

ABSTRACT

Title of Thesis:

RELATIONAL MEMORY IN EARLY
CHILDHOOD: DOES UNITIZATION
HELP?

Alison Marie Robey, Master of Science, 2016

Thesis Directed By:

Assistant Professor Tracy Riggins,
Department of Psychology

Young children often experience relational memory failures, which are thought to be due to underdeveloped recollection processes. Manipulations with adults, however, have suggested that relational memory tasks can be accomplished with familiarity, a processes that is fully developed during early childhood. The goal of the present study was to determine if relational memory performance could be improved in early childhood by teaching children a memory strategy (i.e., unitization) shown to increase familiarity in adults. Six- and 8-year old children were taught to use visualization strategies that either unitized or did not unitize pictures and colored borders. Analysis revealed inconclusive results regarding differences in familiarity between the two conditions, suggesting that the unitization memory strategy did not improve the contribution of familiarity as it has been shown to do in adults. Based on these findings, it cannot be concluded that unitization strategies increase the contribution of familiarity in childhood.

RELATIONAL MEMORY IN EARLY CHILDHOOD: DOES UNITIZATION HELP?

by

Alison Marie Robey

Thesis submitted to the Faculty of the Graduate School of the
University of Maryland, College Park, in partial fulfillment
Of the requirement for the degree of
Master of Science
2016

Advisory Committee: Assistant
Professor Tracy Riggins, Chair
Professor Michael Dougherty
Assistant Professor L. Robert Slevc

© Copyright by
Alison Marie Robey
2016

Table of Contents

Table of Contents.....	ii
List of Tables.....	iii
List of Figures.....	iv
Chapter 1: Introduction.....	1
A Dual Process Theory of Memory.....	2
Measuring the Contribution of Recollection & Familiarity.....	4
Unitization Increases the Contribution of Familiarity.....	5
Perceptual Biding with Unitization.....	6
Semantic Biding with Unitization.....	7
Unitization as a Strategy.....	7
Memory Development.....	8
Increasing Memory Performance in Special Populations.....	10
Unitization in Childhood.....	11
Current Study.....	12
Chapter 2: Method.....	14
Participants.....	14
Materials.....	14
Training Stimuli.....	14
Encoding Stimuli.....	15
Retrieval Stimuli.....	15
Procedure.....	15
Training.....	16
Encoding.....	17
Retrieval.....	18
Hypotheses.....	18
Chapter 3: Data Analytic Approach & Results.....	20
Differences in Memory Performance.....	20
State Trace Analysis.....	21
Contribution of Familiarity and Recollection.....	22
Linearity Analysis.....	23
Parameter Estimates.....	23
Chapter 4: Discussion.....	27
Appendices.....	31
References.....	32

List of Tables

Table 1. Bayes Factor Interpretations (Jeffreys 1961)

Table 2. Behavioral Results for All Groups

Table 3. Estimates of Familiarity and Recollection

List of Figures

Figure 1. State-traces for the Unitized and Non-Unitized Conditions Collapsed across Age

Figure 2. ROC Curves for Each of the Four Conditions

Chapter 1: Introduction

The ability to bind one piece of information to another piece of information and remember it across a delay (i.e., relational memory) is present in the first few years of life (e.g., Bemis & Leichtman, 2013). For example, young children are often tasked with remembering the route from their house to the bus stop, which lunch box on a shelf full of lunch boxes is theirs, and even curriculum material such as learning relations between animals and their habitats. Although young children are expected to complete tasks such as these successfully, they often fail. One possible explanation for these failures is that basic relational memory abilities have not yet reached maturity (Sluzenski, Newcombe, & Kovacs, 2006).

Historically, relational memory abilities have been thought to rely on recollection, one of the two cognitive processes that have been argued to support recognition memory in adults (Yonelinas, 2002). During childhood, recollection has been shown to follow a protracted developmental trajectory into the adolescent years (Ghetti & Bauer, 2012). However, it has recently been suggested in adult literature that if two pieces of to-be-remembered information are bound in a unitized fashion, the contribution of another cognitive process, familiarity, is significantly increased (Yonelinas, Kroll, Dobbins, & Soltani, 1999). This is a particularly exciting possibility from a developmental perspective as familiarity is thought to reach maturity before recollection (i.e., between 6-8 years of age, Ghetti & Angelini, 2008). Specifically, if children unitize to-be-remembered pieces of information, they may be less prone to errors/forgetting due to the increase in reliance on their ‘mature’ familiarity process.

The goal of the present study was to take what is known about manipulations that increase the contribution of familiarity to relational memory processes in adults and determine if the same memory strategy would improve children's performance on a relational memory task. First, a prominent dual-process theory of memory and the concept of unitization will be discussed. Then, stimuli manipulations that make use of unitization phenomena will be reviewed, along with how unitization may be used as a strategy through visual imagery. Finally, what is known about memory development will be discussed and evidence will be provided as to why a visual unitization strategy may improve relational memory performance during early childhood.

A Dual Process Theory of Memory

Yonelinas (2002), proposed that recognition memory is a dual process system, composed of two, independent cognitive processes: familiarity and recollection. Familiarity is reflected as a global feeling of knowing, whereas recollection requires the remembering of specific contextual details surrounding an event. For example, you may have experienced a time when you were walking through the grocery and saw someone you had met before, but were not able to recall who they were or where you met them. This would be an example of familiarity. However, if you were able to remember that the person's name was Jessica, and she was in your yoga class last year, that would be an example of recollection. Many differences are known to exist between these processes (see Yonelinas, 2002 for review), with one of the most apparent being their ability to support the learning of novel relations, as in relational memory tasks (Diana, Reder, Arndt, & Park, 2006).

When novel relations are remembered through relational memory, different components of a memory episode are bound together. This type of binding is involved in many memory tasks ranging from source memory tasks (binding of information to a source; for review see Johnson, Hastroudi, & Lindsay, 1993), to memory context tasks (binding of an item to its context; e.g., Kensinger, Piguet, Krendl, & Corkin, 2005), to associative memory tasks (novel-word pairs; binding of one word to another word; e.g., Wolford, 1971). For the purposes of this paper, these tasks will all be referred to as relational memory tasks as they all require the binding of elements in memory.

Relational memory tasks are different from item memory tasks that simply require participants to respond whether a stimulus is old (has been encountered before) or new (has not been encountered before), because they require memory for a bound associations. For many years it was thought that familiarity could support item memory tasks, but recollection was required for relational memory tasks. However, recent work has shown that familiarity is able to support associations if to-be-remembered information is encoded in a coherent gestalt fashion (i.e., if it is unitized Yonelinas, et al., 1999). For example, Yonelinas, et al. (1999) presented participants with faces either right-side up or up-side down and found that up-right faces, which are processed holistically, could be recalled through the use of familiarity, whereas up-side-down faces, which are processed as individual features and therefore require binding, could not be retrieved with familiarity alone. Thus, whether or not familiarity can support memory for relations between items is entirely dependent on the way items are initially processed (Diana, Yonelinas, & Ranganath, 2008).

