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Effects of Aging and Reward Motivation on Non-Verbal Recognition Memory

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EFFECTS OF AGING AND REWARD MOTIVATION ON NON-VERBAL RECOGNITION MEMORY

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EFFECTS OF AGING AND REWARD MOTIVATION ON
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I dedicate this thesis to my parents, Perry and Sherri Luttrell, who have dedicated their lives to making those of my sister and I better than we have ever deserved. I am grateful for your continuous encouragement and support throughout my education.

I also dedicate this work to my beloved fiancé, Tanner Greenwell. Your patience and support made all the difference while I was away at school. Although earning a Master's of Science brings me much pride, the title that I will find the most pride in holding is that of your wife.

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CONTENTS

EFFECTS OF AGING AND REWARD MOTIVATION ON
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There is a long history of research on the effects of reward motivation on memory, but there are still questions concerning how such motivational variables affect memory. In a study that examined the influence of reward anticipation on episodic memory, Adcock, Thangavel, Whitfield-Gabireli, Knutson, and Gabrieli (2006) found that memory was better for scenes preceded by high value reward cues than low value cues (see also Cushman, 2012; Spaniol, Schain, & Bowen, 2013). More recently, Castel, Murayama, Friedman, McGillivray, & Link (2013) observed that anticipation of reward influences selective attention to "to be remembered" (TBR) words and the memories that are formed in both younger (YA) and older adults (OA). Finally, in an examination of reward-motivated memory for both word items and pairs, Mutter, Luttrell, & Steen (2013) found that high reward enhanced associative memory for word pairs for both YA and OA. The theoretical explanation for this finding attributed word pair stimuli as promoting and high reward motivation as selectively enhancing relational encoding strategies for both OA and YA, producing reward effects for associative recognition performance only.

The present study conceptually replicated the methodology from Mutter, Luttrell, and Steen (2013) in an examination of how reward motivation at study affects non-verbal single item recognition and dual item recognition for picture pair stimuli. It was expected

that high reward will induce both YA and OA to engage in more extensive encoding of TBR information, but that, due to age-related associative deficits (e.g., Naveh – Benjamin, Hussain, Guez, & Bar-On, 2003), the type of encoded representations would differ for the two groups. YA would perform better than OA on the types of recognition that require memory for relational information (i.e., associative and context recognition), but YA and OA would perform equally well on the types of recognition that require memory for item-specific information (i.e., pair and no context recognition). As compared to the word pair stimuli used by Mutter and colleagues (2013), it was expected that picture pair stimuli would alternatively promote item-specific encoding strategies for both OA and YA and high reward would selectively enhance single item recognition performance.

CHAPTER 1

Introduction

The act of recognizing refers to the mental process of remembering a previous exposure to an object, event, or other target stimulus and appropriately perceiving it as "old" (Mandler, 1980). Recognition judgments are made thousands of times each day and are arguably the most adaptively valuable cognitive function available. However, some recognition judgments are much more difficult to make than others. There are a variety of different types of recognition memory and each has a different set of cognitive demands that are required to accurately make a recognition judgment.

Single item recognition. Conventional item recognition involves studying a list of individual stimuli and discriminating the individual items that were seen before from distractors that were not seen. Although similar to conventional recognition (Naveh-Benjamin, 2000), single item recognition is the ability to identify the previous exposure of a single stimulus that is presented together with another stimulus in a pair (Mandler, 1980). Items are both studied and tested as stimulus pairs (e.g., *chair* + *flower*) but test instructions require a recognition judgment of only one of the items in each pair (e.g., the item on the right). Single item recognition can be broken down into two sub-types: context and no context recognition (Clark, 1992, Humphreys, 1976). The sub-type of recognition performance that is measured depends on how the study items are combined in the test pairs that are presented (Humphreys, 1976).

Context recognition refers to a recognition judgment of an item made in the same context that it was learned. The studied items can either be presented in the same familiar context or a different unfamiliar context. At test, targets that are presented in the same context as studied (i.e., target is presented with an item it was paired with during study) must be discriminated from a new distractor item presented with an old item from study. When targets are presented in the same familiar context, participants can rely on context cues from the other stimulus in the pair to aid memory retrieval. This should enhance recognition performance for these items as compared to recognizing targets presented in a different unfamiliar context.

Another form of single item recognition is no context recognition. This refers to a recognition judgment of an item made in a different context than it was learned. At test, targets that are presented in a different context from that seen during study (i.e., target is presented with an item seen during study but not the item it was originally paired with) must be discriminated from new distractor item pairs that were not seen during study. In the former case, although the other item in the pair cannot act as context cue, a strong memory trace for the target can aid memory retrieval and discrimination. In the latter case, correct rejection should come easily as the participant has no experience with either of the stimuli in the test pair.

Dual item recognition. Dual item recognition is the type of recognition memory used most often in daily life, because much of what we learn is presented to us in pairs (Kausler, 1994). Consider that a name and a face, a word and a meaning, etc. initially were two seemingly unrelated pieces of information (i.e., there is nothing about a face that suggests the name “John”). However, after one or more learning trials, the two components become linked, one piece naturally cuing memory retrieval of the other (Humphreys, 1976; Kausler, 1994). In a dual item recognition test stimulus pairs are presented both at study and at test, and test instructions require recognition judgments regarding the state of each pair as a whole. Like single item recognition, dual item recognition can be broken down into two subtypes: associative and pair recognition (Clark, 1992; Clark & Shiffrin, 1992).

Associative recognition can be considered the more difficult of the two types of dual item recognition. At study, pairs of stimuli are presented (i.e., AB) and at test, intact pairs from study (i.e., AB) as well as rearranged combinations of pairs from study (i.e., AD) are presented. Because a dual item recognition test requires a judgment of the entire pair, only intact pairs should be endorsed as “old”. However, discriminating between these two types of test pairs requires strong associative memory traces for the stimulus pairs presented at study because all of the individual stimuli in the test pairs are familiar and have a common source. Therefore, if only information for the individual items were encoded and not information for the relationships between items in each pair, all rearranged test pairs would be inappropriately endorsed as “old”.

Pair recognition is considerably less difficult than associative recognition. At study, stimulus pairs are presented, and, at test, the pairs can either be presented as intact pairs from study (i.e., AB) or new distractor pairs that were not seen during study (i.e., XY). This “all or nothing” discrimination is made more easily because both of the stimuli in the pairs are either familiar or unfamiliar. Therefore, although information for the relationships is helpful, participants can rely on the memory traces for individual items and still make accurate recognition judgments.

Theoretical Considerations

Retrieval processes in recognition. Retrieval processes in recognition can best be described in terms of a dual process model that involves two complimentary retrieval mechanisms: recollection and familiarity. Recollection is a retrieval process that accesses both memory for an item and its source, or interitem information (Mandler, 1980). Recollection is characterized as a recapitulation or re-experiencing of the initial exposure to the target because memories of peripheral information, such as thoughts, emotional reactions, contextual details, and distractors, are retrieved along with the target (Mandler & Boeck, 1974). Upon the presentation of the cue, a retrieval check is engaged and scans multiple memory sources until a match is achieved. Upon achievement of a match for the target, the memory trace is retrieved. Along with the memory for the actual target, memory for peripheral information is also retrieved.

On the other hand, familiarity can best be described as intraitem memory, meaning that information about the details of specific items is accessed (Mandler, 1980). Unlike recollection, effective familiarity requires attention to distinctive information about a single item at encoding, such that memory for the item is highly detailed and independent of other pieces of information. This strategy integrates the details of the item into a cohesive memory trace (Mandler, 1980). Although this sounds much like the organization process involved in recollection, it should be noted that recollection retrieval processes involve integrating information about multiple sources of information into a memory trace (e.g., items in a list, context information, etc.), whereas familiarity retrieval processes involve integrating details of a single source of information into a memory trace. Familiarity is a rapid retrieval process that facilitates quicker recognition than recollection (Mandler & Boeck, 1974). It serves a discriminative function such that the experienced sense of familiarity must exceed a specific threshold of acceptability to facilitate a recognition judgment (Einstein & Hunt, 1980).

Neurological evidence for two recognition retrieval processes. Neurological evidence that supports recollection and familiarity as recognition retrieval processes typically focus on the medial temporal lobe (MTL) as the region of interest. The MTL is involved in memory-related processing from anticipation, encoding, storage, and retrieval (Adcock et al., 2006; Daw & Shohamy, 2008). The hippocampus, a central structure in the MTL, has a primary role in declarative memory formation and consolidation. More specifically, the hippocampus binds disparate pieces of information together (e.g., a location and food reward; background context and target item) into a single memory trace such that one piece of information can cue memory of the other (Danker & Anderson, 2010). For example, in spatial learning tasks, such as the win-shift radial arm task, require that rats consistently revisit previously baited arms to earn reward. Rats with hippocampal lesions do not learn the context dependency of the reward (Yin & Knowlton, 2004). Thus, the hippocampus is considered the critical structure for relational encoding and recollection retrieval processes in dual item recognition.

