Integrating Emotional Content within Visuospatial Working Memory Across the Lifespan

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Abstract

Prior research has shown that visuospatial working memory ability can be affected by a variety of factors including age, emotion, and spatial organization. Visuospatial working memory has been shown to decline as we age, but could be enhanced by the emotionality of to-be-remembered information. Spatial organization has also been shown to aid location memory. The current study examined how these factors differentially affect visual working memory, spatial working memory, and binding. Participants were recruited online via Amazon Mechanical Turk and then split into three different age groups (younger, middle, and older adults). Participants were shown a series of grids containing objects in specific locations. They were then asked about the identity of objects within the grid, the location of objects, or a combination of these features. We found that, consistent with previous research, spatial organization aided memory for the location of objects. We also found that participants were more likely to rely on gist memory when the tested on the identity of negative objects. Finally, we found that emotional arousal helped facilitate the binding of visual and spatial features, but only when the information was presented in a spatially organized configuration.

Keywords: aging, emotion, spatial organization, visuospatial working memory

Integrating Emotional Content within Visuospatial Working Memory Across the Lifespan

Throughout daily life we are faced with the task of binding visual and spatial information within the environment. This task is controlled by the visuospatial subcomponent of working memory. Baddeley and Hitch (1974) suggested that working memory is the short-term maintenance of a limited amount of information in the mind, and the ability to manipulate that information; in other words, it is the amount of on-line cognitive resources available for processing information. Working memory ability is supported by two sub-systems: the phonological loop (PL) and visuospatial sketchpad (VSS). The current study is interested in the VSS, which stores visual and spatial information from the environment for a limited amount of time. Visuospatial working memory ability has been shown to decline as we get older (Morris, Craik, & Gick, 1990). This decline is especially present when the binding of visual and spatial information is necessary (Thomas, Bonura, Taylor, & Brunyé, 2012). However, further studies have shown that emotional information may be better remembered in the context of visuospatial working memory as compared to neutral information (Mather & Nesmith, 2008). This may be due to emotional information facilitating the binding of visual and spatial information. Further, older adults have been shown to preferentially process positively valenced information.

The present study examines visuospatial working memory. Specifically, we are interested in how identity and spatial information is bound together, and how that binding processes changes as we age. As such, the present study tests the hypothesis that standard age-related deficits in binding will be mitigated by presenting emotionally valenced objects in specific spatial locations within a grid. Hopefully, when more is known about working memory capacity in older adults, meaningful intervention can be applied to minimize visual working memory, spatial working memory, and binding errors.

Visuospatial Working Memory

In order to have an effectively functioning visuospatial working memory, one must be able to accurately remember both what an object is, as well as its location in the environment. Binding facilitates this process of remembering visual information together with spatial information. Binding is defined as the association formed between multiple features of an item (Mitchell, Johnson, Raye, Mather and D'Esposito, 2000). In order to have successful visuospatial working memory, the identity and location of the item must be bound.

However, there is much evidence to suggest that visual and spatial information are processed separately. Tresch, Sinnamon, and Seamon (1993) were able to selectively impair visual and spatial memory in a behavioral visuospatial working memory task. Participants were presented with either a dot in a spatial location in their periphery, or a colored object in the center of the screen. They then performed a secondary task, where they either had to find the stationary dot from a group of moving dots or categorize colors in a monochromatic display. These secondary tasks were intended to impair the participants' spatial or visual working memory by providing interference. The researchers found that participants' spatial memory for the location of the dot was impaired by the secondary movement task, while participants' visual working memory of the color of the original object was impaired by the secondary categorization task. No impairments were found when participants' spatial working memory was tested after the secondary color categorization task, and vice versa. Thus, Tresch et al. (1993) provide an important dissociation between visual and spatial working memory, lending solid behavioral evidence to the theory of separate processing mechanisms.

This behavioral evidence for separate visual and spatial working memory processing is supported by neuropsychological research. Darling, Della Sala, Logie and Cantagallo (2006) studied two brain-injured participants, one who exhibited impairments in spatial memory, and the other in visual memory. They found that on a visuospatial working memory task the patient with the spatial memory impairment had significant difficulty locating the stimuli. However, when asked to identify the presented object, the results were virtually indistinguishable from the control group. The opposite result occurred for the participant with the impairment in visual memory. This research provides substantial neuropsychological data lending further evidence to separate cognitive processing mechanisms for visual and spatial memory.

Additional behavioral, neuroscientific, and neuropsychological studies provide further evidence for this distinction between visual and spatial working memory processing (Courtney, Ungerleider, Keil, & Haxby, 1996; Della Sala, Gray, Baddeley, Allamano, & Wilson, 1999; Goodale & Milner, 1992; Logie & Marchetti, 1991; Mishkin, Ungerleider, & Macko, 1983). While the type of task varies by study, the results of each support a distinction between working memory systems. This distinction is vitally important to the current study, as it seeks to determine how various factors can differentially affect identity memory and location memory. Thus, we will further explore how spatial and visual information are processed, both separately and together, to gain a better understanding of changes in these two types of memory.

Processing of Identity and Spatial Information

Spatial information is information about an object’s location in the environment. In contrast, visual information refers to physical features of an object. These two types of information are ever present in daily life. For example, you may try to remember which specific objects are in which aisles in the grocery store or perhaps where you left your belongings when you arrived home. In the case of the current study, the spatial information refers to sections of the presented grids in which objects are located and the visual information is the objects themselves. But how is spatial information processed and remembered compared to visual information? Research suggests that the processing of spatial information may use less cognitive resources and may therefore be prioritized over the processing of visual information.

Johnston and Pashler (1990) presented stimuli to participants and then asked about both identity and location information. When participants were unable to correctly locate the stimuli, they rarely could identify the object. The researchers suggest that there is only a small chance of identifying an object if one is unable to locate it. Further, they found that subjects could sometimes know the exact location of an object, but not its identity. Thus, their evidence would imply that location information may be processed before identity information or that the processing of identity information requires more effort than the processing of location information. As the current study is interested in differences in identity and location processing, it is important to note that spatial processing may be less effortful than identity processing.

This finding was supported by Thomas et al. (2012). Participants were presented with grids containing various objects and were asked to attend to the identity of the objects within the grid, the location of the objects, or both of these features. They found that, across age groups, participants had better memory for the location of objects as compared to the identity memory or the combination. This result remained even when the number of objects in the grids increased. Thus, the researchers suggest that the processing of location information may be easier than the processing of identity information or the combination.

Further, Taylor, Thomas, Artuso, and Eastman (2014) explored the effect of spatial organization on the processing of identity and location information. The researchers found that presenting participants with objects in a spatially organized configuration helped facilitate location memory. They concluded that location memory was prioritized over identity memory and this prioritization was enhanced by organizing objects in a spatial configuration. Thus, much evidence suggests that spatial information may be easier to process than object information. This finding is consistent throughout a variety of different conditions, including when participants were tested on more objects or the objects were in a specific spatial configuration. The current study compares memory for identity and location information in various configurations and prior research indicates that spatial memory may be prioritized over visual memory.

Binding

While it is important to consider visual and spatial processing separately, most objects we encounter in the environment have both visual and spatial features. In order to successfully remember the object, it is therefore necessary to remember both pieces of information. Accurate visuospatial working memory is dependent on the successful binding of visual and spatial information. However, research has shown, in a variety of contexts, that binding is a more demanding cognitive process than remembering single features of an object. Researchers have theorized that this task is more cognitively demanding due to the necessity to attend to multiple features when the item is presented (also known as the point of encoding). Thus, researchers have suggested that because remembering features requires attention, it is a more cognitively demanding task than remembering a single feature. The current study seeks to determine how various factors may affect binding.

This finding was supported by Brown and Brockmole (2010), who asked participants to remember the color, shape, or both features of presented objects. Some participants concurrently counted backwards from three (an attention demanding task) while others served as a control group. They found that the participants performing the attention demanding task performed significantly worse when required to remember bound features as compared to single features. Similarly, Hyun, Woodman, & Luck (2009) collected physiological data while testing participants' memory for either single features independently or feature-location combinations. The researchers found that significantly more attentional resources were required to bind the target's features to its location compared to memory for individual features. These findings suggest that maintaining multiple features of an object is a more cognitively demanding task than maintaining a single feature. As will be discussed, research has shown that our ability to bind multiple features declines as we grow older. The current study examines how the ability to bind multiple features varies along with changes in age and other factors.

Visuospatial Working Memory and Aging Deficits

As we age, like many other cognitive processes, our working memory ability declines in efficiency and accuracy (Morris et al., 1990). One major theory behind this overall decline in visuospatial working memory (VSWM) across the lifespan is the declining ability for older adults to bind visual and spatial information. Mitchell et al. (2000) used neuroscientific data to show that older adults had more difficulty in tasks that required feature binding as compared to younger adults. Thomas et al. (2012) found similar results using behavioral data. When older adults were presented with objects in a grid during a VSWM task, they had great difficulty binding visual and spatial information together, and were thus unable to recognize the association when tested on the combination of the features. This finding was also replicated with neuropsychological data, as Glisky and Kong (2008) found that greater demands were placed on older adults' working memory processes when required to integrate information as compared to younger adults. Thus, there is much converging evidence that VSWM's decline throughout the lifespan is due, at least in part, to a diminishing ability to bind features. The current study seeks to determine whether emotional context can mitigate this decline in VSWM ability.

Emotion and Binding

One factor that seems to affect encoding ability and the subsequent likelihood of recall is the emotionality of the information to be remembered. There have been numerous studies suggesting that emotion has an effect on recall ability. Murray and Kensinger (2012) explored the effects of emotion on encoding in younger adults with a mental imagery task. They found that emotional-neutral word pairs better facilitated recall compared to neutral-neutral word pairs because the emotional item triggered a priority binding mechanism for emotional information. In addition, Mather and Nesmith (2008) showed that emotionally arousing features improved the binding of a picture to its location in a visuospatial working memory task.

