonetheless, future work is needed to further rule out this possibility.

Failures in Feature Memory and Binding

Experiment 3 sought to examine the basis for the decreased feature combination memory seen in Experiments 1 and 2. Previous research investigating impaired feature combination memory is mixed with some investigations attributing errors to binding deficits (e.g., Mitchell, Johnson, Raye, Mather, & D'Esposito, 2000; Cowan, Naveh-Benjamin, Kilib, & Saults, 2006), and others implicating feature memory failures (e.g., Brockmole, Parra, Della Sala, & Logie, 2008). Specifically, Mitchell et al. (2000) found a general binding deficit at encoding in older adults. Brockmole et al. (2008) on the other hand, found that older adults' demonstrated an identity memory failure. We predicted that similar to Brockmole et al. (2008), older adults' combination performance would be dependent on feature memory and not feature binding. In contrast to this hypothesis, we found that like Mitchell et al. (2000), the majority of older adults' errors were due to deficient identity and location binding. However, like Brockmole et al. (2008), older adults were also impaired in their identity memory. Specifically, on a significant proportion of the trials, older adults remembered a presented location, but failed to remember the corresponding identity. Subsequent preliminary analyses of older adults' error latencies further suggest identity memory's role in combination errors. Specifically, when location was old (*Means:* "old-location/old-identity" = 3576.01, "old-location/new–identity" = 3555.43) older adults took approximately 400 – 500 ms longer to false alarm than when location was new (*Means:* "new-location/old-identity" = 3068.33, "new-location/new-identity" = 3165.87). This suggests that older adults were taking more time deciphering whether a given identity was studied or not. Moreover, this increased decision time did not resolve the identity confusion, as recognition performance did not improve. Younger adults' combination errors on the other hand only reflected feature binding errors, although they made far fewer combination errors overall than older adults. These findings suggest that both feature binding failures (Mitchell et al., 2000) and identity memory failures (Brockmole et al., 2008) contribute to older adults' poor combination memory. Additional research would be useful in order to further parse the respective contributions of identity memory and binding for combination memory.

Metacognitive Monitoring of Spatial Location.

These studies also sought to investigate metacognitive accuracy for spatial material, as only one previous study has done so. We predicted that older adults' deficient cue use when predicting future performance (e.g., Bieman-Copland & Charness, 1994; Matvey et al., 2002) would negatively affect their absolute metacognitive accuracy for "automatic" location information. In support of this hypothesis, we indeed found that in Experiment 1, older adults' absolute metacognitive accuracy was impaired for location information. One possible explanation for this finding is that older adults may have been unaware of the effectiveness of cues from location information. Specifically older adults may not have realized that location information requires less effortful processing; thus impairing absolute metacognitive accuracy. Interestingly, younger adults also demonstrated a decline in absolute accuracy for location information in Experiment 1b. This finding may be due to the additional study time younger adults were given in this experiment. Previous research (e.g., Koriat, 1997; Koriat, Sheffer, & Ma'ayan, 2002; Meeter & Nelson, 2003) has shown that when the number of study trials were increased, participants underestimated their future recall overall (i.e., absolute accuracy); however, participants' ability to predict which items would be recalled (i.e., relative accuracy) was improved or unaffected. According to Koriat (1997), this "Underconfidence-with-Practice" effect is due to participants' basing JOLs on intrinsic (i.e., item difficulty) rather than extrinsic cues (i.e. more study trials). In the current investigation, increasing younger adults' study time may have caused underconfidence for less effortfully processed location information based on incorrect perceived item difficulty.

When not strategically attending to grid information (Experiment 2 and 3), absolute accuracy for younger adults deceased with more items to remember. Older adults' absolute accuracy on the other hand, remained relatively constant. These findings suggest that the inability to strategically process grid information may increase older adults' sensitivity to cues for task difficulty (i.e., array size increases). These findings also suggest that older adults may be using general knowledge or expectations about the task to cue metacognition. Specifically, metacognitive judgments may have been driven by the idea that larger array sizes should be more difficult to remember (i.e., theory-based metacognition; Kelley & Jacoby, 1996; Koriat & Levy-Sadot, 1999.)