Research that has shown that relations are better remembered when processed holistically or in a unitary rather than non-unitary fashion (Asch, Ceraso, Heimer, 1960; Ceraso, Kourtzi, & Ray, 1998). Graf & Schacter (1989) refer to this process as *unitization*, taking previously separate items and representing them as a single unit. Unitization consistently leads to better recall than other mechanisms, such as *grouping*, or keeping representations separate and forming associations. Whether stimuli are unitized or grouped determines the ways in which they may later be recalled. Relations that are unitized can be retrieved through the support of familiarity, whereas relations that are grouped require recollection (Tibon, Vakil, Goldstein, & Levy, 2012). More specifically, it has been shown that unitization uniquely increases the contribution of familiarity despite the fact that the contribution of recollection remains unaltered (Diana, Ven den Boom, Yonelinas, 2011)

Measuring the Contribution of Recollection & Familiarity

There are several methods available to discriminate the contribution of familiarity and recollection during memory retrieval (reaction time, ERPs, patients with specific lesions, see Yonelinas, 2002, for review). Most relevant to the present report are receiver operating characteristics (ROCs), which make use of the fact that familiarity reflects a continuous index of memory strength with signal-detection properties, whereas recollection represents a threshold process requiring the retrieval of specific information (Yonelinas, 1994). ROCs offer an effective mechanism in capturing the differences between familiarity and recollection. Under the assumption that familiarity relies on a continuous index of memory strength, memory decisions are based on a criterion decision level that dissects two overlapping, symmetrical, underlying distributions, one for old

items and one for new. As the criterion decision level lowers, a greater proportion of hits to false alarms are accepted, leading to a curvilinear ROC. With recollection however, the underlying distribution for old items is skewed toward high confidence responses, and as the criterion decision level decreases few hits are added leading to linear ROC (Yonelinas, 1997). Manipulations to the contribution of recollection and familiarity can be observed in ROCs; increases in recollection result in ROC shifting up only at high confidence criterion levels, whereas increases in familiarity result in the ROC shifting up the most a mid-confidence criterion level and thus having greater curvature (Yonelinas, 1994). Models of dual process theories may also be fit to ROC points allowing for the extraction of parameter estimates for familiarity and recollection (for review see Yonelinas & Parks, 2007).

Unitization Increases the Contribution of Familiarity

The methods described above have shown that when items are unitized, the contribution of familiarity is increased relative to situations when items are not unitized (Ecker, Maybery, & Zimmer, 2013; Giovanello, Keane, & Verfaellie, 2006; Kan, et al., 2011; Kuo & Van Petten, 2008; Mitchell, Johnson, Raye, & Green, 2004; Quamme, Yonelinas, & Norman, 2007; Rhodes & Donaldson, 2007; Rhodes & Donaldson, 2008; Wilton, 1989). Improvements in memory due to unitization have been observed within perceptual or feature binding, when information that is a direct feature of the stimuli (e.g., color of the item or voice of speaker) is better remembered than external features (Ecker, et al., 2013; Kan et al., 2011; Kuo & Van Petten, 2008; Mitchell, et al., 2004; Wilton, 1989). It has also been observed in semantic domains, such as novel-word pairs, with pairs that can be semantically integrated being shown to be easier to remember than those

which cannot be integrated (Giovanello, et al., 2006; Quamme, et al., 2007; Rhodes & Donaldson, 2007). These are elaborated upon below.

Perceptual Binding with Unitization. As alluded to above in the Yonelinas face study, one area in which to-be-remembered pieces of information are naturally processed in a holistic manner is perceptual feature binding. To-be-remembered items may be comprised of intra-item features such as features that are direct aspect of the item itself (e.g., color, shape, format, voice) but may also contain extra-item features such as features that are integral to the item, but not a direct aspect of the item (e.g., spatial location, background, other nearby items, or temporal order; Moscovitch, 1992). Memory performance for intra-item perceptual features is better than extra-item perceptual features (Ecker, et al., 2013; Kan et al., 2011; Kuo & Van Petten, 2008; Mitchell, et al., 2004; Wilton, 1989). For example, when presented with colored shapes (intra-item) on black & white backgrounds versus black & white shapes on colored backgrounds (extra-item), participants are better able to recognize the colored shapes (Wilton, 1989). Likewise, when presented with colored items or items surrounded by a colored border, participants are better able to remember the color if it was an intra-item feature (Kuo & Van Petten, 2008). This same phenomena has been shown with features other than color, as when the format of items (e.g., pictures or words, intra-item) and the location of the items (extra-item) are manipulated participants are more likely to remember the format than location (Mitchell, et. al., 2004). Intra-item binding does not need to be intentional (Ecker, et. al., 2013) and can occur with more than one individual item (Kan et al., 2011). The most critical characteristic of intra-item binding is that features are processed as one coherent object, allowing the unitization of features as a single entity during encoding.

Semantic Binding with Unitization. Similar to perceptual binding, holistic processing can also occur with semantic binding, such as manipulations to the processing of word pairs. Giovanello, et al., (2006), found that when word pairs were presented as either compound word pairs (e.g., RAIN – BOW) or unrelated pairs (e.g., RAIN – FORK), participants were better able to remember the compound word pairs. Extending this finding, Rhodes & Donaldson (2007), found that word pairs that are known to be associated (e.g., TRAFFIC – JAM) are more readily remembered than pairs that are simply semantically related (e.g., CEREAL – BREAD). In both of the above studies it was also found that the words pairs that were more easily remembered (i.e., compound word pairs and associated word pairs) expressed a greater contribution of familiarity when being recalled. Holistic processing of novel words pairs can also be induced under certain manipulations (Quamme, et. al., 2007). When presented with novel word pairs such as CLOUD – LAWN, subjects were given sentences that either promoted holistic processing (e.g., a cloud lawn is a grassy area used for sky gazing) or that kept the words separate (e.g., while the boy laid in the lawn, he looked up at the clouds). When the word pairs were encouraged to be encoded holistically, the contribution of familiarity increased during recall, however memory performance was equal across conditions.

Unitization as a Strategy

The studies described above all promoted unitization through the manipulation of stimulus properties. However, familiarity can also be heightened through unitization in the form of participant initiated strategies (Rhodes & Donaldson, 2008). It has been shown, in adults, that visual imagery is a useful memory strategy that improves memory performance on relational memory tasks more than overt strategies such as rehearsal

(Bower, 1970; McGee, 1980). Visual imagery has been used to promote unitization and in doing so, increase familiarity in non-unitized stimuli. For example, Diana, et al. (2008) tasked participants with remembering a word and the background color on which it was presented. Participants in the unitized condition were instructed to visualize a situation in which the item would be the color of the background. In contrast, participants in the non-unitized condition were instructed to visualize the item associated with another item the color of the background (e.g., a stop sign if the background was red and a dollar bill if the background was green). Results showed that although no statistical difference was observed in the ability to discriminate old from new items or the background color of the items between conditions, participants in the unitized condition showed a significant increase the contribution of familiarity to recall, as shown by ROC curves (see also Bastin, et al., 2013).

Memory Development

Previous research has shown that performance on relational memory tasks improves throughout childhood (Bemis & Leichtman, 2013; Drumme & Newcombe, 2002; Fandakova, Shing, & Lindenberger, 2013; Lloyd, Doydum, & Newcombe, 2009; Lorschach & Reimer, 2005; Riggins, 2014; Scarf, Gross, Colombo, & Hayne, 2013; Yim, Dennis, & Sloutsky, 2013). For example, when tasked with remembering items, backgrounds, and item + background combinations, 4-, 6-, & 8-year-old children showed no differences in their abilities to remember items or backgrounds. However, the ability to remember item + background pairs, improved with age (Sluzenski, et. al., 2006). Likewise, when the same aged children were tested on a novel fact paradigm that required remembering new facts along with who taught the facts, no age-related

differences were observed in memory for the facts, but age-related improvements were observed in memory for who taught the facts (Drummey & Newcombe, 2002). In fact, a subsequent longitudinal study examining change between 4-10 years, pinpointed the period between 5- to 7-years of age as showing the most dramatic improvements in relational memory (Riggins, 2014). Gradual improvements continue into adolescence, particularly on difficult relational memory problems such as binding multiple items to locations on a grid (Lorsbach & Reimer, 2005).