But why does emotional information lead to better binding? Mather (2007) proposed an explanation for this enhanced memorial binding of emotional information, suggesting that emotional information is more likely to attract one's attention, and one is then likely to spend more time attending to the emotional information. The results of her study support this notion, as participants were more likely to remember the color or location of emotional words, as compared to neutral words. Mather concluded that participants were more likely to give their attention to positive or negative information rather than neutral information. So, if binding is a cognitively draining process because it requires a significant amount of attention, perhaps emotion can help focus attention and thus aid memory for multiple features.

This preference to bind emotional information may be enhanced throughout the lifespan. Diehl, Coyle, and Labouvie-Vief (1996) found that older adults tend to favor positive or negative information over neutral information. Further, older adults tend to pay more attention to positive information, as opposed to negative information, in what is know as the positivity effect (Urry & Gross, 2010). The current study is interested in investigating whether older adults are able to better focus on emotionally valenced information, especially positive information, to increase their ability to bind information.

The Current Study

So far, we have presented evidence that older adults' visuospatial working memory ability seems to decrease with age (Brockmole & Logie, 2013; Hale & Myerson, 2011; Uttl & Graf; 1993) and that this decrease is at least somewhat attributed to ineffective binding (Mitchell et al., 2000; Thomas et al., 2012). We discussed possible methods of increasing effective binding and have proposed that emotional information might enhance binding (Hadley & MacKay, 2006; Mather, 2007; Murray & Kensinger, 2012; Sharot & Phelps, 2004).

Consequently, our study will examine adults' recognition ability of various objects' identity, spatial location, and the combination of these two features in a 5 x 5 grid. In three separate experiments, memory for object identity, object location, and a combination of these features will be assessed. These items will be either emotionally or neutrally valenced to examine the effect of emotion on recognition ability across three different age groups (younger, middle, and older adults).

Consistent with prior research, we hypothesize that older adults will have superior identity memory for emotionally valenced items while younger and middle adults should not have any differences between emotionally valenced and neutral items. We also hypothesize that spatial organization should facilitate location memory across age groups and valence. Finally, we hypothesize that older adults will be better able to bind information when it is emotionally valenced as opposed to neutral. Younger and middle adults should have similar performance on emotionally valenced and neutral trials when binding the visual and spatial information.

General Method

Design

In this study, a 3 (Age: *younger adults, middle adults, older adults)* x 3 (Question type: *object, location, combination*) x 3 (Emotional valence: *negative, neutral, positive*) x 2 (Spatial configuration: *organized, unorganized*) mixed factorial design was used. Age and question type served as between-subjects independent variables, while emotional valence and spatial configuration served as within-subjects independent variables.

Data was collected in two phases and then grouped together into three experiments according to question type. In Experiments 1a and 1b, participants were tested on their object identity memory. On Experiments 2a and 2b, participants were tested on their object location memory. Finally, in Experiments 3a and 3b, participants were tested on the combination of object and location memory.

Recruitment

Participants were recruited using the online marketplace Amazon Mechanical Turk (MTurk). Amazon MTurk is an Internet marketplace where users can create an account and earn money by completing a variety of HITs (Human Intelligence Tasks). Researchers using Amazon Mechanical Turk to collect data are able to restrict those who can see their HIT by a variety of different factors including users' age, location, and HIT completion rate. Users are able to search through HITs, filtering by keywords and minimum compensation amounts. After completing a task successfully, participants are paid through Amazon MTurk. Recently, Amazon MTurk has been used as a psychological research tool to collect data from a wide variety of participants. Some advantages of using Amazon MTurk as a research tool include access to a large, diverse participant pool, rapid collection of data, and low cost of conducting empirical research (Mason & Suri, 2011). Researchers that have conducted studies on Amazon MTurk suggest that it is as reliable as traditional testing and thus its efficacy as a psychological research tool has been strengthened (Buhrmester, Kwang, & Gosling, 2011).

Participants

Participants were recruited on Amazon MTurk consisted of 1368 US citizens. Of these 1368 participants, 1290 completed the entire task. When analyzing the data, 436 were randomly dropped (leaving 854 total participants) in order to have relatively even experimental groups. Participants' ages ranged from 18 to 76 years of age (*M* = 40.63, *SD* = 12.81, 508 females). The average years of education for all participants was 14.62.

For the purposes of this research, participants were divided across experiments into six groups: 2 younger adult groups (ranging in age from 18 to 34 years), 2 middle adult groups (ranging in age from 35 to 50 years), and 2 older adult groups (ranging in age from 51 to 76 years). Demographic information for each group is discussed in later sections.

Materials

The stimuli were 30 (10 containing negative objects, 10 containing neutral, and 10 containing positive) 5 x 5 grids containing 5 objects in various places throughout the grid. Objects within the matrix were selected from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). This list is a set of normative emotional ratings for a large quantity of words in the English language. This word list served as a guide for selecting valenced objects from various picture databases. The ANEW uses a visual scale from 1 to 9 called the Self Assessment Manikin (SAM), which allows participants to rate their emotional reaction (1 = *low pleasure* or *negative valence* and 9 = *high pleasure* or *positive valence*) to a word by choosing the depiction that most accurately portrays their inner state. In addition to emotional reaction, the ANEW collected participants' ratings of physical arousal; however, this measure did not influence stimuli selection.

As our study sought to examine participants' memory for visual objects, we selected only concrete nouns from the ANEW. The concrete nouns consisted of various animals and objects and were selected based on their emotional valence, frequency in the English language, and presence in normed picture databases (Bonin et al., 2003; Nishimoto et al., 2011; Snodgrass & Vanderwart, 1980).

SAM ranges from 1 (low pleasure) to 9 (high pleasure). The present study defined negative emotional stimuli as ranging from 1.00 to 3.67, neutral stimuli as ranging from 3.68 to 6.33, and positive emotional stimuli from 6.34 to 9.00. This evenly split up the SAM rating of words into valenced categories. The negative condition consisted of 20 objects such as "bomb," "devil," and "spider" and descriptive statistics according to their SAM ratings were calculated ($M = 3.01$, $SD = 0.56$). The neutral condition consisted of 20 objects such as "arm," "fork," and "table" ($M = 5.16$, $SD = 0.21$). The positive condition consisted of objects such as "baby," "flower," and "treasure" ($M = 7.44$, $SD = 0.43$). Complete SAM ratings for all included items can be found in the Appendix.

Pictures of concrete nouns were presented in either a spatially organized or unorganized configuration within the grids. Fifteen of the 30 presented grids were organized in a spatial configuration (either in a T-shape, V-shape, L-shape, straight line, diagonal, or cross). The remaining 15 presented grids contained objects in an unorganized fashion. Organized and unorganized grids were presented randomly to participants and varied in order within the different counterbalances. Examples of each different type of grid can be seen in *Figure 1*.

Overall, there were twenty-four different counterbalances (twelve collected in the first phase and twelve collected in the second). For each phase, three counterbalances asked participants about object identity, three asked participants about object location, and the remaining six asked about the combination of these two features. For each counterbalance, objects within grids did not appear more than twice and never in the same spatial position. In addition, each spatial location was not used more than three times within a counterbalance. This ensured an equal representation of objects and spatial locations throughout the counterbalances.

General Procedure

On Amazon MTurk eligible participants clicked on a HIT where they were informed about the procedure of the study and then linked away to Qualtrics, an online data collection software often used to collect psychological data. On Qualtrics, participants read an informed consent form and if they chose to continue, participants clicked a button indicating consent and moved to the beginning of the experiment. Then, participants were given a questionnaire that collected information such as age, gender, education, financial status, and handedness. Following, they were given instructions about the task and presented with a practice trial. Upon completion of the practice trial, the participants were presented with their first test grid. After presentation, the grid disappeared and participants were then tested on their memory of the grid with a forced-choice recognition question. The specific question asked varied depending on the specific experiment. After the participants answered, the next grid would appear and the process repeated until all 30 grids and questions were complete. On average, the task took around 10 minutes to complete.

After completing all the grids, participants were given a debriefing form explaining the research goals and providing contact information if they had any questions. Participants were also given a compensation code, which they could enter on Amazon MTurk to receive their compensation. Participants were paid $0.30 for their participation.

Experiment 1 Methods: Identity

In the identity condition (Experiments 1a and 1b), participants' object identity memory was assessed for stimuli within the grid. After participants viewed the presented grid, they were shown a specific object and asked, "Was this item presented in the previous grid?" An example of this question type is illustrated in Figure 2. In Experiment 1a, grids were presented to participants for 3 seconds, while in Experiment 1b, the grids were presented for only 2 seconds. This reduction in presentation time was aimed to reduce the high hit rates seen in Experiment 1a. Demographic information for participants in Experiments 1a and 1b follows.

Experiment 1a participants. Participants in this experiment were US citizens recruited through Amazon MTurk ($N = 101$, 56 females). Participants' ages overall ranged from 18 to 66 years of age ($M = 38.36$, $SD = 13.45$). Participants were split into three groups by age ($M_{young} = 24.68$, $SD_{young} = 3.50$, $M_{middle} = 40.86$, $SD_{middle} = 5.42$, $M_{older} = 56.64$, $SD_{older} = 4.69$). The average amount of education for all groups was 14.69 years. Complete demographic information for all three age groups can be found in *Table 2*.