In addition, in Experiment 1b age-related differences in relative metacognitive accuracy were found for spatial location. This is surprising given the extensive previous episodic research demonstrating no age differences for relative accuracy measures (e.g., Bieman-Copland & Charness, 1994; Matvey et al., 2002). One potential explanation for this finding relates to the importance of recollecting contextual information for relative metacognitive accuracy. Daniels, Toth, and Hertzog (2009) found age differences in relative accuracy when participants recollected contextual information at test. Similarly, Thomas, Bulevich, and Dubois (in press) also found the recollection of contextual information to be crucial for older adults' relative accuracy. Specifically, Thomas et al., (in press) found age-differences in relative accuracy when participants retrieved contextual "partial" information after making metacognitive judgments. When the retrieval of contextual information was made prior to metacognitive judgments, however, these age-differences diminished. Dunlosky, Rawson, and Middleton (2005) also found that the recall of specific information prior to making metacognitive judgments improved relative accuracy. These findings suggest that metacognitive judgments are based on the information accessed prior to making metacognitive judgments (i.e., Accessibility Hypothesis; Koriat, 1993, 1995). In the current investigation, older adults' may not have sufficiently recollected location information before making JOLs, and thus their relative metacognitive accuracy suffered. Future research is needed to further test this hypothesis.

Conclusion

The present research sought to investigate the relationship between location and identity memory, aging, and metacognitive monitoring using a visuospatial-working memory paradigm. We found that location memory was less sensitive to increasing array size regardless of encoding strategies. Identity and combination memory on the other hand, were differentially affected by the strategies used during learning. These results support the idea that location is less effortfully processed compared to identity or combination information (e.g., Hasher & Zacks, 1979). Older and younger adults metacognitive monitoring also differed depending on strategy use, with younger adults being better calibrated for location information when using strategic processing.

When not attending to specific grid information, older adults may have utilized cues to task difficulty to improve absolute metacognitive accuracy.

This research also sought to examine the basis for poor feature combination memory in the current paradigm. We found that for both older and younger adults, impaired identity-location combination memory was due to deficient feature binding, and to a lesser extent feature memory. Specifically, feature-binding failures contributed to the most to both age groups' errors; however, age-differences were found in feature memory's role on impaired combination memory. These results demonstrate age differences in identity and combination memory, as well as metacognitive monitoring as a function of encoding strategies. This research contributes to the lacking literature regarding strategy use in visuo-spatial working memory as well as metacognition for spatial material.

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Table 1. *Experiment 1a - 2 Means and Standard Deviations for the proportion of items correctly recognized by Age, Question Type, and Array Size.*

			Array Size							
			2		3		4		5	
Exp	Age	Question Type	M	SD	M	SD	M	SD	M	SD
Exp 1a	Older Adults	Object	.93	.07	.81	.07	.78	.13	.73	.13
		Location	.87	.10	.85	.08	.84	.10	.81	.09
		Combo	.84	.13	.78	.12	.65	.17	.67	.11
	Younger Adults	Object	.95	.05	.78	.09	.78	.16	.73	.11
		Location	.90	.11	.88	.11	.84	.10	.87	.09
		Combo	.91	.10	.76	.15	.73	.11	.76	.08
Exp 1b	Older Adults	Object	.89	.11	.73	.16	.70	.12	.65	.15
		Location	.86	.13	.77	.11	.78	.12	.76	.12
		Combo	.74	.17	.73	.14	.63	.14	.60	.14
	Younger Adults	Object	.98	.04	.84	.10	.92	.09	.78	.09
		Location	.94	.09	.91	.10	.88	.09	.89	.08
		Combo	.93	.06	.85	.11	.72	.09	.64	.09
Exp 2	Older Adults	Object	.84	.14	.70	.12	.64	.12	.60	.12
		Location	.77	.14	.63	.16	.66	.08	.61	.15
		Combo	.69	.15	.70	.14	.60	.17	.54	.19
	Younger Adults	Object	.91	.11	.76	.12	.78	.14	.65	.15
		Location	.88	.09	.80	.13	.81	.09	.76	.15
		Combo	.85	.11	.83	.14	.71	.11	.66	.12

Table 2. *Experiments 1a and 1b Judgment of Learning Means and Standard Deviations for Older and Younger Adults by Question Type and Array Size.*