The results of the above studies exploring the development of relational memory are consistent with studies exploring the development of familiarity and recollection. Billingsley, Smith, & McAndrews (2002), used a remember/know paradigm and observed changes in recollection from childhood (8-10 years of age) to adulthood, but no changes in familiarity. Likewise, in two conjoint-recognition studies exploring the development of familiarity and recollection, it was found that from early childhood to late childhood (5- to 11-years of age) recollection improved, where familiarity did not change (Brainerd, Holliday, & Reyna, 2004). When testing 6-, 8-, 10-, 12- and 14- year old children using ROCs, Ghetti and Angelini (2008) observed that recollection improved throughout all age groups, whereas familiarity did not (when sufficient processing time was given, see Ghetti & Angelini; 2008 for details). This supports the notion that familiarity is relatively mature by early childhood (i.e., 6 years of age), however, recollection continues to develop into adolescence (Brainerd, et al., 2004; Ghetti & Angelini, 2008).

Together, studies above suggest protracted development of recollection between middle childhood and adolescence, but relative maturity of familiarity during this time. It

is possible that if a mechanism was used to increase reliance on familiarity during this period, it may improve children's relational memory by increasing the contribution of this relatively more mature processes. One proposed mechanism is unitization through visual imagery. Below, it will be discussed how unitization has been used to improve relational memory performance in populations similar to children.

Increasing Memory Performance in Special Populations

It is reasonable to suggest that unitization may boost relational memory performance (by increasing the contribution of familiarity) in young children who do not have fully developed recollection, as these strategies have been shown to improve performance in populations in which recollection has been compromised. First, in a case study, visual unitization strategies in which perceptual items were combined into a single visual image were shown to improve associative memory in an amnesiac with temporal lobe damage (Ryan, Moses, Barense, & Rosenbaum, 2013). Second, Quamme et al. (2007) tested patients with amnesia due to hippocampal lesions and hypoxia on their ability to learn novel word pairs with a sentence unitization strategy. Hypoxics, known to have deficits in recollection but not familiarity, benefited from the unitization strategy due to the increases in familiarity. Those with hippocampal lesions, known to have difficulty with both familiarity and recollection, however, did not benefit from the strategy. This work emphasizes the need for intact familiarity processes in order for unitization to be beneficial in increasing relational memory performance in those with compromised recollection.

Third, elderly adults have also been shown to benefit from unitization strategies. It is well documented that elderly adults experience declines in episodic memory. The

associative deficit hypothesis proposes that elderly adults have intact item memory, but have difficulty with relational memory tasks that require binding (for review see Naveh-Benjamin, 2000). When learning novel words pairs, creating sentences that unitized the words during encoding reduced the associative deficit in older adults (Naveh-Benjamin, Brav, & Levy, 2007). Likewise, Bastin et al. (2013) trained younger and older adults in using a visual unitization strategy to remember words and the background color on which they were presented. Under this condition participants generated an explanation for why the word would be the color of the background and then visualized their explanation. Age-related differences in relational memory were decreased with the unitization strategy, and ROC analysis showed that for the older adults, the contribution of familiarity was increased with unitization. It is important to note however, that unitization only increased relational memory performance for trials in which participants rated their explanations as easy to visualize. This emphasizes the importance of the visualization and not just the explanations when using a visual unitization strategy (Bastin, et al., 2013).

Unitization in Childhood

Based on research in adults showing improvements in relational memory performance, younger children may also benefit from a unitization strategy on relational memory tasks. Specifically, the hypothesis is that because familiarity has been shown to reach maturity earlier in development, unitization strategies may improve children's relational memory as it will increase reliance on relatively mature familiarity abilities. The direct question has not been empirically tested, however, there is some evidence that provides indirect support for this hypothesis. For example, the same patterns of enhanced relational memory for intra-item perceptual details such as a colored shapes compared to

extra-item perceptual details such as a colored borders, that are seen in adults, are observed in children as young as 5 years old (Hale & Piper, 1973; Spiker & Cantor, 1980). Although memory strategies show significant development from preschool to elementary school years, there is also support for the notion that children as young as 4 years of age can utilize memory strategies after training (for review see Schneider & Sodian, 1997). For visual imagery strategies specifically, children as young as 5 years old have been to be capable of using visual imagery strategies after training and having them improve memory performance (Ryan, Ledger, & Weed, 1987).

Current Study

The goal of the present study was to determine if using a visual unitization strategy will improve performance on an associative memory task in children. Although this strategy has been used to boost relational memory performance in adult populations, it has yet to be tested in children. Two groups of children, 6-year olds and 8-year olds, were brought to the lab. These age groups were chosen because they both have fully development familiarity process, while the 8-year olds have substantially more developed recollection processes (Ghetti & Angelini, 2008). Children will be presented with common animals and items printed in black and white surrounded by either a red or yellow border. The encoding strategy will be manipulated between-groups in order to limit carry-over effects from one strategy to the other. One group will be trained on a visual unitization strategy (*Unitization* group) and the other will be trained on interactive visualization strategy (*Non-Unitization* group). During retrieval, children will be shown only the black & white images and will be asked to remember if the image's border was red or yellow and to make a confidence judgment on that decision. Confidence judgments

will be used to construct ROCs curves and determine the relative contribution of familiarity and recollection for each group. Children have been shown to make accurate self-memory judgments by 5 years of age and ROCs curves have been constructed to observe the relative contribution of familiarity and recollection for children as young as 6 years of age (Ghetti & Angelini, 2008; Roebbers, Gelhaar, & Schneider, 2004). It was predicted that relational memory differences between the younger and older children would be decreased by the visual unitization strategy due to the increased contribution of familiarity, which was thought to be mature in both groups.

Chapter 2: Method

Participants

A total of 84, 6- and 8-year old children recruited from the University Infant and Child Studies Database. Children were assigned to the four experiment groups: *Unitized* 6-year old (n = 21), *Non-Unitized* 6-year old (n = 19), *Unitized* 8-year olds (n = 19), and *Non-Unitized*

8-year olds (n = 21). This sample size was determined from a power analysis with parameter estimates based on the results of Diana, et al. (2008). To ensure all children were capable of understanding the task instructions and completing the task, participants with known developmental disorders, who were colorblind, or who heard English less than 50% of the time were excluded from participation. Parents provided informed consent for all participants and 8-year-old children also provided written assent. All children received a small gift for participating.

Materials

Training stimuli. Four black and white images from the Snodgrass & Vanderwart (1980) line drawings were used for the training portion of the study. These images were standardized, contain common objects and animals, and had been frequently used with children of similar ages to the present study (e.g., Cycowicz, Friedman, & Duff, 2003; Lloyd, et al., 2009). The images were printed on standard stock paper. Two of the images were surrounded by a red border and two were surrounded by a yellow border. Colored images of a red apple and a yellow school bus were laid on the desk within all children's view. Red and yellow crayons were provided to ensure the children understand the task.

Encoding stimuli. An additional 120 black and white images from the Snodgrass and Vanderwart (1980) line drawings were used for the encoding portion of the task. All images were presented on a computer monitor to keep exposure as consistent as possible between subjects. Half of the images were surrounded by a red border and half by a yellow border. All images were adjusted to be similar in size and as centered as possible within the border. The image-color pairings were counterbalanced between subjects and presented in random order. Stimulus presentation and randomization was programmed with E-Prime® 2.0 (Psychology Software tools). Participants' verbal responses during the encoding phase were recorded using an OLYMPUS digital voice recorder VN-8100 PC.