Experiment 1b participants. Participants in this experiment were US citizens recruited through Amazon MTurk ($N = 116$, 77 females). Participants' ages overall ranged from 20 to 71 years of age (M = 41.96, SD = 12.34). Participants were split into three groups by age (M_{young} = 28.78, SD_{young} = 4.25, M_{middle} = 42.63, SD_{middle} = 4.34, M_{older} = 57.94, SD_{older} = 4.70). The average amount of education for all groups was 14.47 years. Complete demographic information for all three age groups can be found in *Table 2*.

Experiment 2 Methods: Location

In the location condition (Experiments 2a and 2b), participants' spatial memory was assessed for the location of objects within the grid. In this condition, after participants viewed the presented grid, they were shown a grid with one location highlighted in red and were asked, "Was there an object in this particular location in the previous grid?" An example of this question type is illustrated in Figure 3. In Experiment 2a, grids were presented to participants for 3 seconds, while in Experiment 2b, the grids were presented for only 2 seconds. Again, this reduction in study time was intended to reduce high hit rates. Demographic information for participants in Experiments 1a and 1b follows.

Experiment 2a participants. Participants in this experiment were US citizens recruited through Amazon MTurk (N = 105, 62 females). Participants' ages overall ranged from 19 to 73 years of age (M = 39.90, SD = 5.09). Participants were split into three groups by age (M_{young} = 27.63, SD_{young} = 4.17, M_{middle} = 42.10, SD_{middle} = 4.24, M_{older} =59.09, SD_{older} = 5.09). The average amount of education for all groups was 15.07 years. Complete demographic information for all three age groups can be found in *Table 2.*

Experiment 2b participants. Participants in this experiment were US citizens recruited through Amazon MTurk (N = 87, 47 females). Participants' ages overall ranged from 19 to 66 years of age (M = 42.63, SD = 12.72). Participants were split into three groups by age (M_{young} = 27.54, SD_{young} = 4.97, M_{middle} = 42.84, SD_{middle} = 2.99, M_{older} = 57.50, SD_{older} = 3.91). The average amount of education for all groups was 14.02 years. Complete demographic information for all three age groups can be found in *Table 2.*

Experiment 3 Methods: Combination

Finally, in the combination condition, participants' memory for both the object identity and location was assessed. After viewing the presented grid, participants were shown a grid containing one object in a specific spatial location and asked, "Was this item presented in this location in the previous grid?" An example of this question type is illustrated in Figure 4. Similar to the previous experiments, grids in Experiment 3a were presented to participants for 3 seconds, while in Experiment 3b, the grids were presented for only 2 seconds. Again, this reduction in presentation time was aimed to reduce the high hit rates seen in Experiment 3a. Demographic information for participants in Experiments 3a and 3b follows.

Experiment 3a participants. Participants in this experiment were US citizens recruited through Amazon MTurk (*N* = 194, 123 females). Participants' ages overall ranged from 18 to 76 years of age (*M* = 40.79, *SD* = 13.17). Participants were split into three groups by age (M_{young} = 27.07, SD_{young} = 4.75, M_{middle} = 41.24, SD_{middle} = 4.78, M_{older} = 58.08, SD_{older} = 6.21). The average amount of education for all groups was 14.45 years. Complete demographic information for all three groups can be found in *Table 2*.

Experiment 3b participants. Participants in this experiment were US citizens recruited through Amazon MTurk (*N* = 251, 143 females). Participants' ages overall ranged from 18 to 73 years of age (*M* = 40.43, *SD* = 12.43). Participants were split into three groups by age (M_{young} = 27.74, SD_{young} = 4.60, M_{middle} = 40.80, SD_{middle} = 4.23, M_{older}

= 58.13, SD_{older} = 5.28). The average amount of education for all groups was 14.82 years. Complete demographic information for all three groups can be found in *Table 2*.

Results

As the current study seeks to analyze visual memory, spatial memory, and binding, results were grouped by question type. As previously discussed, in Experiments 1a and 1b, participants were tested on object identity. In Experiments 2a and 2b, participants were tested on object location. Finally, in Experiments 3a and 3b, participants were tested on the combination of these two features. For all experiments, we analyzed both hit rates and false alarms using a 3 (Valence: Negative, Neutral, Positive) x 3 (Age: Young, Middle, Older adults) x 2 (Organization: Organized, Unorganized) mixed-factor ANOVA. Further statistical tests were conducted to determine the direction of each main effect and interaction. Full descriptive statistics for hit and false alarm rates can be found in Tables 2-7. *Figures 5-10* illustrate hit minus false alarm rates for each experiment.

Experiment 1a: Identity Hits

For identity hits in Experiment 1a, we found no main effects. However, we did find an interaction between valence and age, F (4, 196) = 2.64, p = 0.04. Middle adults had higher hit rates on negative trials (M = 0.89) and positive trials (M = 0.91) as compared to neutral trials (M = 0.81). This effect was not seen for the younger or older adults. To decompose this interaction, we compared valence within each age group. For the middle adults, we found a marginal main effect of valence, F (2, 66) = 2.54, p = 0.09. For the younger and older adults, we found no effect of valence. This interaction between valence and age was not further decomposed.

We also found an interaction between valence and organization, *F* (2, 196) = 8.34, $p < 0.01$. To decompose this interaction we compared organization within each valence. In the negative condition, we found no significant difference in performance between organized (*M* = 0.91) and unorganized trials (*M* = 0.91). In the neutral condition, participants performed significantly better on the organized trials (*M* = 0.95) as compared to the unorganized trials (*M* = 0.85), *t* (100) = 3.13, $p < 0.01$. After the Bonferroni correction, no significant difference was found in the positive condition.

Experiment 1a: Identity False Alarms

For identity false alarms in Experiment 1a, we found a main effect of valence, *F* (2, 196) = 3.37, $p = 0.04$. Participants had higher false alarm rates in the negative condition (*M* = 0.13) as compared to the neutral condition (*M* = 0.07), *t* (100) = 2.54, $p = 0.01$. After the Bonferroni correction, no other significant differences were found between valences.

Additionally, we found a main effect of age, F (2, 98) = 4.15, $p = 0.02$. Middle adults (*M* = 0.09) had significantly higher false alarm rates than older adults (*M* = 0.04), t (59) = 2.58, $p = 0.01$. In addition, younger adults (*M* = 0.09) had significantly higher false alarm rates than older adults (*M* = 0.04), *t* (65) = 2.92, $p = 0.01$. There was no significant difference in false alarm rates between younger and middle adults.

We also found an interaction between organization and age group, *F* (2, 196) = 5.07, $p = 0.01$. To decompose this interaction, we compared organization within each age group. For younger adults, participants had significantly higher false alarm rates on organized (*M* = 0.14) as compared to unorganized trials (*M* = 0.04), *t* (39) = 3.91, *p* <

0.01. For middle and older adults, there was no significant difference in false alarm rates between organized and unorganized trials.

Experiment 1b: Identity Hits

For identity hits in Experiment 1b, we only found a marginal interaction between valence and organization, F (2, 226) = 2.35, p = .10. As this interaction was only marginal, it was not further decomposed.

Experiment 1b: Identity False Alarms

For identity false alarms in Experiment 1b, we found a main effect of valence, F = 24.71, p < 0.01. Participants had significantly higher false alarm rates in the negative condition (M = 0.17) as compared to the neutral condition (M = 0.08) and the positive condition (M = 0.08), t (115) = 6.06, p < 0.01 and t (115) = 5.95, p < 0.01, respectively. This finding is consistent with identity false alarm data from Experiment 1a. There was no significant difference in false alarm rates between the neutral and positive conditions.

We also found a marginal three-way interaction between valence, organization, and age, F (4, 226) = 2.24, p = 0.07. For younger adults, false alarm rates in the negative condition were higher on unorganized trials (M = 0.22) as compared to organized trials (M = 0.15). In the neutral and positive conditions, younger adults had higher false alarm rates on the organized trials $M_{neutral}$ = 0.09, $M_{positive}$ = 0.07) as compared to the unorganized trials ($M_{neutral}$ = 0.05, $M_{positive}$ = 0.04). For middle adults, in the negative condition, there were higher false alarm rates on the unorganized trials (M = 0.18) as compared to the organized trials (M = 0.13). In the neutral and positive conditions, middle adults had higher false alarm rates on organized trials ($M_{neutral}$ = 0.11, $M_{positive}$ = 0.07) as compared to unorganized trials ($M_{neutral}$ = 0.05, $M_{positive}$ = 0.03). For older adults, in the negative condition, there were higher false alarm rates on organized trials (*M* = 0.19) as compared to unorganized trials (*M* = 0.16). Finally, in the neutral and positive conditions, older adults had higher false alarm rates on the unorganized trials ($M_{neutral}$ = 0.10, $M_{positive}$ = 0.13) as compared to organized trials ($M_{neutral}$ = 0.05, $M_{positive}$ = 0.10).

Experiments 1a and 1b Discussion

In Experiment 1a, older adults have higher hit rates and lower false alarm rates as compared to younger adults and middle adults. This does not change as a function of valence. This conflicts with previous research that found that older adults should have worse identity memory than younger adults. With regards to this finding, we suggest that the older adults in our experiment are younger on average than older adult groups in the previous research and thus, more technologically savvy. This would explain why our older adults have such high performance.

When participants had longer study time (3 seconds in Experiment 1a) valence interacted with both age and organization to affect hits on identity trials. Middle adults correct responses seemed to be affected by valence, while younger and older adults showed no effect of valence. Further, organized grids only benefitted identity memory when the objects within the grid were neutral. When the objects were emotionally valenced, organization had no effect on hit rate. These effects completely disappeared when study time was reduced to 2 seconds in Experiment 1b. This would suggest that these interactions on identity trials require a longer study time in order to emerge.