			Array Size							
			2		3		4		5	
Exp	Age	Question Type	M	SD	M	SD	M	SD	M	SD
Exp 1a	Older Adults	Object	7.02	2.28	6.41	2.34	5.56	2.20	5.02	2.14
		Location	5.98	2.43	5.63	2.53	5.08	2.55	4.94	2.47
		Combo	5.98	2.38	5.20	2.37	4.78	2.22	4.05	2.09
	Younger Adults	Object	7.92	1.33	6.79	1.56	5.50	1.17	4.64	1.39
		Location	7.44	1.45	7.07	1.50	6.41	1.62	6.03	1.78
		Combo	7.36	1.66	5.64	1.62	4.73	1.34	4.16	1.15
Exp 1b	Older Adults	Object	6.92	1.98	5.95	2.04	5.04	1.91	4.66	1.94
		Location	6.06	2.16	5.62	2.11	5.05	2.02	4.76	2.14
		Combo	5.88	2.42	4.99	2.13	3.98	2.07	4.26	1.91
	Younger Adults	Object	8.41	0.76	7.67	1.12	6.61	1.09	5.58	1.34
		Location	7.70	1.10	7.16	1.18	6.44	1.36	6.33	1.36
		Combo	7.31	1.21	5.78	1.43	4.17	1.33	4.76	1.49

Table 3. *Experiments 1a and 1b Gamma correlation Means and Standard Deviations for Older and Younger Adults by Question Type.*

		Question Type					
		Identity		Location		Combo	
Exp	Age	M	SD	M	SD	M	SD
Exp 1a	Older Adults	.19	.28	.21	.46	.40	.32
	Younger Adults	.25	.33	.17	.48	.39	.22
Exp 1b	Older Adults	.42	.21	.08	.39	.18	.25
	Younger Adults	.41	.38	.45	.38	.33	.34

Table 4. *Experiments 1a and 1b Predicted and Actual Performance Means and Standard Deviations for Older and Younger Adults by Question Type.*

			Question Type					
			Identity		Location		Combo	
Exp	Age	Performance	M	SD	M	SD	M	SD
Exp 1a	Older Adults	Predicted	.60	.22	.54	.25	.50	.22
		Actual	.82	.05	.84	.06	.74	.09
	Younger Adults	Predicted	.62	.14	.67	.15	.55	.13
		Actual	.81	.08	.87	.09	.79	.07
Exp 1b	Older Adults	Predicted	.56	.19	.54	.21	.48	.21
		Actual	.74	.10	.79	.10	.67	.12
	Younger Adults	Predicted	.71	.09	.69	.12	.55	.12
		Actual	.88	.06	.91	.06	.78	.06

Table 5. *Experiments 2 and 3 Gamma correlation Means and Standard Deviations for Older and Younger Adults by Array Size.*

		Array Size							
		2		3		4		5	
Exp	Age	M	SD	M	SD	M	SD	M	SD
Exp 2	Older Adults	.06	.45	.23	.41	.04	.43	-.02	.42
	Younger Adults	.12	.56	.30	.40	.14	.31	.07	.29
Exp 3	Older Adults	.14	.45	.04	.36	.03	.41	-.11	.36
	Younger Adults	-.24	.70	.02	.42	.23	.35	.04	.23

Table 6. *Experiments 2 and 3 Predicted and Actual Performance Means and Standard Deviations for Older and Younger Adults by Array Size.*

			Array Size							
			2		3		4		5	
Exp	Age	Performance	M	SD	M	SD	M	SD	M	SD
Exp 2	Older Adults	Predicted	.51	.22	.42	.17	.36	.17	.33	.17
		Actual	.77	.09	.68	.08	.63	.08	.58	.07
	Younger Adults	Predicted	.76	.10	.63	.13	.52	.15	.47	.14
		Actual	.88	.07	.80	.07	.77	.08	.69	.09
Exp 3	Older Adults	Predicted	.44	.20	.30	.20	.28	.18	.28	.18
		Actual	.72	.13	.66	.11	.59	.10	.59	.09
	Younger Adults	Predicted	.76	.11	.65	.12	.48	.12	.45	.15
		Actual	.91	.06	.77	.08	.77	.10	.68	.09

Table 7. *Experiment 3 Means and Standard Deviations for the proportion of items incorrectly recognized by Age and Lure Type.*

	Lure Type (Location – Identity)							
	Old – Old		New – Old		Old – New		New - New	
Age	M	SD	M	SD	M	SD	M	SD
Older Adults	.47	.18	.37	.17	.22	.12	.11	.09
Younger Adults	.24	.15	.18	.11	.07	.07	.03	.05

Figure Captions

Figure 1. The twenty possible simple 2D objects that could be placed within the study grids.