Retrieval. During the retrieval portion the same images displayed during encoding were shown again except without the colored borders. A 3-point smiley face confidence scale was presented at the bottom of the screen to aid children in their confidence decision. Similar scales have been used in previous research with children of this age and have been shown to aid in helping children make accurate memory judgments (Roebbers, et al., 2004). To ensure consistency across participants, all verbal responses were recorded by the experimenter with a standard keyboard.

Procedure

This study took place in 1 session that lasted approximately an hour and a half. The session consists of three portions: (1) training to ensure participants understood the task (2) encoding, and (3) retrieval. The procedure was modified from the methods of Diana, et al. (2008) to be appropriate for use with children. Between the encoding and retrieval portions participants received a 10 minute snack break. The study was explained

to the participants as a story-telling exercise. Participants were randomly assigned to either the *Unitization* or *Non-Unitization* group. Participants in the *Unitization* group used a visual unitization strategy, imagining the pictured item the color of the border. Participants in the *Non-Unitization* group also used a visualization strategy, but no unitization, imagining the pictured item with another item the color of the border. The University Institutional Review Board approved all of the following methods (see Appendix A).

Training. To ensure participants fully understood the directions of the task, they participated in a brief training session. First, participants were trained in how to visualize. Participants were instructed to close their eyes and picture in their mind a red apple. They were told basic features of an apple to aid the visualization process and then opened their eyes and a printed image of an apple was revealed. Participants were asked to confirm if what they pictured in their minds looked similar to the image. This process was repeated with a yellow school bus.

Once successful visualization of the red apple and yellow school bus were established, participants were trained on the specific visualization instructions for their randomly assigned condition. All subjects were presented with 4 training stimuli, an elephant with a red border, a shirt with a yellow border, a yoyo with a red border, and a butterfly with a yellow border. Participants in the *Unitized* condition were instructed to come up with a story for why the pictured item might be the color of the border. They were informed that the stories did not need to be realistic and they could be as creative as they wanted. Children who struggled during the practice were provided with example stories to use as a guide. After the children had provided their story, they were told to

visualize the story in the same manner in which they visualized the apple and school bus. Participants were asked what color the item they were picturing was. Then, participants were given the red and yellow crayon, and asked to color the printed stimuli the way they pictured it. Participants passed the practice trial if they completed coloring in the image with the correct color. Participants were given feedback if they did not fully color in the image. This process was repeated for all 4 training items. If by the end of the 4 trials participants had not correctly colored any of the stimuli, they were excluded from analysis. A total of 4 children were excluded, 1 for not passing the practice trials, and 3 who refused to complete the task.

Participants in the *Non-Unitized* group completed the same training as those in the *Unitized* group, with the exception that they were instructed to come up with a story for why the pictured item would be with another item the color of the border. The associated items for the red and yellow border were an apple and a school bus. After the child gave their story, they were told to visualize their story like they did with the apple and school bus during training. Participants were then given a red and yellow crayon to color the printed stimuli the way they pictured it. Participants were corrected if they did not draw the correct associated item next to the stimuli. As in the *Unitized* condition, this process was repeated for all 4 training items and if by the end of the 4 trials participants had drawn the correct item next to the stimuli, they were excluded from analysis. The training portion lasted on average 6 minutes.

Encoding. After the training portion, participants began the encoding portion of the experiment. Participants were presented with stimuli from the same image set as those viewed during the training portion. The images remained on the screen for the length of

time it took the participants to come up with their story, in order to reduce the cognitive load during encoding (see Ghetti & Angelini, 2008 for rationale). Similar to the training, participants were instructed to come up with a story based on their condition, and then picture the story in their mind. Once the story and visualization were complete, the experiment moved on to the next stimulus. If children provided stories that were not appropriate for their given condition, they were corrected by the experimenter and asked to try again. This process continued for 120 stimuli and lasted on average 35 minutes.

Retrieval. The retrieval portion began approximately 10 minutes after the encoding portion had ended. Participants again viewed the images they saw during encoding, but during retrieval all images were presented with no border. Participants were first instructed to respond whether the image was originally presented with a red or yellow border. Once the color judgment had been made, participants rated their confidence of that judgment on a 3-point scale. A smiley face scale was provided to aid the children in their judgments. A happy face represented a 3, very confident, a neutral face will represented a 2, a little confident, and a confused face will represent a 1, not confident or guessing. Participants were told to use the entire scale in their judgments. The retrieval portion last on average 17 minutes.

Hypotheses

Hypothesis 1: 8-year-old children will recall the correct color for items more often than 6-year-old children

Hypothesis 2: Children will benefit from a visual unitization strategy and those in the *Unitization* group will recall the correct color for items more often than those in the *Non-Unitization* group.

Hypothesis 3: 8-year-old children in the *Non-Unitization* group will perform better than the 6-year-old children in the *Non-Unitization* group due to the need for recollection, whereas no difference will be present between the two unitization groups due to the increased contribution of familiarity.

Hypothesis 4: ROCs analyses will show that the visual unitization strategy leads to a greater contribution of familiarity compared to an interactive visualization strategy as observed with greater curvature for the ROC in the *Unitization* group.

Hypothesis 5: Parameter estimates of recollection will be greater for 8-year-old children than 6-year-old children, but equal across conditions.

Hypothesis 6: Parameter estimates of familiarity will be greater for participants in the *Unitized* condition than the *Non-Unitized* condition

Chapter 3: Data Analytic Approach & Results

All analyses consisted of a model comparison approach utilizing Bayes Factors within the ANOVA framework (Rouder, Morey, Speckman, & Province, 2012). This approach provides an index of how well the data support are particular model, allowing for claims to be made regarding null effects. Bayes Factors greater than 1 represent greater support for the alternative hypothesis, whereas Bayes Factors less than 1 represent greater support for the null hypothesis. Table 1 summaries potential interpretations of the strength of various Bayes Factors (Jeffreys, 1961).

Table 1: Bayes Factor Interpretations (Jeffreys 1961)

	For Null	For Alternative
Weak Support (Uninformative)	.33 – 1	1-3
Substantial Evidence	.10 - .33	3-10
Strong Evidence	.03 - .1	10 - 30
Decisive Evidence	<.01	>100

Differences in memory performance. A measure of children’s ability to discriminate the correct from incorrect color (d'), regardless of confidence rating, served as the dependent variable for the comparison of groups. Main effects of Age (Hypothesis 1), Condition (Hypothesis 2) and an Age * Condition interaction (Hypothesis 3) were tested against a null model. Due to suggestions from past developmental work (Lloyd, et

al., 2009), proportion of items with the color correct and color incorrect were also analyzed separately.

The number of color correct items, color incorrect items, and d' for each group are presented in Table 2. Overall the data regarding differences in memory accuracy were non-informative, as all results provided only weak support for the hypothesized effects (Hypotheses 1-3). d' : main effect of Age ($BF_{10} = 1.19$), main effect of Condition ($BF_{10} = 1.61$), interaction ($BF_{10} = 0.65$). Source correct: main effect of Age: ($BF_{10} = 0.58$), main effect of Condition ($BF_{10} = 0.65$), interaction ($BF_{10} = 0.39$). Source incorrect: main effect of Age: ($BF_{10} = 0.79$), main effect of Condition ($BF_{10} = .90$), interaction ($BF_{10} = 0.48$).