With regards to false alarms on identity trials, participants produced significantly more false alarms on negative trials in both experiments. In addition, with a longer study time, older adults had significantly less false alarms than middle or younger adults on all trials. When study time is reduced, we found no difference in false alarm rate between age groups. This suggests that older adults are superior to other age groups when tested on object identity memory if they are given adequate study time. In addition, when given less study time, younger and middle adults follow a similar pattern across valences and organization, with higher false alarm rates on organized trials in the negative condition, but higher false alarm rates on unorganized trials in the neutral and positive conditions. Older adults show the exact opposite effect, suggesting that they are processing visual information differently than younger and middle adults with varying valences and organization.

Experiment 2a: Location Hits

For location hit trials in Experiment 2a, we found a main effect of valence, F (2, 204) = 3.08, $p = 0.48$. Participants performed significantly better on neutral trials (M = 0.88), as compared to positive trials (M = 0.82). This was confirmed using a t-test with a Bonferroni correction, t (104) = 2.24, $p = 0.27$. The differences between negative and positive, and negative and neutral were not significant. In addition, we found a main effect of organization with participants performing significantly better on organized (M = 0.92), as compared to unorganized trials (M = 0.78), F (1, 102) = 30.64, $p < 0.01$.

We also found an interaction between valence and organization, F (2, 204) = 10.17, $p < 0.01$. While there was no significant difference between organized and unorganized grids on positive trials, participants performed significantly better on organized grids as compared to unorganized grids on neutral and negative trials, t (104) = 4.56, $p < 0.01$ and t (104) = 6.30, $p < 0.01$ respectively.

Finally, we found an interaction between organization and age group, F (2, 204) = 4.28, p = 0.02. Younger adults performed better on unorganized trials as compared to middle-age adults, t (80) = 2.15, p = 0.04. This comparison was the only significant one following the Bonferroni correction.

Experiment 2a: Location False Alarms

For location false alarms in Experiment 2a, we found a main effect of valence, F (2, 204) = 3.76, p = 0.03. Participants had significantly higher false alarms on negative trials (M = 0.12), as compared to neutral trials (M = 0.07), t (104) = 2.40, p = 0.02. No other comparisons were significant, after the Bonferroni correction. In addition, we found a main effect of organization, as all participants had significantly higher false alarm rates on unorganized trials (M = 0.18) as compared to organized trials (M = 0.02), F (1, 102) = 82.21, p < 0.01.

We also found an interaction between valence and organization, F (2, 204) = 5.02, p = 0.01. While there was no difference across valence for false alarms on organized trials, participants were more likely to false alarm on negative, unorganized trials as compared to neutral, unorganized trials, t (104) = 2.74, p = .01. No other comparisons were significant after the Bonferroni correction.

Experiment 2b: Location Hits

For location hits in Experiment 2b, we found a main effect of valence, F (2, 168) = 3.41, p = 0.04. Participants performed significantly better on neutral trials (M = 0.88) as compared to negative trials (M = 0.81). This was confirmed using a t-test with a Bonferroni correction, t (86) = 2.59, p = 0.01. The differences between negative and positive, and neutral and positive were not significant. In addition, we found a main effect of organization, *F* (1,84) = 14.33, $p < 0.01$. Participants performed significantly better on organized trials (*M* = 0.88), as compared to unorganized trials (*M* = 0.80).

Finally, we found an interaction between valence and organization, *F* (2, 168) = 19.86, $p < 0.01$. To decompose this interaction, we compared performance on organized and unorganized trials within valence. For negative grids, there was a significant difference in performance on organized trials (*M* = 0.95) as compared to unorganized trials (*M* = 0.68), t (86) = 8.00, $p < 0.01$. However, this difference between organized and unorganized trials was not seen when grids were either neutral ($M_{organized}$ = 0.91, $M_{unorganized}$ = 0.85) or positive ($M_{organized}$ = 0.80, $M_{unorganized}$ = 0.86). No further interactions were significant after the Bonferroni correction.

Experiment 2b: Location False Alarms

For location false alarms in Experiment 2b, we found a main effect of organization, *F* (1, 84) = 72.99, $p < 0.01$. Participants had a significantly higher false alarm rate on unorganized (*M* = 0.19), as compared to organized trials (*M* = 0.03).

In addition, we found a three-way interaction between valence, organization, and age, *F* (4, 168) = 2.65, $p = 0.04$. To decompose this interaction, we looked at false alarm rates by age and organization for each valence. In the negative condition, we found a main effect of organization, *F* (1, 84) = 23.79, $p < 0.01$). There was no significant effect of age in false alarm rates for positive trials and no further interaction between organization and age group was found.

In the neutral condition, we again found a main effect of organization, *F* (1, 84) = 40.77, $p < 0.01$. In addition, a main effect of age group was found, *F* (2, 84) = 3.27, $p = 0.04$. Young adult participants (*M* = 0.04) had higher false alarm rates than middle adults

(*M*= 0.02) and older adults (*M* = 0.00). Finally, for the neutral condition, we found a marginal interaction between organization and age group, F (2, 84) = 2.63, $p = 0.06$. This interaction appears to be driven by much higher false alarm rates on unorganized as compared to organized trials. As this interaction was marginal, it was not further decomposed.

In the positive condition, we again found a main effect of organization, F (1,84) = 29.08, $p < 0.01$. Participants had higher false alarm rates on the unorganized (*M* = 0.18) as compared to organized trials (*M* = 0.03). In addition, we found an interaction between organization and age group, F (2, 84) = 5.34, $p = 0.01$. It appears as this effect could be driven by the much higher false alarm rates on unorganized trials compared to organized trials for older adults. There was no significant effect of age for positive trials.

Experiments 2a and 2b Discussion

As hypothesized, organization facilitated location memory in both experiments. Participants had significantly higher hits rates on organized trials as compared to unorganized trials. In addition, participants had significantly higher false alarm rates on unorganized trials as compared to organized trials. Thus, organization facilitated memory for spatial information, while the lack of organization hindered this memory. In addition, participants in both experiments had higher hit rates on neutral grids as compared to emotionally valenced grids.

Interestingly, in both experiments hit rate was affected by an interaction between valence and organization. Organization did not seem to have an effect on hit rates in the positive condition. However, in the negative condition, organization facilitated location memory in both experiments. This would suggest that participants are dependent upon organization for location memory on negative trials, but not on positive or emotionally neutral trials. Thus, the results suggest that organization improves location memory overall, and specifically for negative trials. Organization seems to not affect location memory for emotionally neutral or positive information.

Experiment 3a: Combination Hits

For combination hits in Experiment 3a, we found a main effect of valence, F (2, 384) = 4.94, p = .01. Participants had higher hit rates on the negative grids (M = 0.89) as compared to neutral grids (M = 0.83) and positive grids (M = 0.85). Subsequent pairwise comparisons yielded no significant results.

In addition, we found an interaction between valence and organization, F (2, 384) = 6.71, p < 0.01. This interaction is further analyzed in the three-way interaction found between valence, organization, and age, F (4, 384) = 2.55, p = 0.04. To decompose this interaction, we looked at hit rates for valence and organization by each age group. For young adults, we found a main effect of valence, F (2, 136) = 3.68, p = 0.03. In the negative and positive conditions, they performed better on unorganized trials ($M_{negative}$ = 0.93, $M_{positive}$ = 0.86) as compared to organized trials ($M_{negative}$ = 0.87, $M_{positive}$ = 0.78). However, in the neutral condition, young adults performed better on organized trials (M = 0.85) as compared to unorganized trials (M = 0.79). For young adults we also found a marginal interaction between valence and organization, F (2, 384) = 2.63, p = 0.08. This marginal interaction was not further decomposed.

To continue with the decomposition of the three-way interaction between valence, organization, and age for middle adults we found an interaction between valence and organization, F (2, 146) = 12.59, p < 0.01. There was no difference between organized and unorganized trials for middle adults in the negative condition. However, a crossover interaction was found, with middle adults performing better on the organized trials in the neutral condition ($M_{organized}$ = 0.90, $M_{unorganized}$ = 0.76), but better on the unorganized trials in the positive condition ($M_{organized}$ = 0.77, $M_{unorganized}$ = 0.91). Finally, for the older adults, further analysis of the three-way interaction between valence, organization, and age yielded no significant results. Thus, neither valence nor organization affected older adults' hit rates on combination trials.

Experiment 3a: Combination False Alarms

For combination false alarms in Experiment 3a, we found a main effect of organization, F (1, 192) = 17.87, $p < 0.01$. Participants had higher false alarm rates on unorganized trials (M = 0.11) as compared to organized trials (M = 0.07).

We also found an interaction between organization and age, F (2, 384) = 4.40, p = 0.01. For young adults, we found no significant difference in false alarm rates on organized (M = 0.08) as compared to unorganized trials (M = 0.08). However, middle adults had significantly higher false alarm rates on unorganized (M = 0.11) as compared to organized trials (M = 0.07), t (73) = 3.12, $p < 0.01$. This was also found in older adults ($M_{unorganized}$ = 0.13, $M_{organized}$ = 0.06), t (51) = 3.61, $p < 0.01$.

Finally, we found an interaction between valence and organization, F (2, 384) = 3.05, p = 0.05. In the neutral condition, there was no difference in false alarm rates on organized (M = 0.10) as compared to unorganized trials (M = 0.11). In the negative condition, participants had higher false alarm rates on unorganized (M = 0.11) as compared to organized trials (M = 0.06), t (194) = 2.50, p = 0.01. This was also found in the positive condition ($M_{unorganized}$ = 0.11, $M_{organized}$ = 0.04), t (194) = 4.90, $p < 0.01$.