Figure 2. Top left - Sample study grid (4 items). *Top Right* - Sample identity recognition question. *Bottom Left* - Sample location recognition question. *Bottom Right* - Sample identity-location combination recognition question.

Figure 3. Experiment 1a recognition accuracy, mean proportion correct for question type (identity, location, combination) by array size (2, 3, 4, 5).

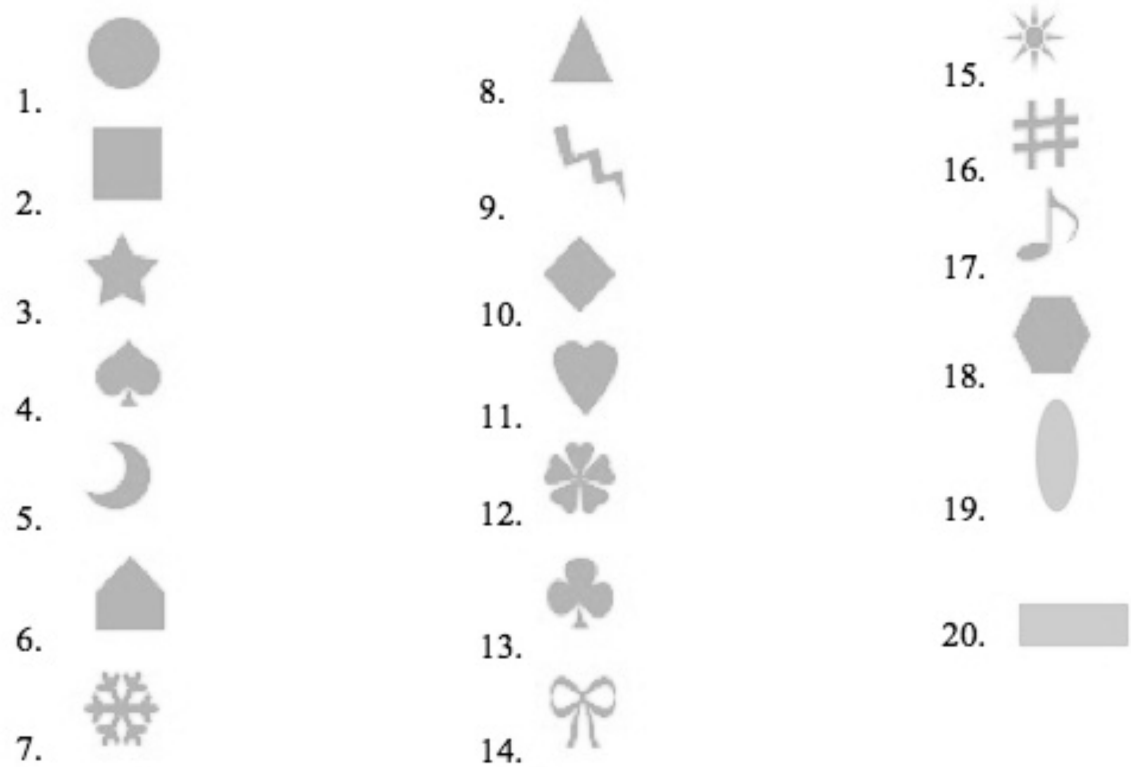
Figure 4. Experiment 1a Judgments of Learning (JOLs) for question type (identity, location, combination) by array size (2, 3, 4, 5).

Figure 5. Experiment 1a older and younger adults' prediction accuracy (predicted performance, actual performance) by question type (identity, location, combination).