In a study that investigated the possible dissociation between MTL structures for memory for items and memory for associations, Davachi, Mitchell, and Wagner (2003) instructed participants to study and take a recognition test over a list of adjective and noun/verb word pairs while undergoing fMRI scanning. In support of previous findings, hippocampal activation at encoding was related to successful source memory, but not item memory, at test. Further, perirhinal activation at encoding was related to successful item memory, but not source memory, at test (Davachi et al., 2003). Thus, the perirhinal cortex is considered the critical structure for item-specific encoding and familiarity retrieval processes in single item recognition. These findings assert that within the MTL there is a clear dissociation between recollection and familiarity retrieval processes that are directly related to differences in activation patterns at encoding, presumably in parallel to employing different encoding strategies (Davachi et al., 2003).

Encoding and retrieval interactions in recognition. The type of information available when making recognition judgments depends on the way the information was encoded and stored into memory. When making recognition judgments, item specific and relational encoding strategies compete to aid formation of the previously discussed memory retrieval processes (Clark, 1992). Relational encoding refers to acquisition of information of similarities or relationships between events (Humphreys, 1976). Relational encoding improves source memory and recollection. Successful recollection is highly dependent upon effective organization and binding of multiple pieces of information into a single memory trace (Einstein & Hunt, 1980). Organizing and binding disparate pieces of information can be achieved through a variety of strategies that include, but are not limited to, focusing on similarities among the pieces of information, forming a sentence or story to include all pieces, and forming a mental image combining all information (Einstein & Hunt, 1980). The retrieval check that is performed during recollection facilitates the judgment of the target event as a function of the other pieces of information provided in the context (Humphreys, 1976). However, this type of information is only helpful in recognition judgments where the knowledge of the context is valuable. Relational information can impair performance when events are presented in a new, but familiar context, because the other events in the context are not reliable cues (Humphreys, 1976).

Relational encoding aids dual item recognition performance because knowledge of the association between the objects in a pair will aid both an associative and a pair recognition judgment (Humphreys, 1976). However, relational information is more essential for successful associative recognition because all of the stimuli in the test pairs are old. Thus, a strong memory trace for relational information is critical for the discrimination. If participants only used item-specific information to make associative recognition judgments, they would incorrectly recognize all stimulus pairs as intact pairs from the study phase and have a high false alarm rate at test. The relational information promotes effective discrimination between intact and rearranged test pairs (Humphreys, 1976; Naveh – Benjamin, 2000). Although this type of information is also valuable in pair recognition judgments, item-specific information can also be used to individually judge each item in the pair. This strategy would be effective only in pair recognition and not associative recognition because there are no rearranged items that require relational information, as the test pairs are either intact from study or new.

Item-specific encoding refers to acquiring distinctive, detailed information about individual objects (Clark, 1992; Humphreys, 1976). Item-specific encoding facilitates item memory and familiarity retrieval processes (Humphreys, 1976). Item specific encoding and familiarity occur in parallel and facilitate quick and accurate memory retrieval for individual items. Relational encoding is typically not adequate to make familiarity recognition judgments because items are not encoded in enough detail to make recognition judgments without contextual cues present to aid memory retrieval.

Item-specific information is most helpful for single item recognition tests, as the judgments are made regarding an individual item presented in the test pair. It is important for performance in context and no context recognition because in each situation correct recognition can be achieved through familiarity-based retrieval of information for the specific target without regard for the other item in the pair (Humphreys, 1976). However, for context recognition, relational encoding is also valuable because it is responsible for binding contextual details to the target (Humphreys, 1976). Therefore, in order to use context cues, these details must be encoded and bound to the target item at study. If not, they cannot aid memory retrieval.

There are other factors that influence whether information is encoded through relational or item-specific methods. The type of information that is to-be-remembered also has an influence (Humphreys, 1976). Some types of information are inherently more readily related than others. For example, words have semantic meanings that encourage interitem integration or binding of information through relational encoding strategies (Mandler, 1980). Word stimuli can easily be organized through strategies such as forming sentences that include all words in a list to set up a recollection retrieval plan. Picture stimuli, on the other hand, are highly distinctive and encourage intraitem integration through item-specific encoding strategies. Pictures are not as readily related to other pictures in a list as words. Instead, the details of each individual picture can be integrated into a distinctive memory for each item. This sets up a familiarity retrieval process such that the items will be recognized quickly and accurately, but without a strong representation for contextual information.

Although both recollection and familiarity have respective benefits for memory retrieval, the best item recognition performance can be found when using both processes. Einstein and Hunt (1980) induced either familiarity retrieval processes through instructing participants to rate the pleasantness of each word in a list, or recollection through instructions to organize words into categories, or both. The combination of both pleasantness ratings and word organization produced the best recognition performance (Einstein & Hunt, 1980). Therefore, these two functionally different retrieval processes compliment each other and optimize memory performance, one focusing on similarities among stimuli and one focusing on unique details of each stimulus.

Reward motivation. There are multiple contributing factors that combine to determine the efficacy of previously discussed encoding strategies on recognition memory. One of these factors is reward motivation. High reward motivation is considered a powerful modulator of behavioral change and adaptability across species. Early Behaviorists found that rewards promote the reoccurrence of targeted behaviors through studies of reinforcement learning. A more recent definition of reward motivation, specifically among cognitive psychologists, emphasizes that manipulating reward incentives induces different levels of effortful cognitive processing (Braver et al., 2014). In terms of recognition memory performance, as the reward for retention of a target stimulus increases (e.g., from $0.25 to $2.50), a congruent increase occurs in cognitive effort expended towards appropriate encoding strategies. Increasing cognitive effort subsequently increases the likelihood that the target will be recognized when cued.

Adcock, Thangavel, Whitfield-Gabireli, Knutson, and Gabrieli (2006) were among the first to investigate the effects of reward motivation on recognition performance. They used a monetary incentive-encoding (MIE) task to test young adults' (ages 18 – 35) item recognition for picture scenes under high and low reward motivation (i.e., reward-motivated item recognition). The task sequence included a randomly presented reward cue (high or low), a picture of a natural scene, and an inter-stimulus distractor task (Adcock et al., 2006). Participants studied the picture scenes for an upcoming test while undergoing fMRI imaging. If they correctly recognized a scene at test, they earned the reward that preceded it in the study phase. Adcock and colleagues found that high rewarded scenes were better recognized than low rewarded scenes and were accompanied with increased activation in various MTL cortical regions. It was speculated that high reward motivation functioned to enhance item recognition of picture stimuli through increased activation in brain regions responsible for memory formation at encoding (Adcock et al., 2006).

Age, recognition, and the associative deficit. Age is another contributing factor to the success of recognition memory performance. Early evidence for such age differences came from Willoughby's (1929) testing of adults of all ages on a task similar to the WAIS Digit Symbol and Digit Symbol Incidental Learning task (Wechsler, 1997). The Digit Symbol test provides a key of numbers from one to nine and a coordinating symbol for each (e.g., 9 = >). Participants spent two minutes writing the correct symbol next to a series of numbers by referencing the provided key. Following this task, the unexpected memory test, Digit Symbol Incidental Learning, is given and participants must try to remember the associated symbol for each number (Wechsler, 1997). In combination, these two assessments can act as a measure of associative learning and memory. An interesting trend in performance was found, such that, as the age of adults increased, their score on the associative memory task decreased (i.e., remembered fewer symbol – number matches at test), with decline starting as early as age 30. The performance of OA (i.e., ages 65 and older) was close to half the score of YA (i.e., ages 16 – 20). Although Willoughby lacked theoretical explanation for this trend, it is a clear reflection of the Associative Deficit Hypothesis (Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003).

Naveh-Benjamin, Hussain, Guez, and Bar-On (2003) examined age differences between younger and older adults in both item and relational or associative recognition. This landmark study discredited the common misconception that older people have poor memories, as it was found that older adults' performance for item recognition was strong and nearly equal to that of younger adults. However, older adults performed dramatically worse than younger adults on the associative recognition task (Naveh-Benjamin et al., 2003). Upon further investigation of possible contributing factors, it was determined that older adults experience an associative deficit that hinders the ability to form and retrieve associatively related pieces of information (Naveh-Benjamin, Brav, & Levy, 2007; Naveh-Banjamin, Craik, Guez, & Kreuger, 2005; Naveh – Benjamin, Guez, & Schulman, 2004). Thus, the deficit exhibited by older adults in associative recognition tasks is not likely due to peripheral disadvantages such as a lack of attentional resources, but rather an actual deterioration or inefficiency of critical memory structures in the brain (Morcom et al., 2009). This landmark finding is known as the Associative Deficit Hypothesis and has been consistently replicated across experimental designs and condition manipulations (Castel & Craik, 2003; Cushman, 2012; Naveh-Benjamin, 2000; Naveh-Benjamin, Brav, & Levy, 2007).