Table 2: Behavioral results for all groups, M(sd)

	Color Correct	Color Incorrect	d'
6-year-olds			
Unitized	75.3 (10.0)	24.6 (10.0)	1.44 (.65)
Non-Unitized	77.5 (11.1)	22.5 (11.1)	1.60 (.72)
8-year-olds			
Unitized	77.3 (10.0)	22.7 (10.0)	1.57 (.65)
Non-Unitized	83.1 (13.1)	15.6 (13.3)	2.19 (.97)

State Trace Analysis. Before exploring the contribution of recollection and familiarity, State-Trace Analysis was performed to determine if patterns in the data seemed to be driven by multiple underlying processes. State-Trace analysis provides a visual method for determining whether separate experimental tasks rely on the same underlying cognitive systems. Graphs depict the covariation of two dependent variables based on independent variables of interest. State traces are fit to the covariation curves. If state traces fall along a single curve, it can be expected that experimental condition rely

on the same, likely singular process. If, however, state traces lay on differing curves, it can be concluded that they rely on differing underlying processes. It should be noted however these interpretations are debated within the field (see Ashby, 2014; Dunn, Kalish, & Newell, 2014). For the present study, state trace curves were fit to the covariation of the proportion of color correct items and confidence levels for children in the *Unitized* and *Non-Unitized* conditions (See Figure 1). As can be seen, the two traces fall along differing paths suggesting that children in the *Unitized & Non-Unitized* condition were relying on differing underlying processes during retrieval.

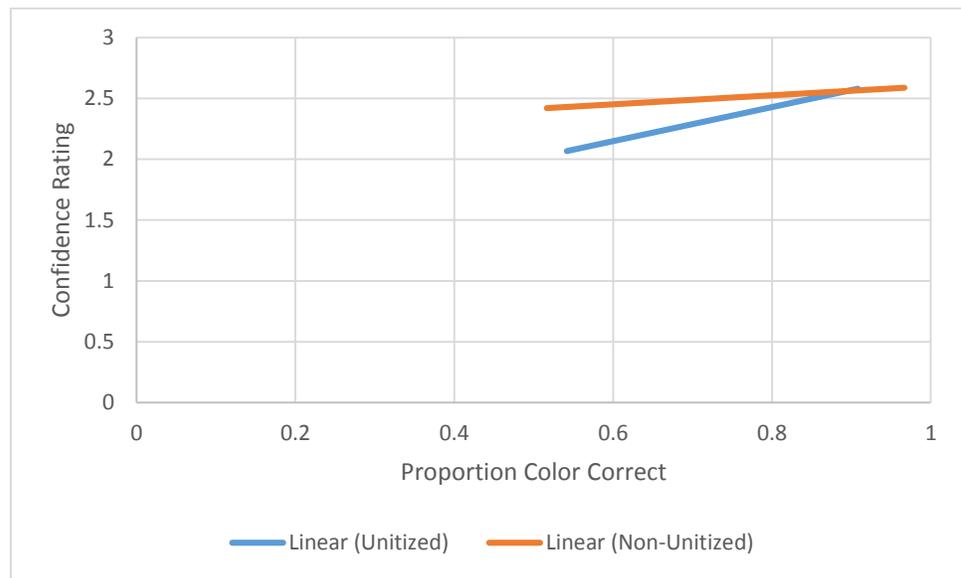


Figure 1. State-traces for the *Unitized* and *Non-Unitized* conditions collapsed across age.

Contribution of familiarity & recollection. To determine if the conditions differed in the contribution of familiarity (Hypothesis 4), Receiver Operating Characteristics (ROCs) were constructed for individual subjects (see Figure 2). For a review of ROC analyses see Yonelinas & Parks (2007). ROCs compare the proportion of color correct to color incorrect responses at different levels of confidence. Participants' 3-

point confidence judgments within each color were combined to create a 6-point scale ranging from Very confident yellow (1) to Very confident red (6). The proportion red and yellow responses were taken cumulatively for each confidence level starting at 6 through confidence level 2, for a total of 5 points. In this way, the cumulative proportion of yellow responses were plotted on the x-axis and cumulative proportion of red responses are plotted on the y-axis similar to proportions of false alarms and hits plotted in traditional ROCs of recognition memory. Confidence levels of 1 are not plotted because they always result in a proportion of 1.0 for both cumulative red and yellow responses.

Linearity Analysis. Once individual's plot were made, linearity analyses were performed. First, polynomial trend lines were fit to each individual's ROCs. The 2nd order coefficient values were recorded for each polynomial trend line (*Unitized* $M(sd) = -2.65 (4.28)$, *Non-Unitized* $M(sd) = -4.00 (2.95)$). Based on the assumption that increasing the contribution of familiarity increases the curvature of the fit-line, the mean 2nd order coefficient served as an index of the level of familiarity contributing to retrieval. Model comparisons were run comparing a model with a main effect of condition to a null model to examine differences in the second-order polynomial term from the linearity analysis (Hypothesis 4). Results were uninformative ($BF_{10} = .74$).

Parameter Estimates. To complement the above linearity analysis, estimates of familiarity and recollection were derived by fitting a dual-process model of memory to the individual ROCs (Yonelinas, 1994; 1997). Under the dual process model, the probability of a source correct response can be defined as the probability an item is recollected as the target color plus the probability that it is not recollected as the target color, but is familiar enough to fall above the threshold level.

$$P(\text{Source Correct}) = R_t + (1-R_t)\phi(d'/2-c_i)$$

In the above equation, R_t represents the recollection estimate of the target color (for the purposes of this paper, red), d' represents the familiarity estimate, c represents a specific criterion level (e.g., confidence level), and ϕ is a function representing the cumulative proportion of responses exceeding a response criterion. The probability of a false alarm, however, is represented as the probability that an item is not recollected as the lure color (for the purpose of this paper, yellow), but is familiar enough to fall above the threshold level.

$$P(\text{Source Incorrect}) = (1-R_l) \phi(-d'/2c_i)$$

These two equations can then be combined to give an overall representation of memory performance.

$$P(\text{Source Correct}) - P(\text{Source Incorrect}) = R_t + (1-R_t)\phi(d'/2c_i) - (1-R_l)\phi(-d'/2c_i)$$

By using a sum of squares search algorithm, this model can be fit to an individual's ROC points. The algorithm finds the best fit of the model by finding the parameters that result in the smallest sum of squares error assuming variance in both hits and false alarms. Specifically, the algorithm finds the parameter estimates for the three free parameters (R_t , R_l , and d') that minimize the distance between the observed known parameters (Source correct rate, Source Incorrect rate, and criterion levels) and those predicted by the model. This results in probability recollection terms that can vary from 0 to 1, and a d' familiarity term that typically varies from 0 to 4. The recollection and familiarity terms were compared between age groups and conditions (Hypotheses 5 & 6) using model comparisons and Bayes Factors (see Table 3)

For the estimates of recollection (Hypothesis 5), effects of Age, Condition and their interaction were compared against a model including only color. There was substantial support for the null in all cases, Age ($BF_{10} = .17$), main effect of Condition ($BF_{10} = .20$), interaction ($BF_{10} = .32$). There were no differences in the contribution of recollection to retrieval between age groups of conditions.

For the estimates of familiarity (Hypothesis 6), effects of Age, Condition, and their interaction were compared against a null model. Again, all results were uninformative, main effect of Age ($BF_{10} = .82$), main effect of Condition ($BF_{10} = .68$), interaction ($BF_{10} = .89$).