Experiment 3b: Combination Hits

For combination hits in Experiment 3b, we found a main effect of valence, F (2, 416) = 10.34, $p < 0.01$. Participants performed better in the negative condition ($M = 0.87$) as compared to the neutral condition ($M = 0.78$), t (210) = 4.52, $p < 0.01$. Participants also performed better in the negative condition as compared to the positive condition ($M = 0.78$), t (210) = 4.21, $p < 0.01$. No other comparisons were significant following the Bonferroni correction.

In addition, we found an interaction between valence and organization, F (2, 416) = 12.90, $p < 0.01$. To decompose this interaction we compared organization within each valence. In the negative condition, there was no significant difference in performance between organized ($M = 0.88$) and unorganized trials ($M = 0.86$). However, in the neutral condition, participants performed significantly better on organized trials ($M = 0.85$) as compared to unorganized trials ($M = 0.76$), t (250) = 4.04, $p < 0.01$. In the positive condition this effect was reversed, with participants performing significantly better on the unorganized trials ($M = 0.83$) as compared to the organized trials ($M = 0.75$), t (250) = 2.81, $p = 0.01$.

Experiment 3b: Combination False Alarms

For combination false alarms in Experiment 3b, we found a main effect of valence, F (2, 496) = 3.31, $p = 0.04$. Participants had higher false alarm rates on neutral ($M = 0.17$) compared to negative ($M = 0.15$) and positive trials ($M = 0.14$). Subsequent pairwise comparisons yielded no significant results. We also found a main effect of organization, F (1, 248) = 14.71, $p < 0.01$. Participants had higher false alarm rates on the unorganized trials ($M = 0.18$) as compared to the organized trials ($M = 0.13$).

Finally, we found an interaction between valence and organization, F (2, 496) = 4.80, $p = 0.01$. To decompose this interaction we compared organization within each valence. In the negative condition, we found no significant difference in false alarm rates between organized ($M = 0.14$) and unorganized trials ($M = 0.15$). However, in the neutral condition, participants had significantly higher false alarm rates on the unorganized trials ($M = 0.21$) as compared to the organized trials ($M = 0.13$), t (250) = 3.91, $p < 0.01$. This effect was also found in the positive condition ($M_{unorganized} = 0.17$, $M_{organized} = 0.12$), t (250) = 3.30, $p < 0.01$.

Experiments 3a and 3b Discussion

In both experiments, valence affected hit rates. While there were no significant pairwise comparisons in Experiment 3a, they were trending towards the same result as Experiment 3b, where hit rates for negative trials were higher than hit rates for neutral or positive trials. This result would suggest that the binding of visual and spatial information is aided by emotionally negative information for all age groups. In addition, valence and organization interacted to affect hit rates false alarm rates in both experiments. Emotionally valenced trials benefit from spatial organization in both experiments (higher hit rates and lower false alarm rates on organized as compared to unorganized trials). However, this effect is not seen in neutral trials until study time is reduced to 2 seconds. This would suggest that participants are relying on organization when the presented objects are emotionally valenced. This reliance on organization only occurs in neutral trials when study time is reduced.

False alarm rates on combination trials were also affected by organization. In both experiments, participants had higher false alarm rates on unorganized compared to organized trials. This result would suggest that unorganized trials hindered the binding of the visual and spatial information compared to the organized trials.

General Discussion

The goals of the current study were to determine how various factors affect visuospatial working memory ability as we age. To do so we tested the effect of emotion and spatial organization on memory for the identity of objects, memory for objects' spatial location, and the binding of these two features. Based on previous research, we predicted that identity memory and binding in older adults would be aided by emotionally valenced information. In addition, we hypothesized that arranging objects in a spatially organized configuration would facilitate location memory across age groups and valences. We discuss the results in relation to these hypotheses in the following sections.

Memory for Identity Information

We hypothesized that older adults would have superior memory for identity information when the information was emotionally valenced. However, older adults showed no difference in memory for identity information between valences. They did, however, have a higher overall hit rate and lower false alarm rate as compared to younger and middle adults. In addition, older adults benefitted from a longer study time (3s in Experiment 1a vs. 2s in Experiment 1b). Older adults were less likely to false alarm than the other age groups when longer study time was allotted. However, this difference between age groups disappeared when study time decreased. So, with more study time, older adults were more accurate on identity trials.

We described prior research indicating that successful allocation of attention may lead to better memory ability (Hyun et al., 2009) and we suggest that when older adults had enough time to study the presented information, they were better able to allocate their attention to salient identity features. One hypothesis as to why older adults may have been better at allocating their attention is that they were fully concentrating on the task at hand. Often younger and middle adults have more computer skills so they may have been distracted by other computer activity while completing the task. We hypothesize that older adults were more concentrated and determined to complete the task and thus allocated more attention towards it.

In addition to study time, valence affected memory for identity information. We found that when participants were presented with negative grids, they were more likely to false alarm. We hypothesize that participants may be more likely to rely on gist memory when responding to object identity questions about negative grids. This finding is consistent with previous research indicating that emotional arousal aids gist memory (Burke, Heuer, & Reisberg, 1992). The negative grids most likely elicited the largest emotional arousal from participants, and thus we hypothesize that the participants relied on this sense of emotional arousal (as opposed to explicit memory of object identity information) to respond.

Finally, and perhaps most interestingly, is the role that spatial organization played on identity memory between the different age groups. We found that younger adults were relying on their spatial gist memory, as they had higher false alarm rates when grids were organized. This over-reliance on spatial gist memory was not found in middle or older adults. We suggest that these age groups have better memory for object identity information regardless of spatial organization, as they do not rely on spatial gist memory.

Memory for Spatial Information

As we hypothesized, spatially organization facilitated location memory across valence and age groups. When grids were spatially organized, participants were able to rely on their memory for the various global shapes to aid their memory for locations within the grid. However, when grids were organized and objects randomly presented throughout, there were no global shapes to rely upon, and thus participants were forced to remember each location individually. This process of remembering multiple separate locations proved to be more difficult than remembering a singular global shape and locations associated with it. Thus, spatial organization facilitated memory for the location of objects by allowing separate spatial locations to be remembered as a whole, global shape.

In addition, participants had better location memory for neutral items as compared to emotionally valenced items. This finding is consistent with prior research that found that emotional stimuli did not enhance spatial memory compared to neutral stimuli (Bannerman, Temminck, & Sahraie, 2012). When participants were presented with emotionally neutral items, their attention was not drawn to identity information, and thus they were able to focus on the location of objects in the grid.

Interestingly, our results show little to suggest that memory for spatial information varies by age group. We hypothesize that memory for spatial information is affected more by emotional valence and spatial organization of objects.

Memory for the Combination of Features

We originally hypothesized that older adults would benefit from the emotionality of to-be-remembered information when required to bind multiple features of an object.

While we did not find that emotion differentially affected age groups, we did find that participants were best able to identify visual and spatial features of an object when information was negatively valenced. This is perhaps due to the high level of emotional arousal produced by the negative items. We suggest that the high level of emotional arousal led to participants allocating more attention to both the individual identity and spatial features of the presented objects. This focused allocation of attention on negative trials allowed for more successful binding of the presented identity and location information. Thus, negative trials were more successfully remembered due to their high emotional arousal level across all age groups. This effect was not seen on positive or neutral trials, as emotional arousal was less intense.

In addition, spatial organization appears to facilitate binding when the presented objects are emotionally valenced. We hypothesize that this is due to the unitization of information when objects are spatially organized. Unitization is a phenomenon where, as opposed to remembering features separately, multiple features of an item are encoded as a single “unit” in memory (Murray & Kensinger, 2013). These researchers suggest that emotional arousal can increase binding when the goal is to remember multiple features. In this section of the current study, participants were asked to remember both identity and location information of objects and thus emotional arousal may have helped to bind the information into a single unit when presented with spatially organized objects. Thus, spatial organization and emotional valence may have helped foster this unitization of location and identity features, leading to better visuospatial working memory ability. On the other hand, when objects were not spatially organized, this unitization of information did not occur, and emotional arousal did not facilitate binding. Thus, our findings support the theory that emotional arousal can aid memory for bound material when the features of an item are unitized at the point of encoding.

Conclusion

Overall, the current study adds evidence towards the effect of emotion on visuospatial working memory ability. While minimal differences were found between age groups, the emotional content of presented information clearly has an influence on visual working memory, spatial working memory, and binding. Negative information appears to draw more attention and thus be better remembered than neutral or positive information. This result runs contrary to previous research showing a positivity effect in older adults (Mather & Carstensen, 2005). Perhaps, in the context of visuospatial working memory, there is an emotionality effect in older adults, where the high emotional arousal level leads to better recognition of the features of an object. Further, the results suggest that binding of visual and spatial information can be aided by emotional valence, but only when the information can be unitized at the point of encoding. Future studies should consider further investigating the effect of emotion on visuospatial working memory ability.