In terms of the previously discussed theoretical considerations, the associative deficit of older adults can be described more specifically as a deficit in relational encoding strategies that affects subsequent recollection retrieval processes. Howard, Bessette-Symons, Zhang, and Hoyer (2006) determined that older and younger adults scored equally on an item recognition test of travel photos. However, as detected by receiver operator characteristic (ROC) curve plots, the recognition performance of each age group was qualitatively different (Howard et al., 2006). ROC curves are scatterplot presentations of the proportion of hits to false alarms in the recognition test. It has been established that recollection retrieval processes produce an asymmetrical, linear ROC curve, whereas familiarity retrieval processes produce a symmetrical, curvilinear ROC curve. Typically, overall recognition performance on a task will reflect a combination of both retrieval processes in a plot that collapses both trends across one another. Although younger and older adults' ROC curves overlapped, indicating similar levels of discriminability among the test items, the shapes of the ROC curves revealed that older adults' performance was lacking a recollection component whereas younger adults revealed both recollection and familiarity (Howard et al., 2006). As previously discussed, encoding and retrieval occur in parallel meaning that you can only retrieve information that was successfully encoded. Older adults' associative deficit extends to general recollection performance and also reflects a deficit in relational encoding strategies.

Physiological investigations of dual item memory mechanisms provided further support for the associative deficit of older adults. Such investigations suggest that the MTL, including the hippocampus undergoes both structural and functional changes throughout the lifespan (Morcom et al., 2009). Due to such structural changes, critical association areas of the aging brain do not perform as well as those of young adults. Functional imaging studies suggest that when compared to young adults, older adults do not reach an equal level of hippocampus activation when performing the same tasks (Bunzeck et al., 2007). Upon consideration of the age-related structural deterioration and lower functioning of the central associative feature of the brain, it should be no surprise that older adults perform below par on associative memory tasks. These findings provide physiological support to the observed associative deficit in older adults.

Age and reward-motivated memory. Turning now to a discussion of how the two variables of interest, age and reward motivation, work in conjunction to modulate recognition memory performance, studies that have previously integrated these constructs will be reviewed. Few studies have addressed the potentially different effects that reward motivation can have on various types of memory abilities or on special populations of interest such as older adults. One study that examined the effects of age and reward motivation on memory was a self-paced study paradigm of word items (Castel, Murayama, Friedman, McGillivray, & Link, 2013). Words were placed along a reward scale (high to low; 1 – 30 points) and could be studied in any order, at any pace, for two minutes. First, it was found that although young and older adults used different study strategies they performed equally well on the task. This supports the assertion that item recognition abilities are left intact with age (Castel et al., 2013; Naveh-Benjamin et al., 2003). Further, for both younger and older adults, high reward word items were remembered better than low reward word items. This finding suggested that rewards modulate older adults' item recognition abilities in much the same way as younger adults. Another study that tested the effects of aging on reward-motivated memory used Adcock et al.'s (2006) MIE task (Spaniol, Schain, & Bowen, 2013). In a study phase, a series of picture items were preceded by either high or low reward cues. Participants studied the pictures, completed inter-stimulus distractor tasks, and then took an item recognition test. Similar to the previously discussed study, these studies found no age differences in recognition of the pictures and high reward items were better recognized than low reward items for both age groups (Spaniol et al., 2013).

Taken together, the evidence suggests that reward-motivated recognition is left relatively intact by the aging process. However, prior studies only included tests of item recognition, so conclusions drawn from them can only be applied to older adults' item recognition ability. These studies do not address the potential effects of reward motivation on older adults' associative recognition.

Current Study

In a study that aimed to investigate how both item and associative recognition changed as a function of reward motivation for older and younger adults, Cushman (2012) combined the monetary incentive encoding (MIE) study task of reward cued picture stimuli with Naveh-Benjamin's testing paradigm (Naveh-Benjamin, 2000) that revealed the associative deficit of older adults. High reward motivation improved item recognition memory, but had no effect on associative recognition for either older or younger adults. Further, as expected older adults performed worse than younger adults only on the associative recognition test. With regard to the specific research question, these findings can be interpreted as meaning that reward motivation does not have the modulatory potential to overcome the associative deficit of older adults. However, in hindsight, some potential design issues were identified that could have affected the reward motivation findings. First, the manipulated values of high and low monetary reward values may not have been distinctive enough to produce differential levels of reward motivation in associative recognition. The values for high and low reward cues were $0.50 and $0.05, respectively. Second, Cushman implemented a testing paradigm that only allowed analysis of reward-motivated item and associative recognition abilities for younger and older adults. However, testing participants with single and dual item recognition tests that can be broken down into respective sub-types could provide finer-grained information about young and old adults' familiarity – based and relational recognition processes.

In a follow up study that addressed these issues, Mutter, Luttrell, and Steen (2013) combined the MIE study task of reward cued word pair stimuli with single item and dual item recognition testing of younger and older adult participants. In the MIE study task, reward motivation was manipulated using a point system in which high and low reward cues were 200 points and 10 points, respectively. Their results indicated that high reward motivation improved dual item recognition performance, but not single item recognition performance for both older and younger adults. These findings were opposite to those of both Cushman (2012) and Spaniol and colleagues (2013) who used picture pairs as stimuli. As previously discussed, the type of to-be-remembered items has an influence on the encoding and retrieval strategies that are employed. Pictures have been found to induce item-specific encoding, which is linked to subsequent familiarity-based retrieval, whereas words induce relational encoding, which is linked to subsequent recollection-based retrieval. This presents the possibility that reward motivation may function to further enhance this tendency to focus on the details of the individual pictures in a picture pair but not the relationships between words in a word pair. Further, in this earlier study, differences in performance for older and younger adults were larger in 1) context recognition than no context recognition and 2) associative recognition than pair recognition. This suggests that older adults are not always equal to young adults on tests of recognition for single words and they are not always worse on tests of word pairs. This finding suggests that the act of separating recognition performance into the finer recognition abilities might improve understanding of the complexity of cognitive aging.

The purpose of the current study is to replicate Cushman's (2012) reward-motivated recognition testing of picture stimuli using the procedure implemented by Mutter, Luttrell, and Steen (2013). This study more effectively addressed how various types of recognition for pictures differ as a function of age and reward motivation. The following hypotheses were tested:

1) It is expected that age and reward motivation will affect single item recognition for pictures.

   1.a) High reward motivation should improve item-specific encoding and familiarity retrieval processes more than low reward motivation and should therefore improve both types of single item recognition performance for both younger and older adults.

   1.b) Younger adults should outperform older adults in context recognition because they will be able to use context cues to aid recollective processes during retrieval whereas older adults will not encode contextual details and cannot use this information at retrieval.

   1.c) Younger and older adults should perform equally well for no context recognition because the context is not preserved from study to test and young adults will not have the advantage of contextual cues to improve recollection at test.

2) It is expected that age and reward motivation will differentially influence dual

item recognition for picture pairs.

2.a) Because high reward motivation should selectively improve item-specific encoding and familiarity retrieval processes more than low reward motivation, it should have no effect on associative recognition. However, high reward motivation could potentially improve pair recognition performance for both younger and older adults because pair recognition item-specific information can be used to effectively discriminate new item pairs from intact pairs.

2.b.) Younger adults should outperform older adults on the associative recognition task because a strong associative link between the items in a pair is required for this test. No effect of reward motivation is expected in this task for either age group.

2.c) The two groups' performance on the pair recognition task should be similar because memory for item specific information about each item in the pair can lead to accurate recognition performance. High reward motivation may also improve performance on this task.

CHAPTER 2

Method

Participants

Forty-eight younger adults (ages 18-29) and 48 older adult participants (ages 60 +) participated in this study. Younger adult participants were WKU students enrolled in various undergraduate psychology courses. They were recruited through the WKU Study Board, an online student subject pool, and received class credit for participating. Older adult participants were citizens from the Bowling Green, Kentucky community and nearby surrounding areas. They were recruited through public fliers, organizational bulletins, and phone calls (i.e., referral, consent to return, etc.). Older participants were compensated $10.00 per hour for the time provided to the study. The experimenters screened older adults over the phone before scheduling their participation session. Older adults were required to successfully pass a Telephone Mini Mental State Exam (TMMSE) to meet inclusion criteria for this study. Although they could decline to answer questions at any point during the telephone assessment, failure to answer the questions or failure to answer them correctly resulted in exclusion from the study. Additionally, all participants were required to speak English fluently, be in good physical and mental health, and take no psychoactive drugs at the time of participation. During the study session, all participants completed a series of individual difference task which measured various sets of cognitive abilities. These tasks were performed following their completion of the experimental task. Performance was compared across age groups and the data are presented in Table 1.

Design

Two quasi – experiments were conducted in this study. The first experiment assessed memory for individual items using a single item recognition test and employed a 2 (Age) x 2 (Reward) x 2 (Recognition Type) mixed factor design. Age (younger vs. older adults) was a between subjects quasi – experimental variable and reward (high: 200 points vs. low: 10 points) and recognition type (context recognition vs. no context recognition) were within subjects variables. Corrected recognition scores, a measure of discrimination, were calculated for each subtype of recognition as a function of the proportion of hits (i.e., correct “old/yes” responses; P (H)) minus the proportion of false alarms (i.e., incorrect “old/yes” responses; P (FA)). For single item recognition, context recognition scores were calculated as the P (H: Intact) – P (FA: New Item) and no context recognition scores were calculated as the P (H: Rearranged) – P (FA: Distractor).