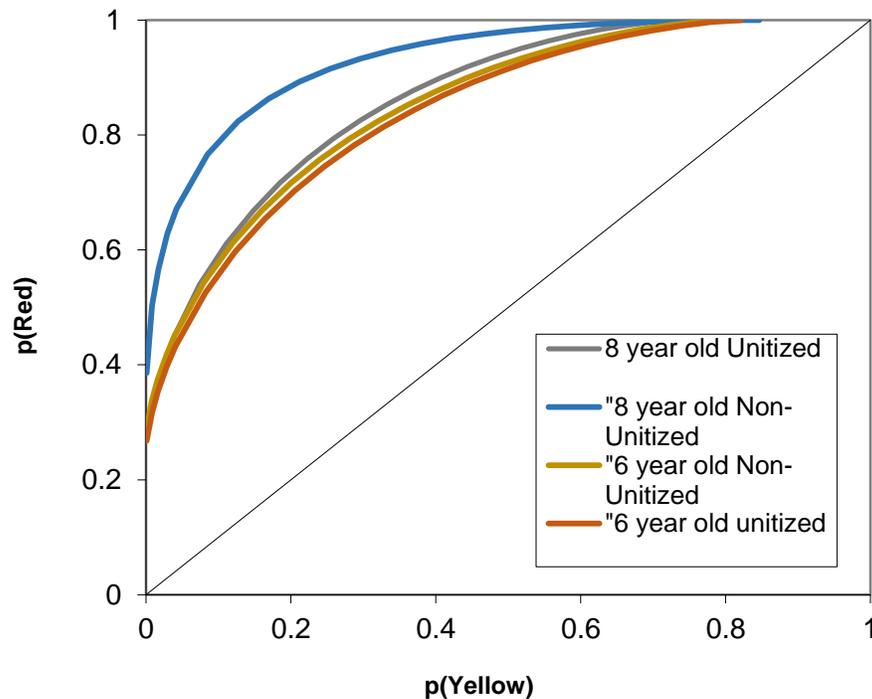


Figure 2. ROC curves for each of the four conditions.

Table 3. Estimates of Familiarity and Recollection, M(sd)

	Familiarity	Recollection (red)	Recollection (Yellow)
6-year-olds			
Unitized	0.93 (.82)	0.26 (.24)	0.18 (.19)
Non-Unitized	0.95 (.84)	0.28 (.26)	0.28 (.24)
8-year-olds			
Unitized	0.98 (.69)	0.26 (.27)	0.26 (.23)
Non-Unitized	1.66 (1.28)	0.33 (.28)	0.15 (.23)

Chapter 4: Discussion

The goal of the present study was to determine if using a visual unitization strategy would improve children's performance on a relational memory task. It was hypothesized that all young children would benefit from a visual unitization strategy, but that 6-year olds would benefit more than 8-year olds. Specifically, based on previous literature that suggests that a visual unitization strategy can increase the contribution of familiarity (Diana, et al., 2008), and that increasing the contribution of familiarity leads to improved memory performance in populations with 'deficits' in recollection (Bastin, et al., 2014; Ryan, et al., 2013), it was expected young children would benefit greatly from this strategy. The hypothesized effects, however, were dependent on the visual unitization strategy increasing the contribution of familiarity in the *Unitized* condition relative to the contribution of familiarity in the *Non-Unitization* condition (Hypothesis 4 & 6). Results, however, were inconclusive regarding differences in the contribution of familiarity to these two conditions regardless of the method of analysis (i.e., linearity analysis or model fit estimates). Unfortunately, since subsequent behavioral differences were dependent upon the *increased* contribution of familiarity to the *Unitized* condition, all results regarding differences in memory performance were also inconclusive (Hypotheses 1-3). The only test obtaining substantial support was the test of differences in the contribution of recollection, which supported no differences between Age groups or Conditions (Hypothesis 5). The lack of differences between conditions was expected, but the lack of differences between age groups is contrary to previous findings (See Ghetti & Angelini, 2008)/.

As reviewed in the Introduction, previous studies in adults using similar methods as the present study have found significant differences in the contribution of familiarity to unitized and non-unitized conditions (Diana et al., 2008; Diana, et al., 2011; and Bastin, et al., 2013). Specifically, in all of these studies and the present study, subjects were instructed to either visualize the stimuli in the specified color, or with another object of the specified color. However, one primary difference between the present study and the previous work however is that the past work was analyzed with null hypothesis significance testing whereas the present study used Bayesian analysis. To confirm there was an effect to replicate, a Bayesian meta-analysis was run combining the three previous studies (Rouder & Morey, 2011). Results suggest strong support for an effect in adult populations ($BF_{10} = 362.96$).

Despite the similar methodological approach between the present study and previous research, there were small methodological differences that may contribute to the inconsistent findings. First, past studies presented words on colored backgrounds, while the present studied presented pictures with colored borders. This decision was made so that younger children were not affected by less developed reading skills, however the use of picture rather than words may have impacted the visualizations. Second, directions for the *Non-Unitized* condition differed from previous research in adults. Adults were instructed to have the targeted item “*associated*” with another item the color of the background, whereas children were instructed to have the target item ‘*interact*’ with another item the color of the background. In the present study, the word ‘associated’ was removed as it was thought to be too challenging for young children. However this

difference in instructions may have caused the children's *Non-Unitized* condition to in fact be unitizing the items relative to the adult instructions.

Aside from these methodological differences, another substantial difference was the populations of interest. Although the manipulation has been successful with adult populations, children are known to use different underlying processes or neural substrates to accomplish the same tasks (e.g., Goldman & Alexander, 1977). Even if the children are unitizing, the skill is likely still developing and maybe be occurring through different mechanisms. In addition, children's visualization skills may also differ from adults as they are still developing. Although visualization has been shown to improve children's memory performance as young as 5 years-of-age, the strategy has been shown to benefit older children more than younger children (Pressley, 1977). What is unknown however, is if improvements are due to changes in how children use the strategy (production deficiencies; Miller & Seier, 1994) or changes in the underlying process necessary for the strategy to be successful (utilization deficiencies; Miller, Seier, Barron, & Probert, 1994). Given the age of the children in the present study, production deficiencies are likely. Even though these children are capable of benefiting from strategy use, they may not use strategies spontaneously. Although strategy use was monitored during encoding, no reference to the visualization was made during retrieval and therefore children may not have benefited from the strategy at that time.

The present study set out to determine if children's relational memory performance could be improved by using a strategy that was thought to increase the contribution of the mature familiarity processes. Although, the manipulation was not successful in increasing the contribution of familiarity in a child population, this is still an

important area for future research. Young children are faced with many tasks requiring relational memory skills and would benefit from a strategy that reduces their relational memory failures. Future researchers should keep in mind however young children's memory strategy abilities, and provide guidance in using these strategies at all portions of the memory process.

Appendix A

Institutional Review Board Approval Letter



UNIVERSITY OF
MARYLAND

INSTITUTIONAL REVIEW BOARD

1204 Marie Mount Hall
College Park, MD 20742-5125
TEL 301.405.4212
FAX 301.314.1475
irb@umd.edu
www.umresearch.umd.edu/IRB

DATE: September 19, 2013

TO: Tracy Riggins
FROM: University of Maryland College Park (UMCP) IRB

PROJECT TITLE: [356056-4] Neurobehavioral investigation of memory development
REFERENCE #: 08-0612/2270
SUBMISSION TYPE: Continuing Review/Progress Report

ACTION: APPROVED
APPROVAL DATE: September 19, 2013
EXPIRATION DATE: October 18, 2014
REVIEW TYPE: Expedited Review

REVIEW CATEGORY: Expedited review category # 4, 6, & 7

Thank you for your submission of Continuing Review/Progress Report materials for this project. The University of Maryland College Park (UMCP) IRB has APPROVED your submission. This approval is based on an appropriate risk/benefit ratio and a project design wherein the risks have been minimized. All research must be conducted in accordance with this approved submission.