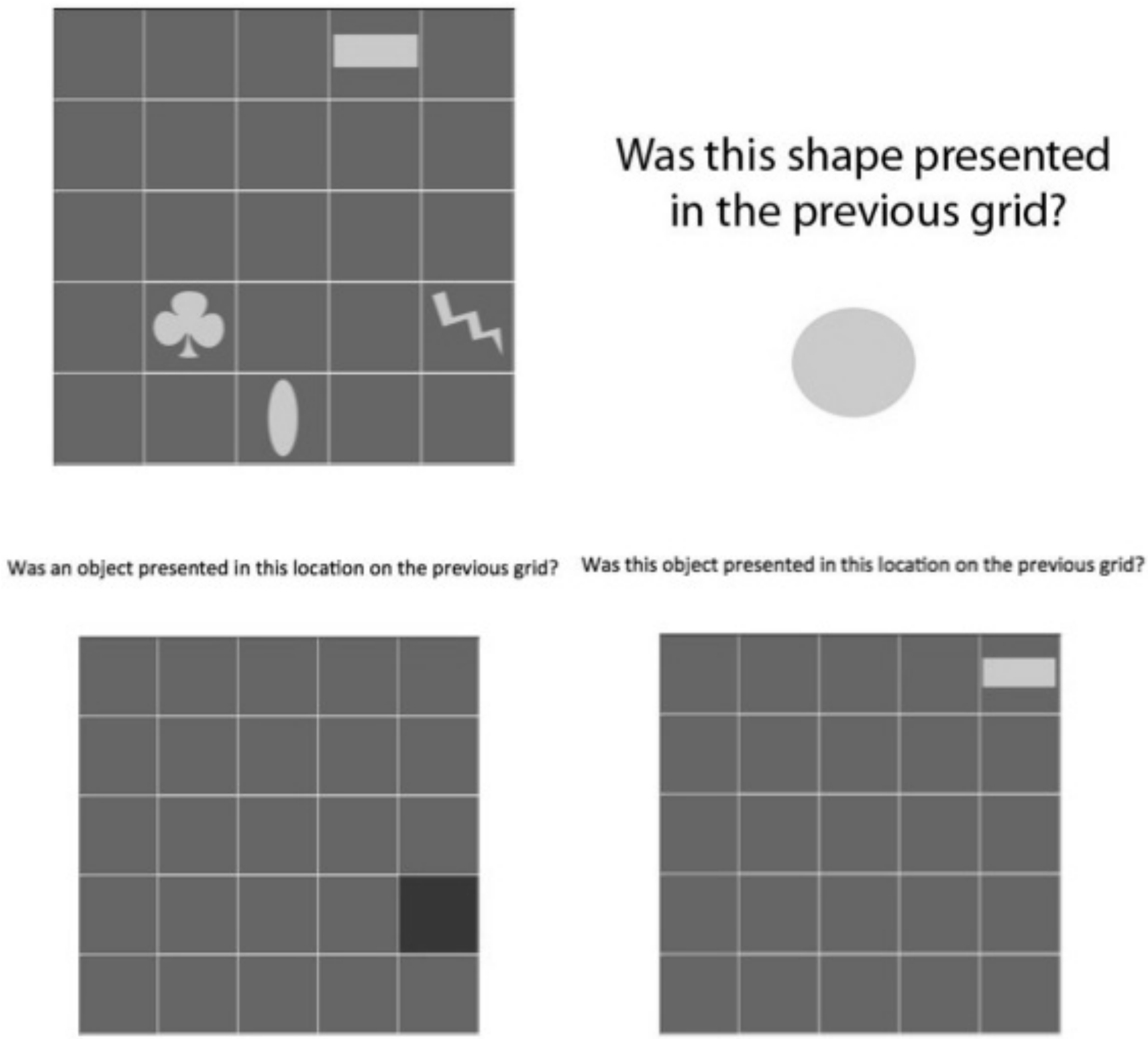
Figure 6. Experiment 1b older and younger adults' prediction accuracy (predicted performance, actual performance) by question type (identity, location, combination).

Figure 7. Experiment 2 recognition accuracy, mean proportion correct for question type (identity, location, combination) and array size (2, 3, 4, 5).