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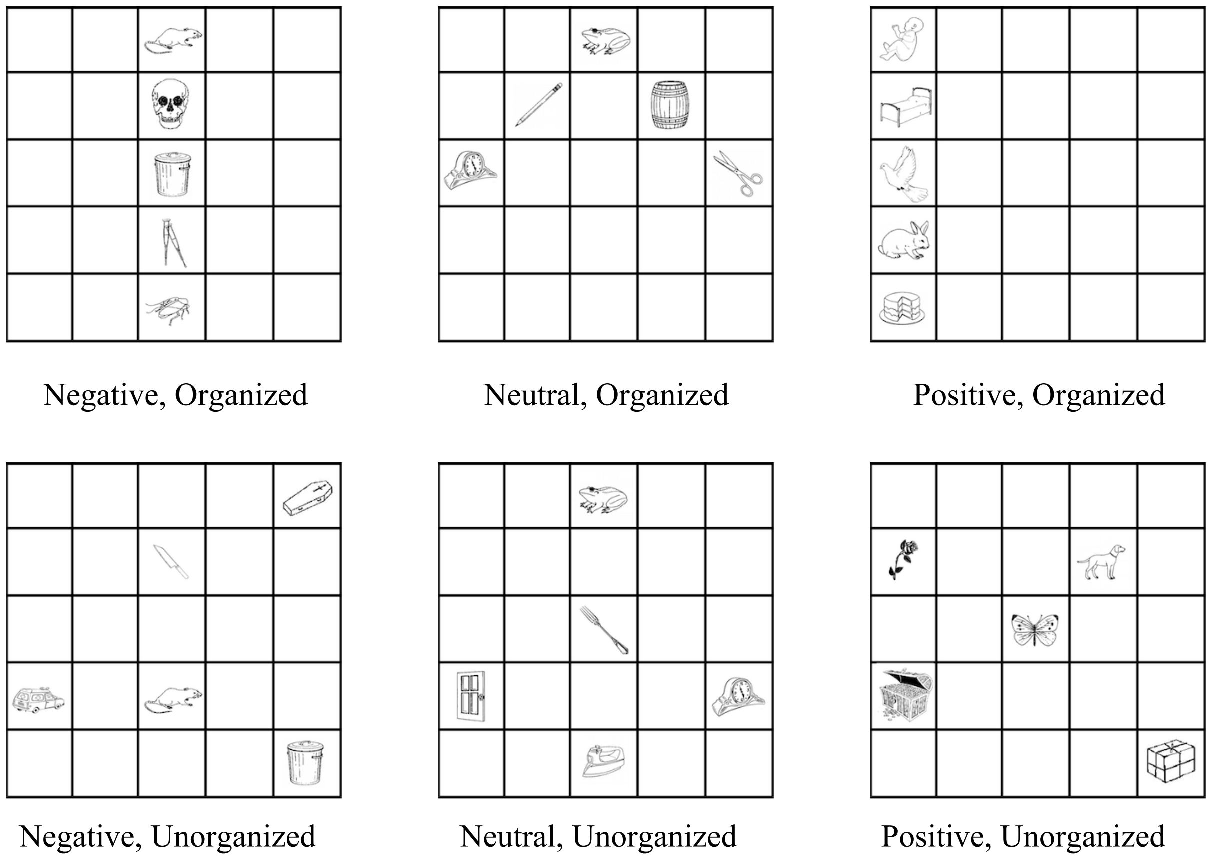


Figure 1. This figure depicts the types of grids presented to participants. Presented grids were categorized by their valence (negative, neutral, or positive) and their organization (organized or unorganized).

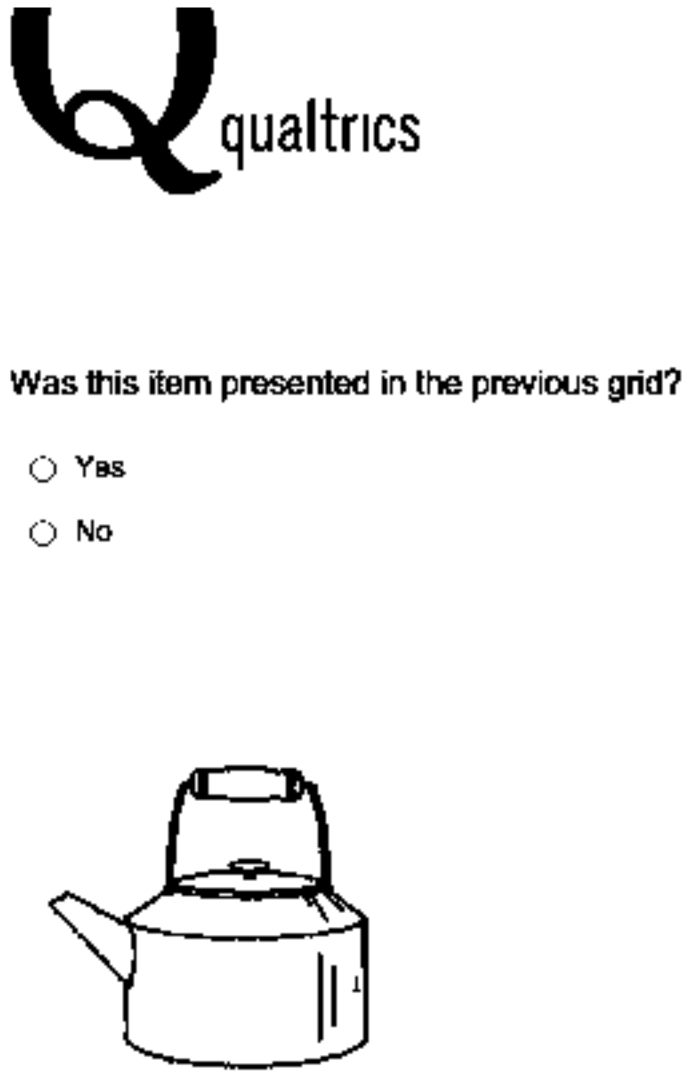


Figure 2. A screenshot of the recognition test presented to participants in the identity condition.

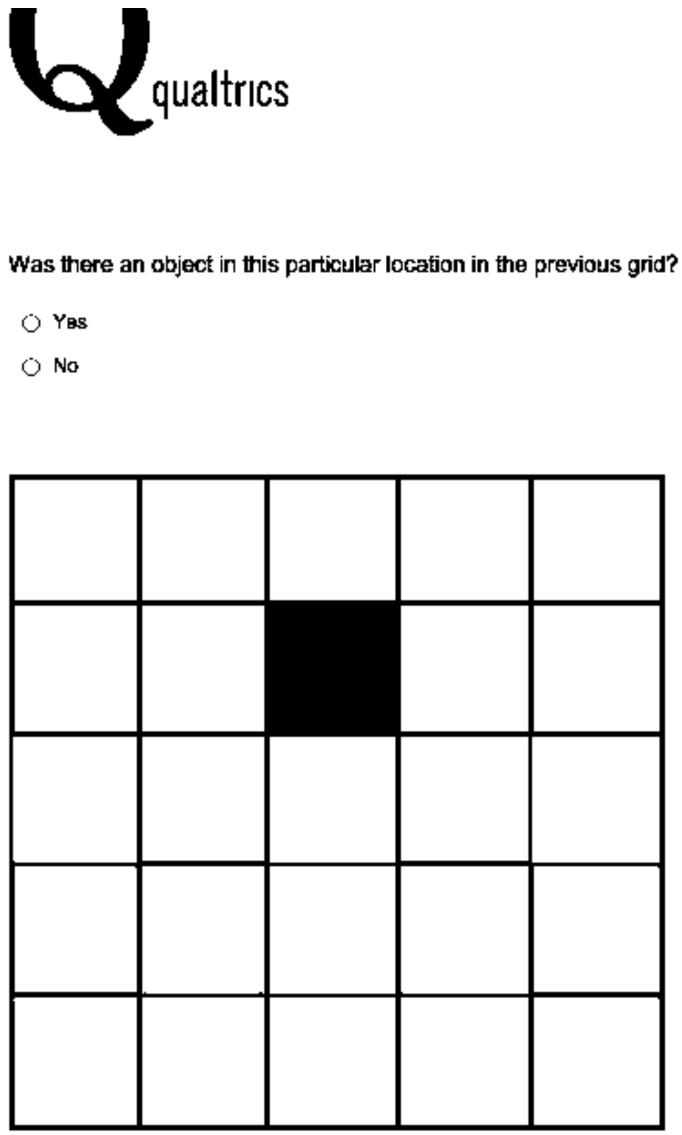


Figure 3. A screenshot from Qualtrics of the recognition test presented to participants in the location condition.