The second experiment assessed memory for pairs of items using a dual item recognition test. In this experiment, age (younger adults vs. older adults) was again a between subjects quasi -variable and reward (high: 200 points vs. low: 10 points) and recognition type (associative recognition vs. pair recognition) were within subjects variables. Corrected recognition scores were calculated from participant responses. For dual item recognition, associative recognition scores were calculated as the P (H: Intact) – P (FA: Rearranged) and pair recognition scores were calculated as the P (H: Intact) – P (FA: Distractor).

Stimuli for each of the experiments were counterbalanced across reward and test item type. Two separate study lists were created to present all stimuli as both high and low reward item during the study phase of the experiment. Four test lists were created to present each stimulus as in all of the four possible test item types. Participants in each age group were randomly assigned to an experiment (i.e., single item or dual item recognition) and to one of the various study list by test list combinations.

Materials

The stimuli used in this study were 108 color pictures of everyday objects like *clock, jacket, globe, purse,* etc. that were previously used by Cushman (2012). The 108 total stimuli were randomly combined to create 48 sets of stimulus pairs for study, with the constraint that the pictures in a pair were not semantically or visually related to one another and the 12 remaining picture items (e.g., *shoe, flower*) were incorporated at test with study stimulus images to create "item" test items. Stimuli for each of the experiments were counterbalanced across reward type and test item type. Counterbalancing across test item type requires that the stimulus pairs be presented at study such that they could later serve as the appropriate test item type. Thirty-six of the total 48 study stimulus pairs were randomly selected to be included into two study lists, such that reward was counterbalanced across items in each list (i.e., high and low). For example, if the stimulus *clock – jacket* was preceded by a high reward in Study List 1, it was preceded by a low reward in Study List 2. The remaining 12 picture pairs that were not selected in to the study list served as "new" distractor picture pairs.

For each experiment, four test lists were created. In each test list, all 96 pictures were presented in 48 picture pairs, with each individual picture presented only once. Test item type was counterbalanced across picture pairs, such that the *clock – jacket and globe - purse* stimuli were presented as an intact pairs in Test List 1 (e.g., *clock – jacket; globe - purse*), a rearranged pairs in Test List 2 with another picture stimulus from study (e.g., *clock – purse; globe – jacket*), a new item pair in Test List 3 presented with a new distractor picture stimulus (e.g., *clock – shoe; globe* - *flower*), and is completely replaced by a distractor pair (i.e., two new pictures) in Test List 4 (e.g., *banana – book; tent* - *ring*). The accuracy of participants' test responses depended upon which study list and test list combination they receive (See Appendix A).

During each trial of the study phase, a picture pair stimulus was preceded by a reward cue stimulus (e.g., high or low) and followed by a distractor task. The high reward cue stimulus includes an image of 20 golden coins and the number 200, indicating the point value that could be gained for subsequent memory of the upcoming stimulus (See Appendix B). The low reward cue stimulus included an image of a single golden coin and the number 10, indicating the point value of the picture pair stimulus (See Appendix B). In the distractor task a sequence of three randomly presented arrows (e.g., <, >) were presented and participants had to attend to and repeat the sequence.

Procedure

All tests were conducted in the Cognition Laboratory at Western Kentucky University. Participants were tested in individual sessions that last approximately an hour and a half. Participation consisted of two parts: an experimental task and individual difference tests. Participants completed the experimental task on a computer and the individual differences tests on paper and computers.

Participants were given an informed consent document upon their arrival in the laboratory. Next, they were given a Biographical and Health Questionnaire (BHQ) to complete. This questionnaire included questions regarding contact information, education, occupation, socioeconomic status, health status, and a list of medications. Participants were informed that they could leave items blank if they are uncomfortable answering, and they could ask the experimenter questions, as clarification may be needed. Upon completion of the BHQ, the experimenter asked the participant to be seated at a desk in front of a computer screen to begin the study phase of the experimental task.

Before beginning the study phase, the experimenter presented an instruction screen and read it aloud to the participant. This instruction screen was the same for both experiments. First, the instructions included a description of the reward, picture pair, and distractor stimuli and how to respond to them. Next, there was an instruction to pay attention to the picture stimuli and how they are paired with one another because there will be a memory test (See full study phase instructions, Appendix C).

During each of the 36 trials in the study phase, a reward cue (high or low) was presented in the center of the screen for 1.5 seconds. Next, in the center of the screen, a fixation cross appeared for 1.5 seconds, followed by a picture pair stimulus (e.g., *globe - jacket*) that was presented for 3.5 seconds. Lastly, the participant saw the distractor arrow sequence for 2.5 seconds and made a manual response to this sequence by indicating the directions of the arrows using assigned keys on the keyboard. Then, a blank screen appeared for 2.5 seconds before the next trial began (See study phase trials, Appendix B).

The test phase began immediately after the study phase. Both recognition tests consisted of 48 test trials including 12 intact picture pairs (i.e., A—B, C—D), 12 rearranged picture pairs (i.e., A—C, B—D), 12 new item picture pairs (i.e., A—X, C—X), and 12 distractor picture pairs (i.e., Y—Z). If participants' test performance was 100% accurate, they earned $10.08 for their performance.

Single item recognition. In this test, participants made 48 Yes/No recognition judgments as to whether the single picture on the right half of the screen was or was not presented in the study phase. Before beginning the single item recognition test, participants were presented with instructions on the computer screen that described the recognition judgments, how points can be earned and lost, and the cash payout that they would earn based upon their performance on the test. For correct recognition judgments, they earned the point value associated with that picture pair in the study phase. However, for incorrect recognition judgments, the associated point value was deducted from their accumulated total. (See full single item recognition test instructions, Appendix D).

Dual item recognition. In this test, participants made 48 Yes/No recognition decisions as to whether a picture pair as a whole was or was not presented in the study phase. Before beginning the dual item recognition test phase participants were presented with instructions on the computer screen that described the recognition judgments, how points can be earned and lost, and the cash payout that they would earn based upon their performance on the test As in the single item recognition task, correct recognition judgments earned associated point values and incorrect recognition judgments lost associated point values. (See full dual item recognition test instructions, Appendix E).

Individual difference measures. After completing the experimental task, all participants received a battery of tests used widely in cognitive aging research to measure specific cognitive abilities. Working memory was measured by the WAIS-III Digit Symbol Substitution test (Wechsler, 1997) and the Reading Span test (Salthouse & Babcock, 1991). The Digit Symbol Substitution test requires that participants maintain a series of symbol – digit pairs to promote quick and accurate performance during this two-minute timed task, (split-half reliability, r =.89). The Reading Span test requires that participants read a series of sentences that accumulate in an ascending fashion across trials and, after responding to a corresponding question for each, recall the final words of each of the sentences (test retest reliability, r =.86). Associative learning and memory was tested using the WAIS-III Digit Symbol Incidental Learning test (Wechsler, 1997). The Digit Symbol Incidental Learning test requires that participants recall the series of incidentally learned symbol – digit pairs following the Digit Symbol Substitution test, (split-half reliability, r =.90). Semantic knowledge was measured using the Advanced Vocabulary Test (Ekstrom, French, Harman, & Dermen, 1976). This is a 60 item, multiple choice test presents target words from the English language, varying in difficulty and require participants to select a synonym for each target word (split-half reliability, r = .83). Scores on these measures were compared across age groups to determine whether there is a difference between younger and older adults on these cognitive abilities. It was found that younger adults outperformed older adults on the Digit Symbol Incidental Learning test in both the single item, $F(1, 47) = 13.40$, $MSE = 23.79$, $p = .00$, and dual item, $F(1, 48) = 10.27$, $MSE = 18.81$, $p = .00$, recognition experiments. Younger adults also outperformed older adults on the Digit Symbol Substitution test in both the single item, $F(1, 47) = 64.74$, $MSE = 128.53$, $p = .00$, and dual item, $F(1, 48) = 58.10$, $MSE = 115.67$, $p = .00$, recognition experiments. Older adults outperformed younger adults on the Advanced Vocabulary test in both the single item, $F(1, 47) = 47.85$, $MSE = 33.59$, $p = .00$, and dual item, $F(1, 48) = 20.29$, $MSE = 53.49$, $p = .00$, recognition experiments. There were no age differences on the Reading Span test in the single item, $F(1, 47) = 1.10$, $MSE = 1.66$, $p = .30$, or the dual item, $F(1, 48) = 3.01$, $MSE = .98$, $p = .09$, recognition experiments.