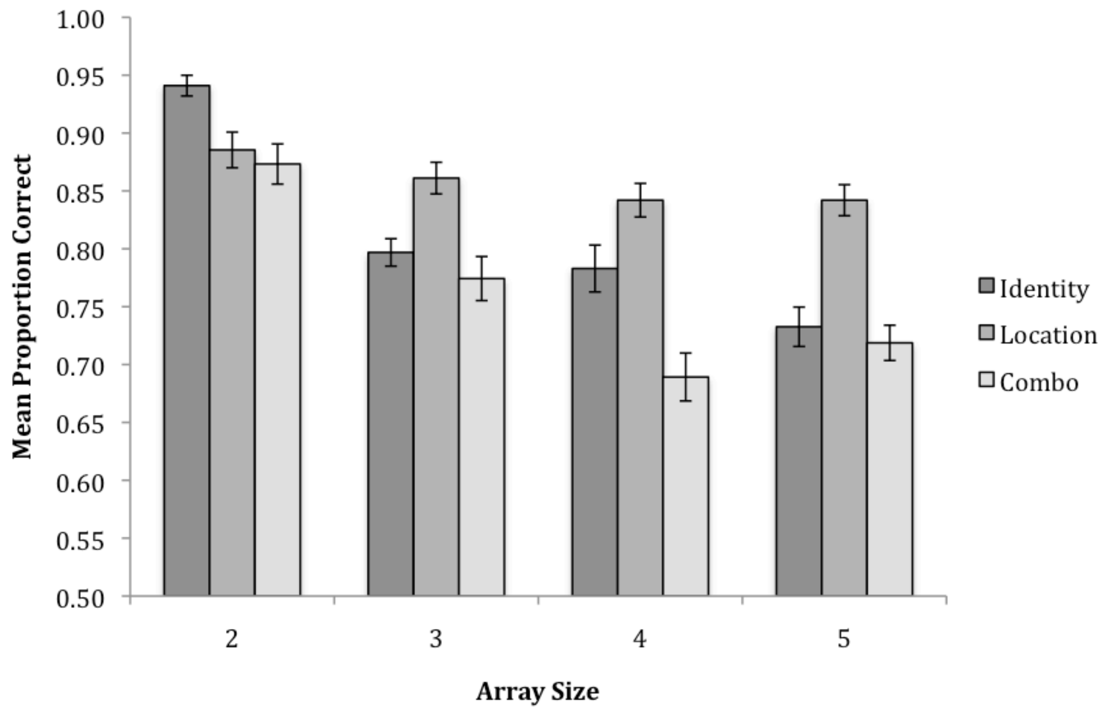
1



2


Was this shape presented
in the previous grid?
Was an object presented in this location on the previous grid?
Was this object presented in this location on the previous grid?

3


1.00