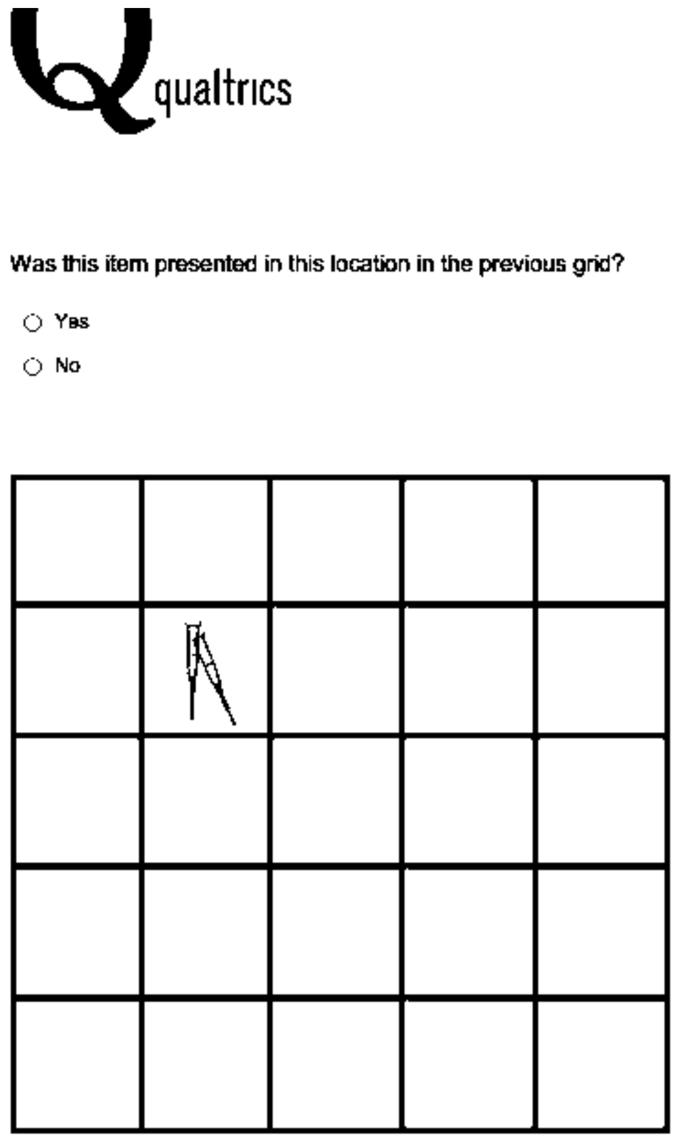
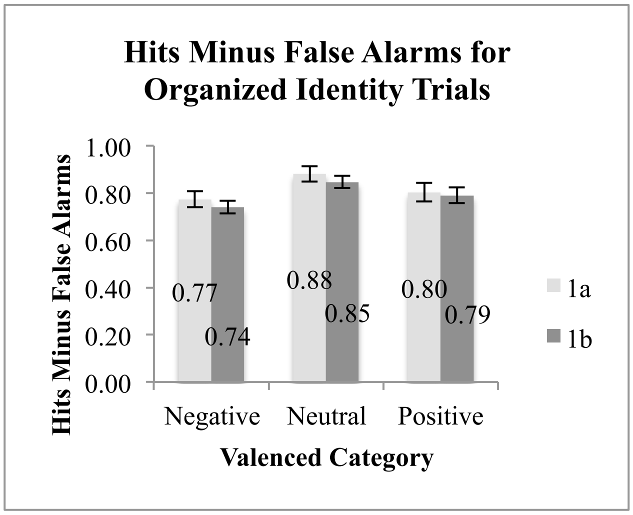
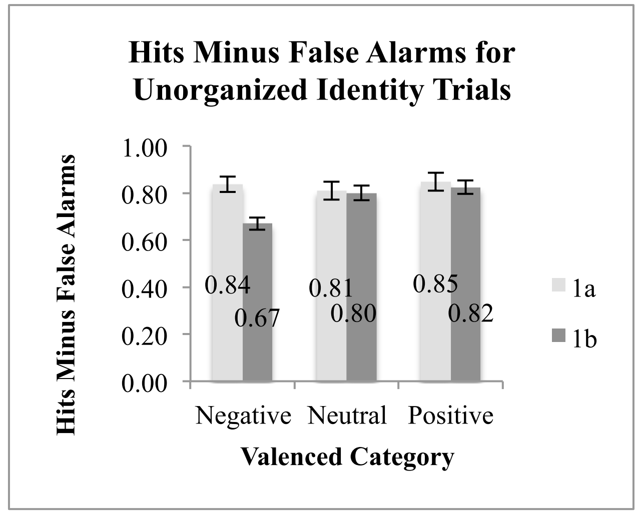
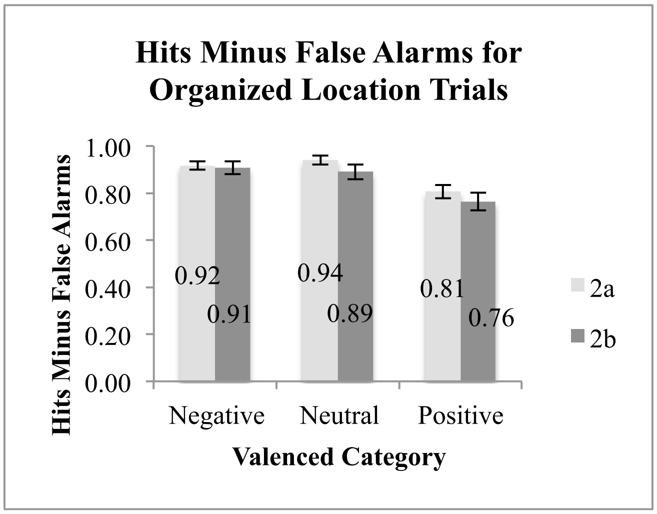


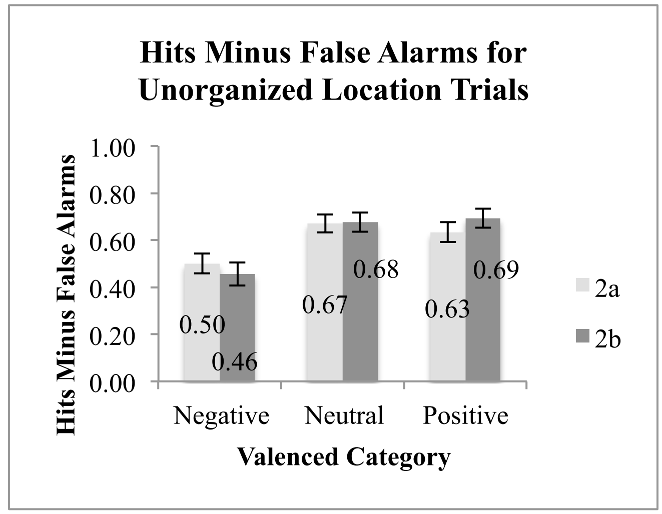
Figure 4. A screenshot from Qualtrics of the recognition test presented to participants in the combination condition.



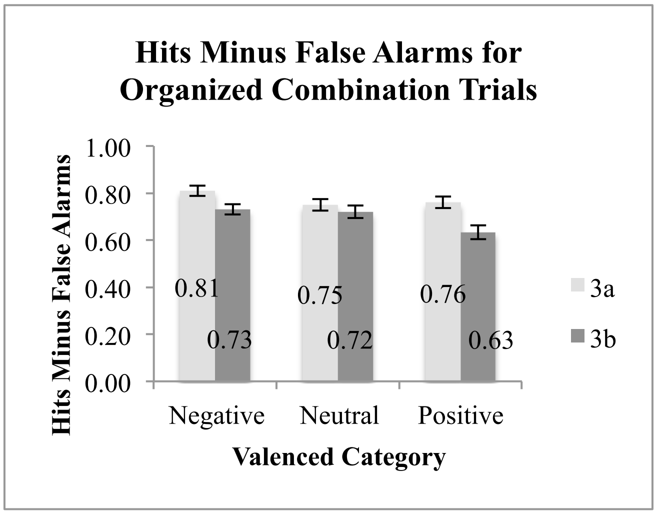


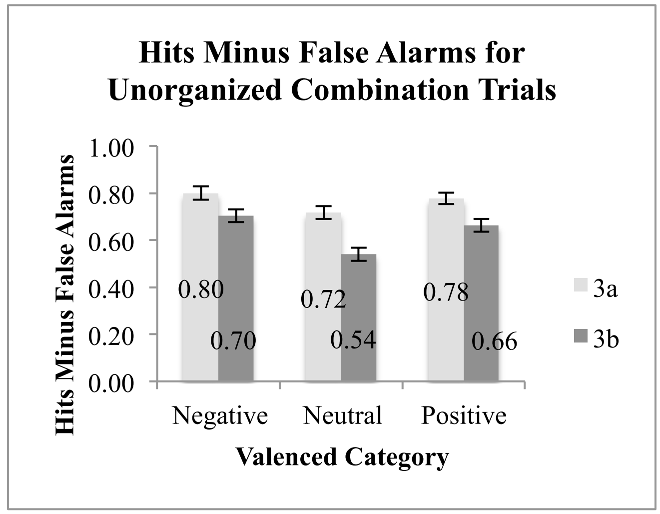
Figures 5 & 6. Hit minus false alarm rates (and standard error) for organized and unorganized identity trials in Experiments 1a and 1b.





Figures 7 & 8. Hit minus false alarm rates (and standard error) for organized and unorganized location trials in Experiments 2a and 2b.





Figures 9 & 10. Hit minus false alarm rates (and standard error) for organized and unorganized combination trials in Experiments 3a and 3b.

Table 1

Demographic Information for Participants Across Experiments

	Age Group	Mean Age (*SD*)	*N* Females (*N* Total)	Average Years of Education
Experiment 1a	Young	24.68 (3.50)	18 (40)	14.60
	Middle	40.86 (5.42)	20 (36)	14.67
	Old	56.64 (4.69)	18 (25)	14.88
	Overall	**38.36 (13.45)**	**56 (101)**	**14.69**
Experiment 1b	Young	28.78 (4.25)	25 (41)	14.00
	Middle	42.63 (4.34)	28 (43)	14.65
	Old	57.94 (4.70)	24 (32)	14.81
	Overall	**41.96 (12.34)**	**77 (116)**	**14.47**
Experiment 2a	Young	27.63 (4.17)	21 (43)	15.02
	Middle	42.10 (4.24)	26 (39)	15.33
	Old	59.09 (5.09)	15 (23)	14.70
	Overall	**39.90 (12.83)**	**62 (105)**	**15.07**
Experiment 2b	Young	27.54 (4.97)	14 (28)	14.21
	Middle	42.84 (2.99)	16 (31)	13.68
	Old	57.50 (3.91)	17 (28)	14.21
	Overall	**42.63 (12.72)**	**47 (87)**	**14.02**
Experiment 3a	Young	27.07 (4.75)	44 (68)	14.50
	Middle	41.24 (4.78)	45 (74)	14.68
	Old	58.08 (6.21)	34 (52)	14.08
	Overall	**40.79 (13.17)**	**123 (194)**	**14.45**
Experiment 3b	Young	27.74 (4.60)	46 (88)	14.70
	Middle	40.80 (4.23)	57 (102)	14.86
	Old	58.13 (5.28)	40 (61)	14.92
	Overall	**40.43 (12.43)**	**143 (251)**	**14.82**