Table 1

Individual Differences Measures

	Single Item Recognition		Dual Item Recognition	
	Younger	Older	Younger	Older
Reading Span	2.71(.96)	2.22(1.51)	2.65(1.09)	2.17(.89)
Advanced Vocabulary	10.23(4.26)	21.51(7.01)*	10.65(6.01)	19.81(8.68)*
WAIS Digit Symbol Substitution	88.38(9.86)*	60.96(11.73)	83.04(10.87)*	59.00(10.55)
WAIS Digit Symbol Incidental Learning	24.54(3.55)*	19.83(5.94)	24.50(3.52)*	20.52(5.11)

Note: Table displays younger and older adult participants' means and standard deviations (in parentheses) for the individual difference measures. Data were submitted to a one-way ANOVA to detect age differences on each individual difference measure. Age differences are indicated by an asterisks (*), which is next to the age group that outperformed the other.

Results

Participants' raw scores from each of the tasks were categorized into hits and false alarms, and mean hit and false alarm rates were calculated. These rates were then transformed into *z* scores to allow for calculations of d-prime (*d'*) scores, a sensitive measure of discriminability. The formula for calculating *d'* scores is $d' = z(\text{hits}) - z(\text{false alarms})$. Calculating respective *d'* scores for each recognition subtype involves various combinations of the four test item types. These formulas are presented in Table 2. Separate *d'* scores were calculated for high and low reward items for each recognition subtype. Mean hit and false alarm rates, standard deviations, and mean standard errors for are reported in Table 3 for single item recognition and Table 4 for dual item recognition. All means comparison analyses were conducted using an alpha level of $p \leq .05$ as criterion of significance.

Table 2

Calculating d' scores for each recognition subtype

Recognition Subtype		Hits	False Alarms
Single Item	Context	Intact	Item
	No Context	Rearranged	Distractor
Dual Item	Pair	Intact	Distractor
	Associative	Intact	Rearranged

Table 3

Single Item Recognition: Hit and False Alarm Rates

		Hits				False Alarms			
Group		High Intact	Low Intact	High Rearr	Low Rearr	High Item	Low Item	High New	Low New
Young	Mean	.93	.94	.84	.83	.04	.06	.03	.02
	N	24	24	24	24	24	24	24	24
	SD	.11	.11	.23	.27	.09	.16	.06	.07
	SEM	.02	.02	.05	.06	.02	.03	.01	.02
Older	Mean	.88	.91	.81	.83	.08	.08	.03	.06
	N	25	25	25	25	25	25	25	25
	SD	.16	.15	.17	.16	.17	.16	.06	.09
	SEM	.03	.03	.03	.03	.04	.03	.01	.02

Table 4

Dual Item Recognition: Hits and False Alarm Rates

		Hits		False Alarms			
Group		High Intact	Low Intact	High New	Low New	High Rearr	Low Rearr
Young	Mean	.91	.94	.05	.06	.35	.33
	N	26	26	26	26	26	26
	SD	.12	.10	.13	.11	.28	.27
	SEM	.02	.02	.03	.02	.06	.05
Older	Mean	.89	.90	.01	.02	.48	.45
	N	24	24	24	24	24	24
	SD	.17	.12	.05	.10	.32	.30
	SEM	.04	.02	.01	.02	.07	.06

Single Item Recognition

Mean *d'* scores and standard errors are illustrated in Figure 1 for younger and older adults' context and no context recognition performance under high and low reward motivation. Differences among these scores were examined in a 2 (Age) x 2 (Reward) x 2 (Recognition Subtype) mixed factorial analysis of variance (ANOVA) with both reward and recognition subtype as repeated measures variables. There were no significant main effects of age, $F(1, 47) = .02$, $MSE = .41$, $p = .90$, reward, $F(1, 47) = .24$, $MSE = .18$, $p = .62$, or recognition subtype, $F(1, 47) = 1.81$, $MSE = .22$, $p = .19$, nor was there a significant age by recognition subtype interaction, $F(1, 47) = .98$, $MSE = .22$, $p = .33$. There was a significant age by reward interaction, $F(1, 47) = 5.41$, $MSE = .18$, $p = .02$, $\omega^2 = .10$, indicating that reward had differential effects on younger and older adults' performance. Younger adults recognized high and low reward picture items equally well, $t(23) = 1.32$, $MSE = .09$, $p = .20$, whereas older adults recognized somewhat more low reward picture items than high, $t(24) = -1.32$, $MSE = .09$, $p = .06$. However, there were no differences between younger and older adult performance under high reward motivation, $t(23) = 1.28$, $MSE = .11$, $p = .22$, nor were there age differences under low reward motivation, , $t(23) = -1.26$, $MSE = .12$, $p = .22$. There was no reward by recognition subtype interaction, $F(1, 47) = .98$, $MSE = .14$, $p = .33$, nor was there a three-way age by reward by recognition subtype interaction, $F(1, 47) = .32$, $MSE = .14$, $p = .56$.

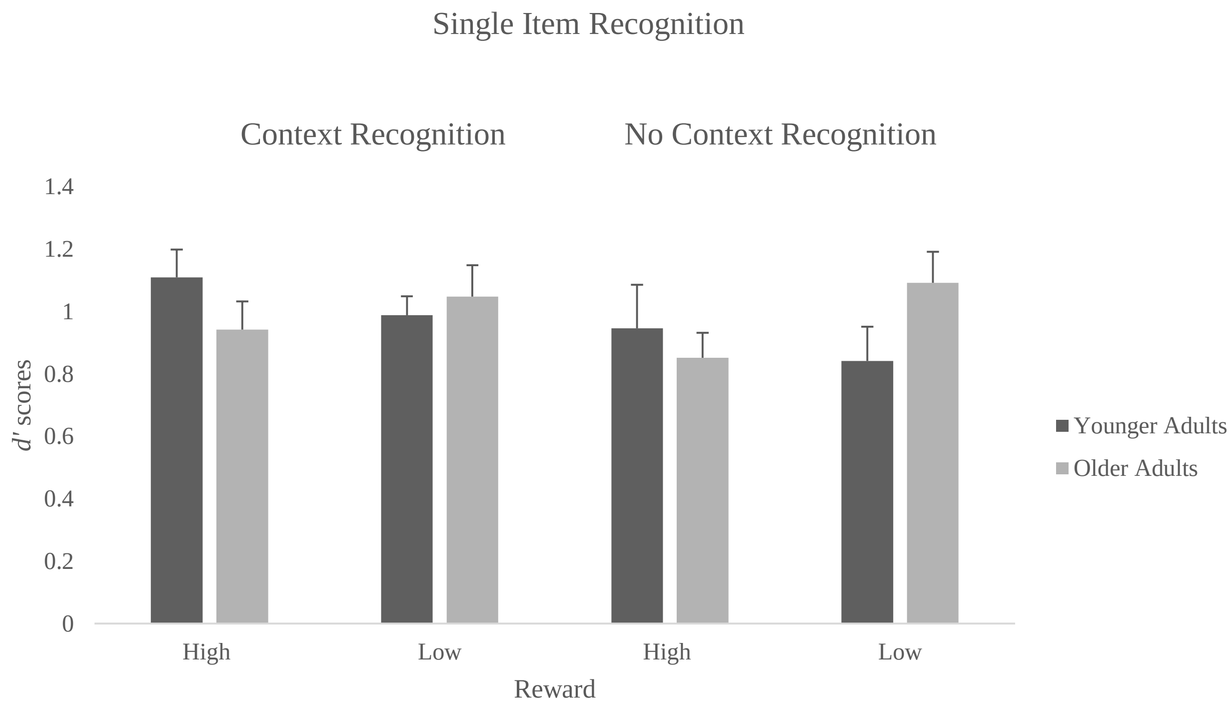

Figure 1. Single item recognition memory performance as a function of age and reward.

Dual Item Recognition

Mean *d*' scores and mean standard errors are illustrated in Figure 2 for younger and older adults' pair and associative recognition performance under high and low reward motivation. Differences among these scores were examined by a 2 (Age) x 2 (Reward) x 2 (Recognition Subtype) mixed factorial analysis of variance (ANOVA) with both reward and recognition subtype as repeated measures variables. There was a significant main effect of age, $F(1, 48) = 9.54$, $MSE = .31$, $p = .00$, $\eta_p^2 = .17$, indicating that overall, younger adults ($M = 1.05$, $SD = .26$) performed better than older adults ($M = .81$, $SD = .29$) on tests of dual item recognition. There were no main effects of reward, $F(1, 48) = 1.27$, $MSE = .18$, $p = .27$, or recognition subtype, $F(1, 48) = 1.35$, $MSE = .26$, $p = .25$. There was a marginal three-way age by reward by recognition subtype interaction, $F(1, 48) = 3.33$, $MSE = .11$, $p = .07$, $\omega^2 = .07$.

Planned comparisons were conducted to examine the predicted effect of reward on pair and associative recognition performance for the two age groups and the effect of age on associative and pair recognition performance. Under high reward, there was a significant main effect of age, indicating that younger adults ($M = 1.03$, $SD = .35$) performed better than older adults ($M = .77$, $SD = .36$), $F(1, 48) = 6.65$, $MSE = .25$, $p = .01$, $\eta_p^2 = .12$. There was no main effect of recognition subtype, $F(1, 48) = 1.03$, $MSE = .18$, $p = .32$, however there was a significant age by recognition subtype interaction, $F(1, 48) = 1.57$, $MSE = .18$, $p = .04$, $\eta_p^2 = .09$. Examining this simple interaction revealed that under high reward motivation, younger adults performed better than older adults on associative recognition $F(1, 48) = 7.32$, $MSE = .33$, $p = .01$, $\eta_p^2 = .88$, but there were no age differences for pair recognition performance, $F(1, 48) = .73$, $MSE = .01$, $p = .40$.