This submission has received Expedited Review based on the applicable federal regulation.

Please remember that informed consent is a process beginning with a description of the project and insurance of participant understanding followed by a signed consent form. Informed consent must continue throughout the project via a dialogue between the researcher and research participant. Federal regulations require each participant receive a copy of the signed consent document.

Please note that any revision to previously approved materials must be approved by this committee prior to initiation. Please use the appropriate revision forms for this procedure which are found on the IRBNet Forms and Templates Page.

All UNANTICIPATED PROBLEMS involving risks to subjects or others (UPIRSOs) and SERIOUS and UNEXPECTED adverse events must be reported promptly to this office. Please use the appropriate reporting forms for this procedure. All FDA and sponsor reporting requirements should also be followed.

All NON-COMPLIANCE issues or COMPLAINTS regarding this project must be reported promptly to this office.

This project has been determined to be a Minimal Risk project. Based on the risks, this project requires continuing review by this committee on an annual basis. Please use the appropriate forms for this procedure. Your documentation for continuing review must be received with sufficient time for review and continued approval before the expiration date of October 18, 2014.

Please note that all research records must be retained for a minimum of three years after the completion of the project.

References

- Asch, S. E., Ceraso, J., & Heimer, W. (1960). Perceptual conditions of association. *Psychological Monographs*, 75, whole No. 3. doi: 10.1037/h0093755.
- Ashby, F. G. (2014). Is state-trace analysis an appropriate tool for assessing the number of cognitive systems? *Psychonomic Bulletin & Review*, 21(4), 935-946. doi:10.3758/s13423-013-0579-x.
- Bastin, C., Diana, R. A., Simon, J., Collette, F., Yonelinas, A. P., & Salmon, E. (2013). Associative memory in aging: The effect of unitization on source memory. *Psychology and Aging*, 28(1), 275-283. doi: 10.1037/a0031566.
- Bemis, R. H., & Leichtman, M. D. (2013). I remember when you taught me that! Preschool children's memories of realistic learning episodes, 621, 603–621. doi:10.1002/icd
- Billingsley, R. L., Smith, M. L., & McAndrews, M. P. (2002). Developmental patterns in priming and familiarity in explicit recollection. *Journal of Experimental Child Psychology*, 82, 251-277. doi: 10.1016/S0022-0965(02)00007-3.
- Bower, G. H. (1970). Imagery as a relational organizer in associative learning. *Journal of Verbal Learning and Verbal Behavior*, 9, 529-533. doi: 10.1016/S0022-5371(70)80096-2.
- Brainerd, C. J., Holliday, R. E., & Reyna, V. F. (2004). Behavioral measurement of remembering phenomenologies: So simple a child can do it. *Child Development*, 75(2), 505–22. doi:10.1111/j.1467-8624.2004.00689.x
- Ceraso, J., Kourtzi, Z., & Ray, S. (1998). The integration of object properties. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 24(5), 1152-1161.

doi:10.1037//0278-7393.24.5.1152

Cycowicz, Y. M., Friedman, D., & Duff, M. (2003). Pictures and their colors: What do children remember? *Journal of Cognitive Neuroscience*, *15*(5), 759-68.

doi:10.1162/089892903322307465

Diana, R. A., Reder, L. M., Arndt, J. & Park, H. (2006). Models of recognition: A review of arguments in favor of a dual-process account. *Psychonomic Bulletin & Review*, *13*(1), 1-21. doi: 10.3758/BF03193807

Diana, R. a, Van den Boom, W., Yonelinas, A. P., & Ranganath, C. (2011). ERP correlates of source memory: Unitized source information increases familiarity-based retrieval. *Brain Research*, *1367*, 278–86.

doi:10.1016/j.brainres.2010.10.030

Diana, R. A., Yonelinas, A. P., Ranganath, C. (2007). Imaging recollection and familiarity in the medial temporal lobe: A three-component model. *Trends in Cognitive Sciences*, *11*(9), 379-386. doi: 10.1016/j.tics.2008.03.001

Diana, R. A., Yonelinas, A. P., & Ranganath, C. (2008). The effect of unitization on familiarity-based source memory: Testing a behavioral prediction derived from neuroimaging data. *Journal of Experimental Psychology: Learning, Memory & Cognition*, *34*(4), 730-740. doi: 10.1037/0278-7393.34.4.730

Drummey, A. B., & Newcombe, N. S. (2002). Developmental changes in source memory. *Developmental Science*, *5*(4), 502–513. doi:10.1111/1467-7687.00243

Dunn, J. C., Kalish, M. L., & Newell, B. R. (2014). State-trace analysis can be an appropriate tool for assessing the number of cognitive systems: A reply to Ashby

- (2014). *Psychonomic Bulletin & Review*, 21(4), 947-954. doi:10.3758/s13423-014-0637-y.
- Ecker, U. K. H., Maybery, M., & Zimmer, H. D. (2013). Binding of intrinsic and extrinsic features in working memory. *Journal of Experimental Psychology: General*, 142(1), 218–34. doi:10.1037/a0028732
- Fandakova, Y., Shing, Y. L., & Lindenberger, U. (2013). Differences in binding and monitoring mechanisms contribute to lifespan age differences in false memory. *Developmental Psychology*, 49(10), 1822–32. doi:10.1037/a0031361
- Ghetti, S., & Angelini, L. (2008). The development of recollection and familiarity in childhood and adolescence: evidence from the dual-process signal detection model. *Child Development*, 79(2), 339–58. doi:10.1111/j.1467-8624.2007.01129.x
- Ghetti, S., & Bauer, P. J., Editors (2012). *Origins and development of recollection: Perspectives from psychology and neuroscience*. New York, NY: Oxford University Press
- Giovanello, K., Keane, M., & Verfaellie, M. (2006). The contribution of familiarity to associative memory in amnesia. *Neuropsychologia*, 44(10), 1859-65. doi:10.1016/j.neuropsychologia.2006.03.004
- Goldman, P. S. & Alexander, G. E. (1977). Maturation of prefrontal cortex in the monkey revealed by local reversible cryogenic depression. *Nature*, 267(5612), 613-615.
- Graf, P. & Schacter D. L. (1989). Unitization and grouping mediate dissociations in memory for new associations. *Journal of Experimental Psychology: Learning, Memory & Cognition*, 15(5), 930-940. doi:10.1037/0278-7393.15.5.930

- Hale, G. A. & Piper, R. A. (1973). Developmental trends in children's incidental learning: Some critical stimulus differences. *Developmental Psychology*, 8(3), 327-335. doi:10.1037/h0034332
- Johnson, M. K., Hastroudi, S. & Lindsay, D. S. (1993). Source Monitoring. *Psychological Bulletin*, 144, 3-28. doi: 10.1037//0033-2909.144.1.3
- Kan, I. P., Keane, M. M., Martin, E., Parks-Stamm, E. J., Lewis, L., & Verfaellie, M. (2011). Implicit memory for novel associations between pictures: effects of stimulus unitization and aging. *Memory & Cognition*, 39(5), 778–90. doi:10.3758/s13421-011-0071-6
- Kensinger, E.A., Piquet, O., Krendl, A.C., and Corkin, S. (2005). Memory for contextual details: Effects of emotion and aging. *Psychology and Aging*, 20, 241-250. doi:10.1037/0882-7974.20.2.241
- Kuo, T. Y., & Van Petten, C. (2008). Perceptual difficulty in source memory encoding and retrieval: Prefrontal versus parietal electrical brain activity. *Neuropsychologia*, 46(8), 2243–57. doi:10.1016/j.neuropsychologia.2008.02.018
- Lloyd, M. E., Doydum, A. O., & Newcombe, N. S. (2009). Memory binding in early childhood: Evidence for a retrieval deficit. *Child Development*, 80(5), 1321–8. doi:10.1111/j.1467-8624.2009.01353.x
- Lorsbach, T. C., & Reimer, J. F. (2005). Feature binding in children and young adults. *The Journal of Genetic Psychology*, 166(3), 313–27. doi:10.3200/GNTP.166.3.313-328
- McGee, R. (1980). Imagery and recognition memory: The effects of relational organization. *Memory and Cognition*, 8(5), 394-399. doi: 10.3758/BF03211135