0.95
0.90
0.85
0.80
0.75
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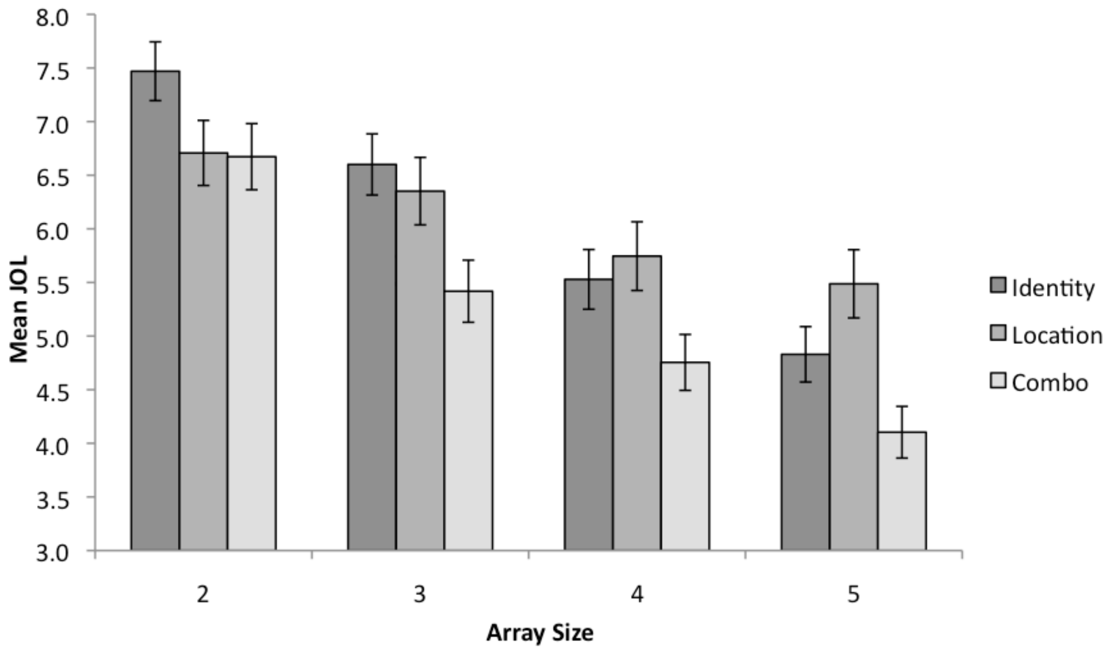
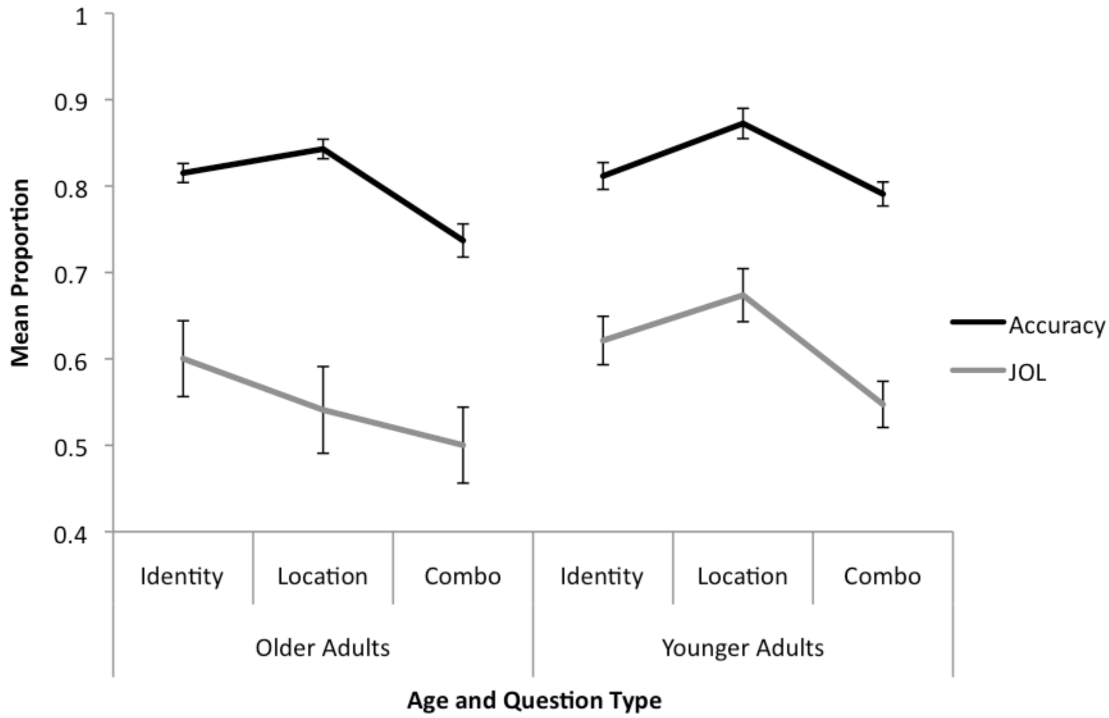
0.50
Mean Proportion Correct
2
3
4
5
Array Size
Identity
Location
Combo