Under low reward, there was a significant main effect of age, indicating that younger adults (*M* = 1.08, *SD* = .32) performed better than older adults overall (*M* = .86, *SD* = .34), $F(1, 48) = 5.31$, *MSE* = .24, $p = .03$, $\eta_p^2 = .10$, but there was no main effect of recognition subtype, $F(1, 48) = .89$, *MSE* = .19, $p = .35$ nor an age by recognition subtype interaction, $F(1, 48) = .02$, *MSE* = .19, $p = .99$.

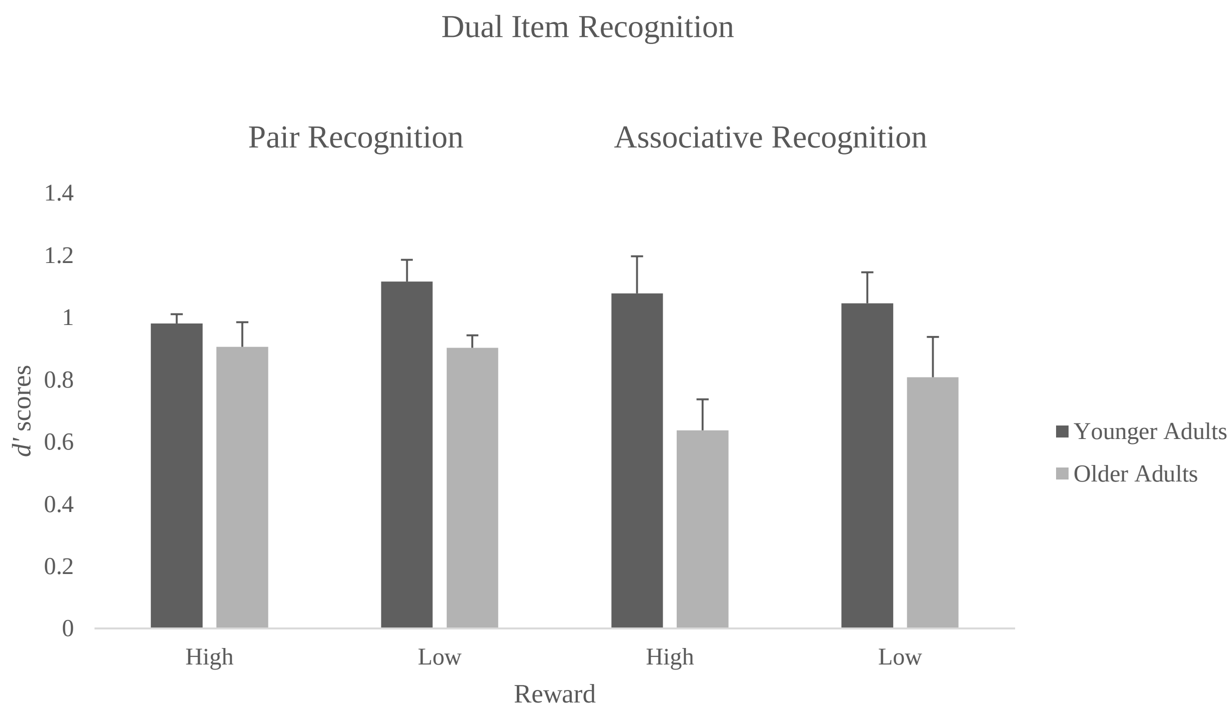

Figure 2. Dual item recognition memory performance as a function of age and reward.

CHAPTER 4

Discussion

The purpose of the current study was to conceptually replicate Cushman's (2012) reward-motivated recognition testing of picture stimuli using the procedure implemented by Mutter, Luttrell, and Steen (2013). This study was designed to more effectively address how various types of recognition for pictures differ as a function of age and reward motivation. For the single item recognition test, it was predicted that high reward would improve both context and no context recognition performance for younger and older adults, and that although younger adults would perform better than older adults on context recognition, there would be no age differences on no context recognition. These predictions were not confirmed. Unexpectedly, younger adults recognized high and low reward pictures equally and older adults recognized marginally more low reward than high reward pictures on tests of both context and no context recognition. Further, there were no age differences for either subtype of single item recognition. For the dual item recognition test, it was predicted that high reward would selectively improve pair recognition but not associative recognition for both younger and older adults. Further, it was expected that younger adults would perform better than older adults on associative recognition, but there would be no age differences on pair recognition. Some, but not all, of these predictions were confirmed. Younger adults had better associative recognition performance than older adults, especially under high reward. Further, there were no age differences in pair recognition performance while under high reward motivation. However, younger adults performed better than older adults on pair recognition while under low reward motivation.

Mutter and colleagues (2013) employed the same type of recognition testing paradigm, but used word-pair stimuli instead of pictures and found that reward had no effect on younger or older adults' single item recognition performance but both groups' dual item recognition performance was enhanced by high reward. However, in Cushman's (2012) study on picture recognition, the opposite effect of reward was observed. Item recognition was enhanced by high reward motivation for both younger and older adults but associative recognition was not. Therefore, we expected that reward would improve single item recognition, but not dual item recognition, for picture stimuli. These predictions were not confirmed in the current study because high reward pictures were not recognized better than low reward pictures on the single item recognition test. In addition, age differences in associative recognition were actually greater for high reward pictures because older adults performed much worse for these stimuli on this test. The findings of the current study do not rule out the possibility of a fundamental difference in the effects of reward on verbal and non-verbal learning, but further research that investigates the reliability of these findings will be necessary in order to make such claims.

The effects of reward motivation on item recognition for picture stimuli in the current study are inconsistent with previous studies that have consistently found that older and younger adults alike have better item recognition for high reward relative to low reward picture targets (Castel et al., 2013; Cushman, 2012; Spaniol et al., 2013). However, the YES - NO item recognition testing paradigm employed in these previous studies was different from the tests of context and no context recognition employed in the current study and it is highly likely that the current testing procedure measured a different type of recognition. An item recognition test involves studying a list of individual stimuli and then discriminating the individual items that were seen before from distractors that were not seen. The single item recognition test differs from the YES - NO item recognition test in that it includes contextual information along with the target stimulus. Thus, single item recognition tests measure one's the ability to identify the previous exposure of a single stimulus that is presented in the context of another stimulus (Mandler, 1980). This test has more ecological validity as a measure of the way that individuals learn and recognize stimuli in their environments because most, if not all, instances of learning and memory occur in the presence of contextual information (Humphreys, 1976) that can be used as an aid to both encoding and retrieval. Therefore, it may be too liberal of a generalization to expect that reward motivation would affect these two types of recognition memory ability the same. This issue will require further research.

There are other possible factors that could have reduced the effectiveness of the reward motivation manipulation in single item recognition. Younger adults' single item recognition performance did not differ for high and low reward motivation and it is possible that this finding is due to ceiling effects in their performance. Although the current study used *d*' scores, a sensitive measure of discriminability, to report recognition performance, there was little variability observed in younger adults' single item recognition performance. This lack of variability is attributed to uniformly high hit rates and low false alarm rates among younger adult participants on the single item recognition test. Previous research has suggested that picture recognition is considerably easier than word recognition, a phenomenon known as the picture superiority effect (Shepard, 1967).

It is therefore possible that the pictures in the task were independently distinctive enough to produce strong single item recognition, leaving little room for reward motivation to have any enhancing effects on performance. As mentioned previously, older adults actually recognized somewhat more low than high reward items, suggesting that high reward motivation may actually have been a distraction to them during encoding. This finding has not been shown previously and the explanation is speculative. Moreover, this unusual effect was only marginally significant when using the pooled error term from the omnibus ANVOA. Had a more conservative error term been used in the analysis, such as that from the simple comparison alone, the effect of reward for older adults would not have reached significance. This suggests that the effect is small and possibly an artifact of the particular testing arrangement in this study. Further research will be necessary to investigate both of these unexpected findings for single item recognition performance. One aim for future studies will be to determine if younger adults' single item recognition performance for pictures is at ceiling and thereby unchanged by manipulations of reward motivation. One possible way to reduce ceiling effects in younger adult performance would be to use a longer retention interval between study and test phases. Another interest for future studies will be to determine if the detrimental effect of high reward on older adults' single item recognition performance is reliable, which would support the idea that high reward motivation distracts older adults during encoding.