- Miller, P. H. & Seier, W. L. (1994). Strategy Utilization deficiencies in children: When, where why. *Advances in Child Development and Behavior*, 25, 107-156.
- Miller, P. H., Seier, W. L., Barron, K. L., Probert, J. S. (1994). What causes a memory strategy utilization deficiency? *Cognitive Development*, 9(1), 77-101.
doi:10.1016/0885-2014(94)90020-5.
- Mitchell, K. J., Johnson, M. K., Raye, C. L., & Green, E. J. (2004). Prefrontal cortex activity associated with source monitoring in working memory task. *Journal of Cognitive Neuroscience*, 16(6), 921-34. doi: 10.1162/0898929041502724
- Moscovitch, M. (1992). Memory and working-with-memory: A component process model Based on modules and central systems. *Journal of Cognitive Neuroscience*, 4(3), 257–67. doi:10.1162/jocn.1992.4.3.257
- Naveh-Benjamin, M. (2000). Adult-age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory and Cognition*, 26, 1170-1187. doi: 10.1037//0278-7393.26.5.1170
- Naveh-Benjamin, M., Brav, T. K., & Levy, O. (2007). The associative memory deficit of older adults: the role of strategy utilization. *Psychology and Aging*, 22(1), 202–8. doi:10.1037/0882-7974.22.1.202
- Pressley, M. (1977). Imagery and children’s learning: Putting the picture in developmental perspective. *Review of Educational Research*, 47, 585-622.
- Quamme, J. R., Yonelinas, A. P., & Norman, K. A. (2007). Effect of unitization on associative recognition in amnesia, 200(1), 192–200. doi:10.1002/hipo.20257
- Rhodes, S. M. & Donaldson, D. I. (2007). Electrophysiological evidence for the influence

- of the unitization processes engaged during episodic retrieval: Enhancing familiarity based remembering. *Neuropsychologia*, 45(2), 412-424.
doi:10.1016/j.neuropsychologia.2006.06.022
- Rhodes, S. M., & Donaldson, D. I. (2008). Electrophysiological evidence for the effect of interactive imagery on episodic memory: Encouraging familiarity for non-unitized stimuli during associative recognition. *NeuroImage*, 39(2), 873–84.
doi:10.1016/j.neuroimage.2007.08.041
- Riggins, T. (2014). Longitudinal investigation of source memory reveals different trajectories for item memory and binding. *Developmental Psychology*, 50(2), 449 – 59. doi:10.1037/a0033622
- Roebbers, C. M., Gelhaar, T., & Schneider, W. (2004). “It’s magic!” The effects of presentation modality on children’s event memory, suggestibility, and confidence judgments. *Journal of Experimental Child Psychology*, 87(4), 320–35.
doi:10.1016/j.jecp.2004.01.004
- Rouder, J. N., & Morey, R. D. (2011). A bayes factor meta-analysis of Bem’s ESP claim. *Psychonomic Bulletin & Review*, 18, 682-689.
- Rouder, J. N., Morey, R. D., Speckman, P. L., & Province, J. M. (2012). Default bayes factors in ANOVA designs. *Journal of Mathematical Psychology*, 56(5), 356-374.
doi:10.1016/j.jmp.2012.08.001
- Ryan, E. B., Ledger, G. W., & Weed, K. A. (1987). Acquisition and transfer of an integrative imagery strategy by young children. *Child Development*, 58(2), 443-452. doi:10.1111/j.1467-8624.1987.tb01392.x
- Ryan, J. Moses, S. Barense, M. & Rosenbaum, R. S. (2013). Intact learning of new

- relations in amnesia as achieved through unitization. *The Journal of Neuroscience*, 33(23), 9601-13. doi: 10.1523/JNEUROSCI.0169-13.2013
- Scarf, D., Gross, J., Colombo, M., & Hayne, H. (2013). To have and to hold: Episodic memory 3- and 4-year-old children. *Developmental Psychobiology*, 55(2), 125–32. doi:10.1002/dev.21004
- Schneider, W. & Sodian, B. (1997). Memory strategy development: Lessons from longitudinal research. *Developmental Review*, 17, 442-461. doi: 10.1006/drev.1997.0441
- Sluzenski, J., Newcombe, N. S., & Kovacs, S. L. (2006). Binding, relational memory, and recall of naturalistic events: A developmental perspective. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 32(1), 89–100. doi:10.1037/0278-7393.32.1.89
- Snodgrass, J. G. & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory*, 6(2), 174-215. doi: 10.1037//2078-7393.6.2.174
- Spiker, C. C. & Cantor J. H. (1980). The effects of stimulus type, training, and chronological age on children's identification and recording of multidimensional stimuli. *Journal of Experimental Child Psychology*, 30(1), 144-158. doi: 10.1016/0022-0965(80)90081-8
- Tibon, R., Vakil, E., Goldstein, A., & Levy, D. a. (2012). Unitization and temporality in associative memory: Evidence from modulation of context effects. *Journal of Memory and Language*, 67(1), 93–105. doi:10.1016/j.jml.2012.02.003

- Wilton, R. N. (1989). The structure of memory: Evidence concerning the recall of surface and background colour of shapes. *The Quarterly Journal of Experimental Psychology Section A*, 41(3), 579–598. doi:10.1080/14640748908402383
- Wolford, G. (1971). Function of distinct associations for paired-associate performance. *Psychological Review*, 78, 303-313. doi: 10.1037/h0031032
- Yim, H., Dennis, S. J., & Sloutsky, V. M. (2013). The development of episodic memory: items, contexts, and relations. *Psychological Science*, 24(11), 2163–72. doi:10.1177/0956797613487385
- Yonelinas, A. P. (1997). Recognition memory ROCs for item and associative information: The contribution of recollection and familiarity. *Memory & Cognition*, 25(6), 747–63. doi:10.3758/BF03211318
- Yonelinas, A. P. (2002). The nature of recollection and familiarity: A review of 30 years of research. *Journal of Memory and Language*, 46(3), 441–517. doi:10.1006/jmla.2002.2864
- Yonelinas, A. P. (1994). Receiver operating characteristics in recognition memory: Evidence for a dual-process model. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20(6), 1341-54. doi: 10.1037//0278-7393.20.6.1341
- Yonelinas, a P., Kroll, N. E., Dobbins, I. G., & Soltani, M. (1999). Recognition memory for faces: when familiarity supports associative recognition judgments. *Psychonomic Bulletin & Review*, 6(4), 654–61. doi: 10.3758/BF03212975
- Yonelinas, A. P. & Parks, C. M. (2007). Receiver operating characteristics (ROCs) in recognition memory: A review. *Psychological Bulletin*, 133(5), 800-32.

doi:10.1037/0033-2909.133.5.800