4


8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
Mean JOL
2
3
4
5
Array Size
Identity
Location
Combo

5


1
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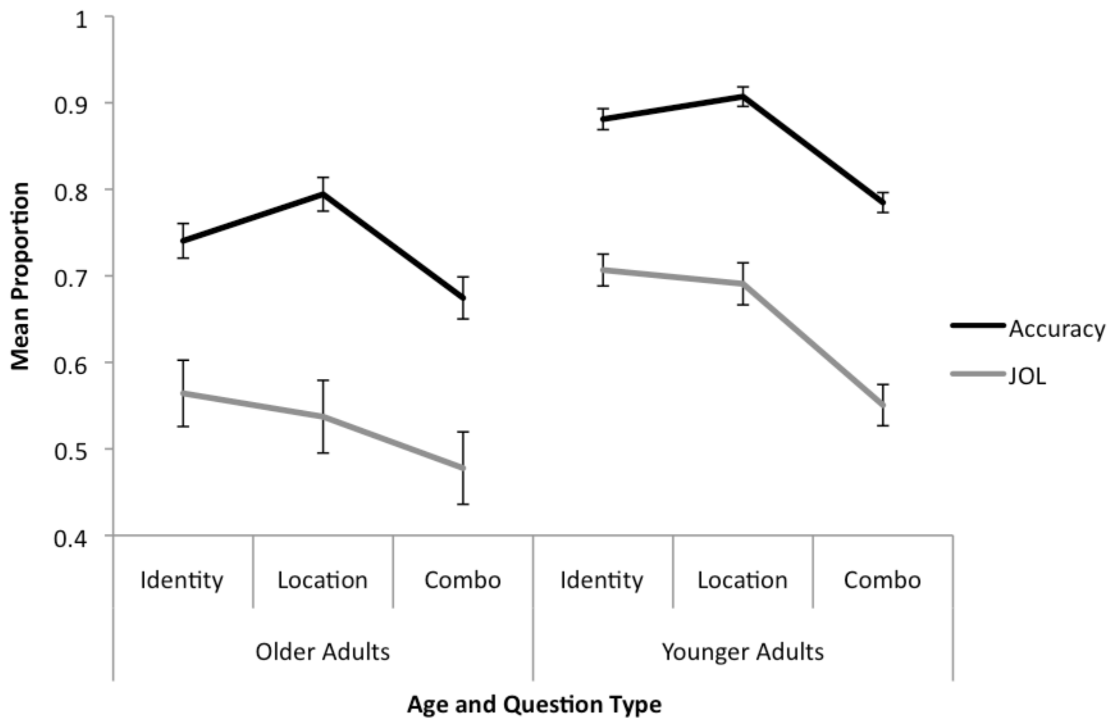
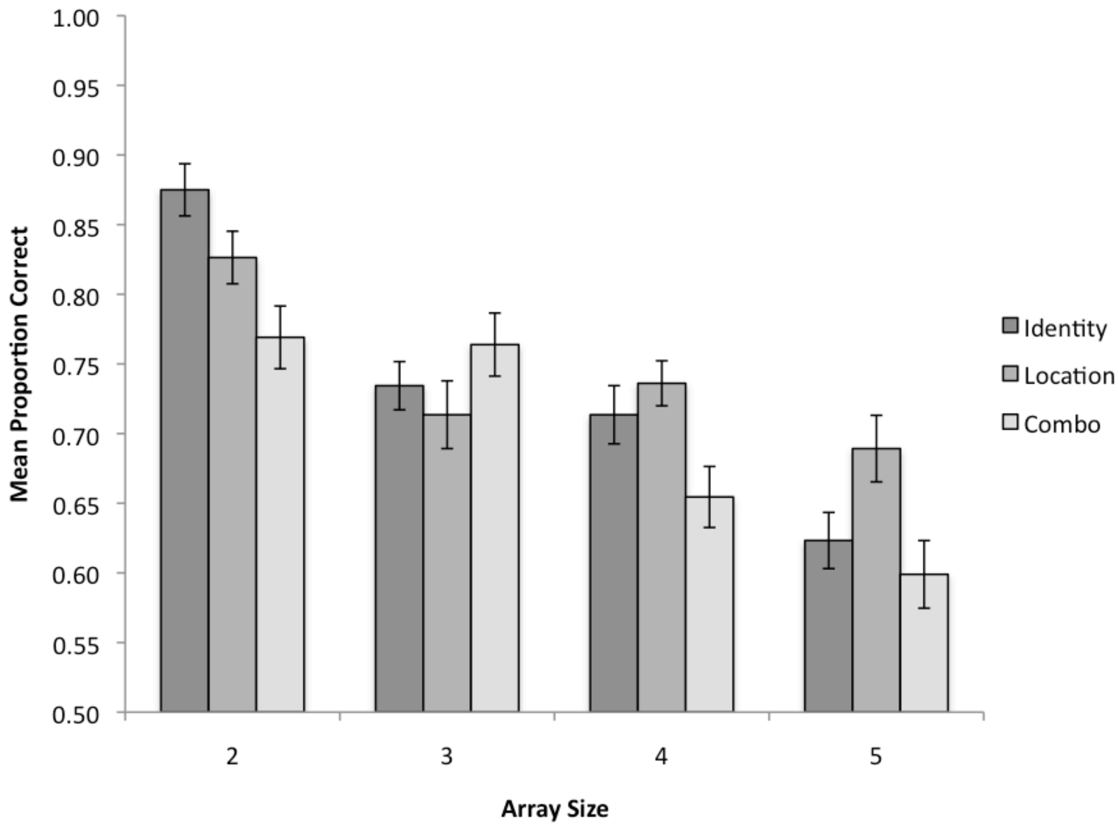
0.8
0.7
0.6
0.5
0.4
Mean Proportion
Accuracy
JOL
Identity
Location
Combo
Identity
Location
Combo
Older Adults
Younger Adults
Age and Question Type

6


1
0.9
0.8
0.7
0.6
0.5
0.4
Mean Proportion
Accuracy
JOL
Identity
Location
Combo
Identity
Location
Combo
Older Adults
Younger Adults
Age and Question Type

7


1.00
0.95
0.90
0.85
0.80
0.75
0.70
0.65
0.60
0.55
0.50
Mean Proportion Correct
2
3
4
5
Array Size
Identity
Location
Combo