It was also predicted that younger adults would perform better than older adults on context recognition but there would be no age differences on no context recognition. However, there were no age differences for either subtype of single item recognition. This finding is consistent with previous research that has uniformly found no differences between younger and older adult performance on tests of YES - NO item recognition (Cushman, 2012; Naveh-Benjamin et al., 2003; Spaniol et al., 2013). Although consistent, the aforementioned differences in testing paradigms should be taken into consideration as the single item recognition and YES – NO item recognition tests could possibly be measuring different types of recognition ability. The current finding also differs from that of Mutter and colleagues (2013) where word-pair stimuli were used and younger adults out-performed older adults in context recognition but the two groups performed equally well for no context recognition. Younger adults are better equipped than older adults to use contextual cues for memory retrieval, so it was again expected that older adults would perform worse than younger adults on the context recognition test for pictures due to their associative deficit. However, it is possible that due to a picture superiority effect, younger adults did not need to rely on contextual information as a strategy to perform well. The pictures were distinctive and easily memorable regardless of their context. If younger adults did not use contextual information for encoding or retrieval, there is no reason to expect that younger and older adults would perform differently on a context recognition test.

Turning now to the dual item recognition test, it was predicted that younger adults would outperform older adults on associative but not pair recognition, and that high reward would selectively improve pair recognition but not associative recognition performance for both younger and older adults. The results of the study partially confirmed the first prediction, but did not support the second prediction. Under high reward motivation, younger adults performed better than older adults on associative recognition, but there were no age differences for pair recognition performance. This is consistent with previous research because it replicates the associative deficit of older adults that is observed throughout the cognitive aging literature (Cushman, 2012; Mutter et al., 2013; Naveh-Benjamin et al., 2003). Further, these results provide support for the preservation of the associative deficit even when reward motivation is high, suggesting that older adults' poorer performance on this task is a product of a deficit and not lack of motivation (Cushman, 2012; Mutter et al., 2013). Finally, this finding also replicates that of Mutter and colleagues (Mutter et al., 2013), who found age differences for associative but not pair recognition performance under high reward using word-pair stimuli.

In contrast to the second prediction, younger adults' pair recognition performance was better for low reward than high reward picture pairs and older adults' was equal for high and low reward pictures. These findings are atypical as they were 1) the only case where younger adults did not perform equally well for low and high reward and 2) the only case where older adults did not perform worse under high than low reward. These findings are also inconsistent with the findings of Mutter and colleagues (2013), who used the same testing paradigm, and observed the predicted enhancing effect of high reward motivation on pair recognition using word-pair stimuli. Specifically, that both younger and older adults alike recognized more high than low reward word-pairs.

Focusing now on dual item recognition performance under low reward motivation, younger adults outperformed older adults both on associative and pair recognition. These results are only partially consistent with the hypotheses for this study, as it was predicted that under low reward motivation, younger adults would outperform older adults on associative recognition, but there would be no age difference in pair recognition. The observation of age differences under low reward motivation on the associative recognition test is consistent with the associative deficit of older adults (Naveh-Benjamin et al., 2003). However, the observation of age differences on the pair recognition test under low reward motivation is inconsistent with both the findings of Mutter and colleagues (2013), who observed no age differences for pair recognition performance under low reward motivation, as well as the findings from the current study, where no age differences were observed on pair recognition under high reward motivation.

The inconsistencies in patterns of performance across tests in this experiment presents complications in interpreting the results and limits the support that is provided to the idea that the associative deficit of older adults may not apply to pair recognition performance (Mutter et al., 2013). While there were consistent age differences in associative recognition under high and low reward motivation, age differences in pair recognition performance were mixed across levels of reward. There were no age differences for pair recognition under high reward, but there were age differences under low reward. Moreover, the lack of age differences observed under high reward on the pair recognition test appears to be due to younger adults performing slightly worse for high than low reward with older adults performing equally well for both rewards. In the previous study by Mutter and colleagues there were no age differences on pair recognition performance, under either high or low reward motivation and younger and older adults alike recognized more high reward than low reward pairs. The discrepancy of the present results with those from this previous study brings into question the reliability of these findings as well as the conclusions drawn from the former study.

The findings from the current study should be interpreted with caution due to the methodological limitations. Ceiling effects in participant performance were limiting to this study because they masked the expected effects of reward motivation found in previous studies and limited the implications that could be drawn from the study overall. The issue of using pictures as stimuli was previously discussed with regards to the phenomenon known as the picture superiority effect. Specifically, this phenomenon suggests that picture recognition is considerably easier than word recognition (Shepard, 1967) and that the pictures in the task could have been independently distinctive enough to produce strong performance. In addition to this, the short retention interval between the study phase and test phases of the experimental protocol is possibly a major limitation of the current study. Previous research suggests memories, especially those encoded under conditions of high arousal, are best consolidated into long term storage during sleep and show enhanced performance at delayed testing relative to immediate (Kleinsmith & Kaplan, 1963). The combined effects of picture superiority and the short retention interval may have produced the ceiling effects observed particularly in younger adults' single item recognition performance. Therefore, a future direction for this research would be to incorporate a longer retention interval into the protocol for this study as a way to deal with the picture superiority issue and eliminate ceiling effects. It is expected that, if the retention interval is lengthened, the effects of reward motivation on picture recognition performance will emerge.

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Appendix A

Table 1: Study Items

Counterbalancing Reward Across Study Item: Study List 1 & 2

		Study List 1	**Study List 2**
Study Item	**Picture Pair Label**	**Reward**	**Reward**
1	baseball - wine	High: 200	Low: 10
2	bird - hose	High: 200	Low: 10
3	cake - trumpet	High: 200	Low: 10
4	crab - mirror	High: 200	Low: 10
5	dustpan - pupil	High: 200	Low: 10
6	fireman - slipper	High: 200	Low: 10
7	hammer - coffee	High: 200	Low: 10
8	insect - drum	High: 200	Low: 10
9	jumprope - cigar	High: 200	Low: 10
10	peach - wheelchair	High: 200	Low: 10
11	rug - statue	High: 200	Low: 10
12	shoes - mailbox	High: 200	Low: 10
13	stone - carrot	High: 200	Low: 10
14	truck - balloon	High: 200	Low: 10
15	umbrella - monkey	High: 200	Low: 10
16	wallet - geese	High: 200	Low: 10
17	banana - dress	High: 200	Low: 10
18	comb - die	High: 200	Low: 10
19	bench - apple	High: 200	Low: 10
20	brush - drill	High: 200	Low: 10
21	cat - soldier	High: 200	Low: 10
22	doll - snail	High: 200	Low: 10
23	earth - rollerskate	High: 200	Low: 10
24	hamburger - screw	High: 200	Low: 10
25	handcuffs - potato	Low: 10	High: 200
26	jacket - piano	Low: 10	High: 200
27	mop - lobster	Low: 10	High: 200
28	rattle - lamp	Low: 10	High: 200
29	sailboat - spoon	Low: 10	High: 200
30	slingshot - plate	Low: 10	High: 200
31	table - caterpillar	Low: 10	High: 200
32	tweezers - chair	Low: 10	High: 200
33	violin - hound	Low: 10	High: 200

34	wheelbarrow - singer	Low: 10	High: 200
35	bell - skull	Low: 10	High: 200
36	broom - candy	Low: 10	High: 200
37	arrow - blossom	Low: 10	High: 200
38	brain - harp	Low: 10	High: 200
39	mousetrap - window	Low: 10	High: 200
40	jelly - kettle	Low: 10	High: 200
41	moss - infant	Low: 10	High: 200
42	cord - house	Low: 10	High: 200
43	globe - lantern	Low: 10	High: 200
44	microscope - turkey	Low: 10	High: 200
45	wheat - watermelon	Low: 10	High: 200
46	tent - stroller	Low: 10	High: 200
47	oven - ruler	Low: 10	High: 200
48	ring - salad	Low: 10	High: 200

**For item test items

N1	rabbit
N2	pillar
N3	scissors
N4	hat
N5	gift
N6	bowl
N7	barrel
N8	door
N9	hinge
N10	ink
N11	seat
N12	keyboard

Table 2: Test Items

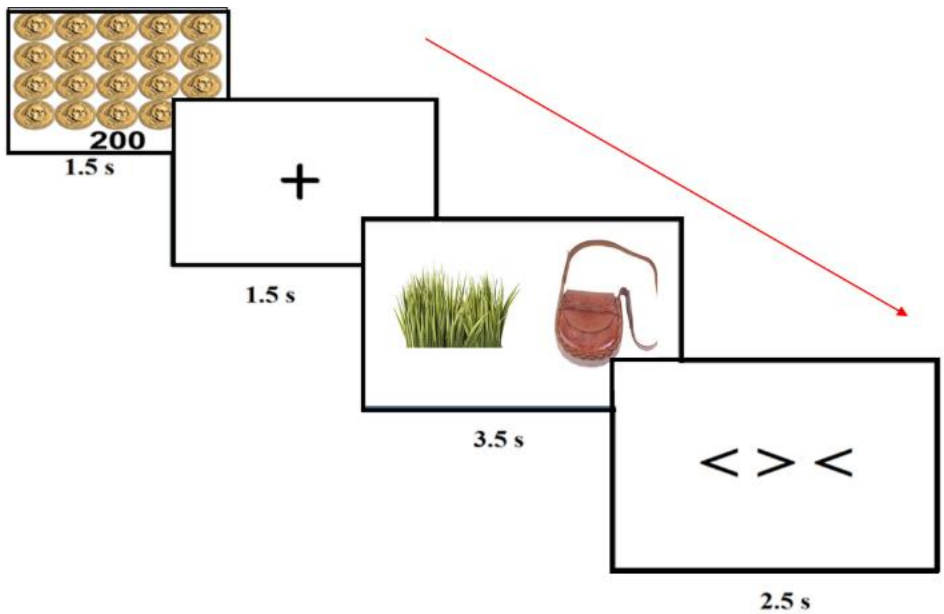
Counterbalancing Test Item Type Across Study Items: Test Lists 1 – 4