Table 2

Descriptive Statistics for Hits on Identity Trials (Experiments 1a and 1b): M (*SD*)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	1a	0.92 (0.17)	0.91 (0.19)	0.98 (0.16)	0.89 (0.24)	0.90 (0.28)	0.93 (0.20)
	1b	0.91 (0.16)	0.91 (0.22)	0.98 (0.16)	0.89 (0.27)	0.84 (0.32)	0.88 (0.19)
Middle Adults	1a	0.90 (0.15)	0.88 (0.21)	0.88 (0.33)	0.74 (0.41)	0.88 (0.32)	0.93 (0.15)
	1b	0.90 (0.16)	0.85 (0.23)	0.95 (0.22)	0.86 (0.26)	0.88 (0.29)	0.93 (0.17)
Older Adults	1a	0.89 (0.15)	0.93 (0.17)	0.99 (0.06)	0.91 (0.27)	0.80 (0.40)	0.91 (0.16)
	1b	0.88 (0.15)	0.81 (0.27)	0.86 (0.28)	0.85 (0.28)	0.89 (0.30)	0.86 (0.22)

Table 3

Descriptive Statistics for False Alarms on Identity Trials (Experiments 1a and 1b): M (SD)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	1a	0.19 (0.25)	0.04 (0.13)	0.13 (0.22)	0.06 (0.17)	0.10 (0.20)	0.03 (0.16)
	1b	0.15 (0.23)	0.22 (0.16)	0.09 (0.13)	0.05 (0.17)	0.07 (0.20)	0.04 (0.14)
Middle Adults	1a	0.13 (0.28)	0.15 (0.31)	0.06 (0.16)	0.04 (0.13)	0.03 (0.12)	0.13 (0.33)
	1b	0.13 (0.19)	0.18 (0.17)	0.11 (0.17)	0.05 (0.14)	0.07 (0.14)	0.03 (0.12)
Older Adults	1a	0.07 (0.23)	0.02 (0.10)	0.02 (0.10)	0.01 (0.06)	0.04 (0.13)	0.07 (0.18)
	1b	0.19 (0.27)	0.16 (0.19)	0.05 (0.12)	0.10 (0.23)	0.10 (0.18)	0.13 (0.28)

Table 4

Descriptive Statistics for Hits on Location Trials (Experiments 2a and 2b): M (SD)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	2a	0.93 (0.21)	0.79 (0.30)	0.93 (0.21)	0.88 (0.26)	0.84 (0.30)	0.85 (0.31)
	2b	0.93 (0.18)	0.69 (0.31)	0.88 (0.32)	0.84 (0.31)	0.84 (0.23)	0.81 (0.37)
Middle Adults	2a	0.97 (0.11)	0.64 (0.38)	0.97 (0.11)	0.77 (0.38)	0.88 (0.21)	0.78 (0.35)
	2b	0.97 (0.13)	0.58 (0.36)	0.95 (0.15)	0.85 (0.27)	0.81 (0.30)	0.90 (0.26)
Older Adults	2a	0.96 (0.14)	0.75 (0.31)	0.98 (0.10)	0.74 (0.40)	0.75 (0.33)	0.81 (0.36)
	2b	0.95 (0.15)	0.76 (0.26)	0.90 (0.25)	0.86 (0.32)	0.74 (0.34)	0.89 (0.26)

Table 5

Descriptive Statistics for False Alarms on Location Trials (Experiments 2a and 2b): M (SD)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	2a	0.08 (0.05)	0.18 (0.30)	0.05 (0.17)	0.12 (0.20)	0.01 (0.05)	0.15 (0.23)
	2b	0.07 (0.21)	0.23 (0.33)	0.04 (0.10)	0.26 (0.28)	0.07 (0.16)	0.12 (0.17)
Middle Adults	2a	0.03 (0.09)	0.20 (0.30)	0.01 (0.06)	0.14 (0.19)	0.04 (0.13)	0.19 (0.20)
	2b	0.03 (0.10)	0.20 (0.29)	0.02 (0.12)	0.12 (0.18)	0.02 (0.12)	0.14 (0.19)
Older Adults	2a	0.00 (0.00)	0.30 (0.36)	0.00 (0.00)	0.12 (0.17)	0.00 (0.00)	0.20 (0.30)
	2b	0.03 (0.10)	0.23 (0.27)	0.00 (0.00)	0.14 (0.24)	0.01 (0.06)	0.26 (0.26)

Table 6

Descriptive Statistics for Hits on Combination Trials (Experiments 3a and 3b): M (SD)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	3a	0.87 (0.29)	0.93 (0.18)	0.85 (0.31)	0.79 (0.04)	0.78 (0.04)	0.86 (0.28)
	3b	0.86 (0.29)	0.85 (0.24)	0.86 (0.29)	0.72 (0.35)	0.73 (0.38)	0.82 (0.34)
Middle Adults	3a	0.86 (0.27)	0.87 (0.25)	0.90 (0.23)	0.76 (0.32)	0.77 (0.35)	0.91 (0.22)
	3b	0.92 (0.02)	0.88 (0.21)	0.84 (0.33)	0.77 (0.32)	0.77 (0.35)	0.82 (0.33)
Older Adults	3a	0.89 (0.25)	0.92 (0.15)	0.82 (0.32)	0.88 (0.25)	0.86 (0.28)	0.90 (0.25)
	3b	0.83 (0.30)	0.83 (0.23)	0.85 (0.31)	0.78 (0.32)	0.76 (0.35)	0.85 (0.28)

Table 7

Descriptive Statistics for False Alarms on Combination Trials (Experiments 3a and 3b): M (*SD*)

		Negative		Neutral		Positive	
		Organized	Unorganized	Organized	Unorganized	Organized	Unorganized
Young Adults	3a	0.09 (0.17)	0.08 (0.18)	0.11 (0.19)	0.08 (0.17)	0.04 (0.11)	0.08 (0.18)
	3b	0.16 (0.25)	0.16 (0.27)	0.13 (0.23)	0.25 (0.28)	0.11 (0.20)	0.18 (0.22)
Middle Adults	3a	0.06 (0.17)	0.13 (0.23)	0.10 (0.18)	0.10 (0.19)	0.04 (0.11)	0.12 (0.20)
	3b	0.13 (0.21)	0.12 (0.21)	0.13 (0.22)	0.17 (0.27)	0.13 (0.23)	0.17 (0.25)
Older Adults	3a	0.04 (0.11)	0.11 (0.11)	0.11 (0.23)	0.10 (0.22)	0.05 (0.11)	0.14 (0.22)
	3b	0.13 (0.20)	0.17 (0.27)	0.13 (0.18)	0.23 (0.31)	0.12 (0.19)	0.15 (0.20)

Appendix

Names of Items and SAM Ratings for Valenced Categories

Valenced Category	Items	Mean SAM Rating (SD)
Negative	Ambulance	2.47 (1.50)
	Bee	3.20 (2.07)
	Bomb	2.10 (1.19)
	Bullet	3.29 (2.06)
	Cockroach	2.81 (2.11)
	Coffin	2.56 (1.96)
	Crutches	3.43 (1.62)
	Dagger	3.38 (1.77)
	Death	1.61 (1.40)
	Devil	2.21 (1.99)
	Garbage	2.98 (1.96)
	Grenade	3.60 (1.88)
	Gun	3.47 (2.48)
	Knife	3.62 (2.18)
	Mosquito	2.80 (1.91)
	Rat	3.02 (1.66)
	Shark	3.65 (2.47)
	Snake	3.31 (2.20)
	Spider	3.33 (1.72)
	Tobacco	3.28 (2.16)
Overall Negative		**3.01 (0.56)**
Neutral	Arm	5.34 (1.82)
	Barrel	5.05 (1.46)
	Bowl	5.33 (1.33)
	Chair	5.08 (0.98)
	Clock	5.14 (1.54)
	Door	5.13 (1.44)
	Fork	5.29 (0.97)
	Frog	5.71 (1.74)
	Hammer	4.88 (1.16)
	Iron	4.90 (1.02)
	Kettle	5.22 (0.91)
	Pencil	5.22 (0.68)
	Pig	5.07 (1.97)
	Scissors	5.05 (0.96)
	Stove	4.98 (1.69)
	Table	5.22 (0.72)
	Thermometer	4.73 (1.05)
	Umbrella	5.16 (1.57)
	Vest	5.25 (1.33)
	Wagon	5.37 (0.97)
Overall Neutral		**5.16 (0.21)**

Valenced Category	Items	Mean SAM Rating (*SD*)
Positive	Baby	8.22 (1.20)
	Bed	7.51 (1.38)
	Bird	7.27 (1.36)
	Bunny	7.24 (1.32)
	Butterfly	7.17 (1.20)
	Cake	7.26 (1.27)
	Car	7.73 (1.63)
	Diamond	7.92 (1.20)
	Dog	7.57 (1.66)
	Flower	6.64 (1.78)
	Gift	7.77 (2.24)
	Heart	7.39 (1.53)
	House	7.26 (1.72)
	Radio	6.73 (1.47)
	Sailboat	7.25 (1.71)
	Star	7.27 (1.66)
	Sun	7.55 (1.85)
	Toy	7.00 (2.01)
	Treasure	8.27 (0.90)
	Trophy	7.78 (1.22)
Overall Positive		**7.44 (0.43)**

Note: SAM (Self Assessment Manikin) Ratings were obtained from the Affective Norms for English Words (ANEW; Bradley & Lang, 1999). Participants rated their emotional reaction to various words on a scale from 1 (low pleasure) to 9 (high pleasure). The present study defined negative emotional stimuli as ranging from 1 to 3.67, neutral stimuli as ranging from 3.68 to 6.33, and positive emotional stimuli from 6.34 to 9.