Test Item Type	**Test List 1** **0 = 7 - 12; 31 - 36**	**Test List 2** **0 = 13 - 18; 37 - 42**	**Test List 3** **0 = 19 -24; 43 - 48**	**Test List 4** **0 = 1 - 6; 25 - 30**
Intact	1 - 1	7 - 7	13 - 13	19 - 19
Intact	2 - 2	8 - 8	14 - 14	20 - 20
Intact	3- 3	9 - 9	15 - 15	21 - 21
Intact	4 - 4	10 - 10	16 - 16	22 - 22
Intact	5 - 5	11 - 11	17 - 17	23 - 23

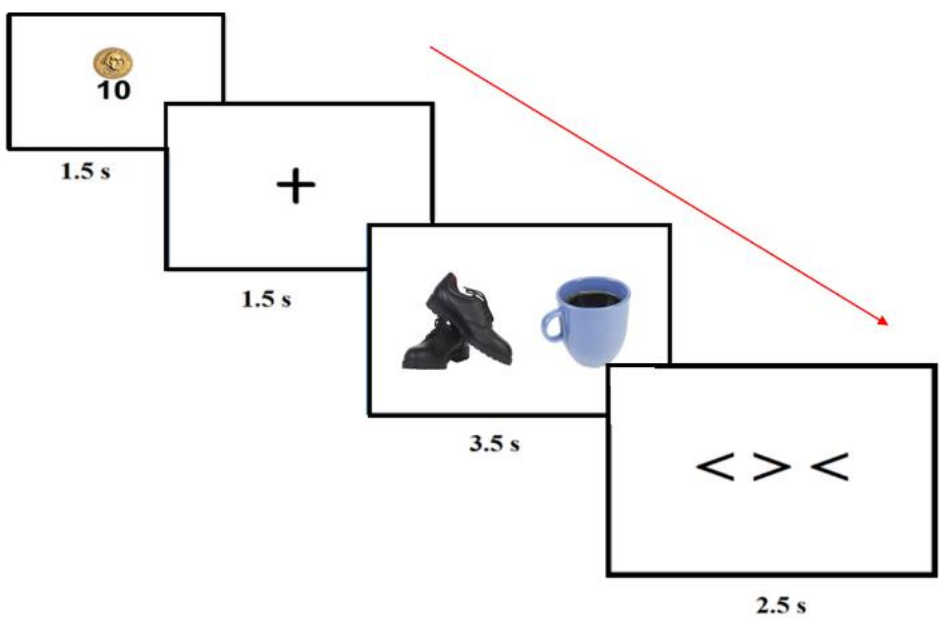
Intact	6 - 6	12 - 12	18 - 18	24 - 24
New	7 - 7	13 - 13	19 - 19	1 - 1
New	8 - 8	14 - 14	20 - 20	2 - 2
New	9 - 9	15- 15	21 - 21	3- 3
New	10 - 10	16 - 16	22 - 22	4 - 4
New	11 - 11	17 - 17	23 - 23	5 - 5
New	12 - 12	18 - 18	24 - 24	6 - 6
Item	13 - N1	19 - N1	1 - N1	7 - N1
Item	14 - N2	20 - N2	2 - N2	8 - N2
Item	15 - N3	21 - N3	3 - N3	9 - N3
Item	16 - N4	22 - N4	4 - N4	10 - N4
Item	17 - N5	23 - N5	5 - N5	11 - N5
Item	18 - N6	24 - N6	6 - N6	12 - N6
Rearranged	19 - 20	1 - 2	7 - 8	13 - 14
Rearranged	20 - 19	2 - 1	8 - 7	14 - 13
Rearranged	21 - 22	3 - 4	9 - 10	15 - 16
Rearranged	22 - 21	4 - 3	10 - 9	16 - 15
Rearranged	23 - 24	5 - 6	11 - 12	17 - 18
Rearranged	24 - 23	6 - 5	12 - 11	18 - 17
Intact	25 - 25	31 - 31	37 - 37	43 - 43
Intact	26 - 26	32 - 32	38 - 38	44 - 44
Intact	27 - 27	33 - 33	39 - 39	45 - 45
Intact	28 - 28	34 - 34	40 - 40	46 - 46
Intact	29 - 29	35 - 35	41 - 41	47 - 47
Intact	30 - 30	36 - 36	42 - 42	48 - 48
New	31 - 31	37 - 37	43 - 43	25 - 25
New	32- 32	38 - 38	44 - 44	26 - 26
New	33 - 33	39 - 39	45 - 45	27 - 27
New	34 - 34	40 - 40	46 - 46	28 - 28
New	35 - 35	41 - 41	47 - 47	29 - 29
New	36 - 36	42 - 42	48 - 48	30 - 30
Item	37 - N7	43 - N7	25 - N7	31 - N7
Item	38 - N8	44 - N8	26 - N8	32 - N8
Item	39 - N9	45 - N9	27 - N9	33 - N9
Item	40 - N10	46 - N10	28 - N10	34 - N10
Item	41 - N11	47 - N11	29 - N11	35 - N11
Item	42 - N12	48 - N12	30 - N12	36 - N12
Rearranged	43 - 44	25 - 26	31 - 32	37 - 38
Rearranged	44 - 43	26 - 25	32 - 31	38 - 37
Rearranged	45 - 46	27 - 28	33 - 34	39 - 40
Rearranged	46 - 45	28 - 27	34 - 33	40 - 39
Rearranged	47 - 48	29 - 30	35 - 36	41 - 42
Rearranged	48 - 47	30 -29	36 - 35	42 - 41

Appendix B

High Reward Study Phase Trial



Low Reward Study Phase Trial



Appendix C

Study Phase Instructions

"Welcome! In this task, you will see several pairs of pictures on the computer screen. Please pay close attention to these pictures and how they are paired with one another because later your memory will be tested.

Before you see each picture pair, you will see a reward cue with either the number "10" or the number "200". These reward cues tell you the number of points you will earn if you remember those items on the later memory test. So, for example, if a picture pair is preceded by the reward cue "200" and you accurately remember this item on the later test, you will earn 200 points, whereas if the picture pair is preceded by the reward cue "10" you will earn 10 points. Of course, if you don't accurately remember the item on the later test, you won't receive any points. After the experiment is over, you will be able to exchange the points you have earned for cash; the more points you have, the more cash you will receive.

After you see the picture pair, a random series of three arrows will appear, followed by the prompt "? ? ?". When you see the prompt, use the arrow keys on the keyboard to indicate the arrow sequence. It is important that you enter the sequence as accurately as possible.

Do you have any questions? If so, please ask the experimenter now. When you are sure you understand the task, you may press the spacebar to begin. The first picture pair you will see is just for practice and you will then have an opportunity to ask questions again."

Appendix D

Single Item Recognition Test Phase Instructions

"In this part of the task, we would like to see how well you remember the individual pictures in the picture pairs you just saw. You will see a series of picture pairs and your job is to indicate whether the SECOND PICTURE in the pair, or the one on the right side of the screen, is a picture you saw during the previous study phase. If you remember seeing the second picture, you should press the Y (Yes) key. If you do not remember seeing the second picture, press the N (No) key.

Accuracy is more important than speed, so take as much time as you need to make your response. You will not receive feedback on the accuracy of your response, but each time you are correct, you will earn the reward points that were associated with that picture pair during the study phase. However, each time you are incorrect, the points associated with that picture pair will be deducted from your accumulated reward total. Therefore, you should try to respond as accurately as possible in order to gain the greatest number of points.

Do you have any questions? If so, please ask them now. When you are sure you understand the procedure, you may press the spacebar to begin."

Appendix E

Dual Item Test Phase Instructions

"In this part of the task, we would like to see how well you remember the picture pairs. You will see a series of picture pairs and your job is to indicate whether the pictures in the pair were PRESENTED TOGETHER during the previous study phase. In other words, you will decide whether or not this is an intact picture pair that you saw previously. If you remember seeing the picture pair, you should press the Y (Yes) key. If you do not remember seeing the picture pair, press the N (No) key.

Accuracy is more important than speed, so take as much time as you need to make your response. You will not receive feedback on the accuracy of your response, but each time you are correct, you will earn the reward points that were associated with that picture pair during the study phase. However, each time you are incorrect, the points associated with that picture pair will be deducted from your accumulated reward total. Therefore, you should try to respond as accurately as possible in order to gain the greatest number of points.

Do you have any questions? If so, please ask them now. When you are sure you understand the procedure, you may press the spacebar to begin."