AGE-RELATED ASSOCIATIVE MEMORY DEFICIT:

SIMULATION AND STRATEGIES TO IMPROVE PERFORMANCE

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Brenda Iok Wong

Master of Arts, Ryerson University, 2013

Bachelor of Science (Honours), University of Toronto, 2010

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Brenda Iok Wong

Psychology, Ryerson University

Abstract

According to the associative deficit hypothesis, older adults experience greater difficulty in remembering associations between pieces of information (associative memory) than young adults, despite their relatively intact memory for individual items (item memory). Recent research suggests that this deficit might be related to older adults' reduced availability of attentional resources – the reservoir of mental energy needed for the operations of cognition functions. The purpose of this Dissertation was to examine the role of attentional resources in associative deficit, and to explore encoding manipulations that might alleviate the deficit in older adults. In Study 1, young adults' attentional resources during encoding of word pairs were depleted using a divided attention task. These participants showed an associative deficit commonly observed in older adults, and were less likely to use effective encoding strategies and recollection-based processes to support their memory in comparison to young adults under full attention. The resemblance in memory performance between young adults under divided attention and older adults suggests that lack of attentional resources might be a contributing factor in older adults' associative deficit. In Study 2, participants' resource load during encoding was reduced by learning individual items and their associations sequentially in two phases. Older adults in this condition showed equivalent memory performance to young adults, and were more likely to use effective encoding strategies and recollection-based processes than older adults in

Study 1 who studied items and associations simultaneously. Finally, Study 3 employed a value-directed learning paradigm, in which participants studied high- and low-value word pairs. Older adults showed similar memory performance for both high- and low-value word pairs as young adults, without any signs of associative deficit. Assigning value to associative information might prompt older adults to prioritize associative encoding over item encoding, which benefits their associative memory. Taken together, these results suggest that depletion of attentional resources during encoding could impair associative memory. Furthermore, older adults' associative deficit could be effectively alleviated with sufficient environmental support during encoding, such as when resource competition between item and associative encoding is minimized (Study 2) or when being guided to prioritize encoding of associations over items (Study 3).

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Chapter 1: General Introduction

Associative memory, the ability to learn and remember relations between units of information (e.g., a face and a name), declines drastically with age (Naveh-Benjamin, 2000). In fact, age differences are often larger in associative memory than in item memory (i.e., memory for individual items, e.g., a face *or* a name; Old & Naveh-Benjamin, 2008), suggesting that deficit in associative memory cannot be explained by age-related declines in general memory function alone. According to Naveh-Benjamin's (2000) associative deficit hypothesis (ADH), older adults' declines in associative memory stem from their poor ability in creating and retrieving links between units of information, including associations between two items, an item and its context, and two pieces of contextual information. Recent evidence suggests that this deficit might be driven by reduced attentional resources in older adults (e.g., Kim & Giovanello, 2011a, 2011b).

The purpose of this dissertation was to examine the role of attentional resources in age-related associative deficit. Attentional resources, or "mental energy", refer to the reservoir of psychological energy that allows for the operations of cognitive functions (Craik & Byrd, 1982; see subsequent sections for detailed definitions). The first chapter of this dissertation presents a review of previous research on age-related associative deficit and the contributing role of older adults' limited attentional resources in this deficit. Chapters 2 to 5 describe three research studies that were conducted to investigate the role of attentional resources in associative deficit in old age. In Study 1, associative deficit was simulated in young adults by dividing their attentional resources needed for relational processing. The effects of reduced attentional resources during encoding on participants' use of effective encoding strategies and recollection and familiarity-based memory processes were examined, as declines in these processes are common contributors to age-related associative deficit (e.g., Cohn, Emrich, & Moscovitch, 2008; Naveh-Benjamin, Brav, & Levy, 2007). In Study 2, participants' resource load for associative encoding was reduced by learning items and associations separately in two encoding phases. This study aimed to investigate whether this manipulation would lead to greater use of effective encoding strategies and recollection-based memory processes, which would in turn facilitate associative memory performance. Finally, the purpose of Study 3 was to test whether older adults could recruit attentional resources to encode valuable associative information, and thus show better associative memory. The overall interpretation of study results and their implications to future research are discussed in Chapter 6.

Associative Deficit Hypothesis

In a typical experiment testing the ADH (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin, Hussain, Guez, & Bar-On, 2003; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004), young and older adults are presented with pairs of items, such as word pairs, during the encoding phase. Participants are either given an intentional or an incidental encoding task. In intentional tasks, participants are informed at the beginning of the study that their memory for the stimulus pairs will be tested. On the other hand, in incidental tasks, they are asked to complete a task using the stimulus pairs, such as evaluating whether the name and the face of a study pair fit well together (Naveh-Benjamin et al., 2009), without being given any information regarding the subsequent memory tests. Their memory for the individual items (item memory) and the association between the items (associative memory) are tested using two recognition tests. In the item memory test, participants are presented with items that have appeared during encoding (old items), along with items that have never been presented to them during encoding (new items). Their item memory is indicated by their ability to recognize studied items, as well as their ability to reject new items (i.e., corrected item memory score = hit rates to old items minus false alarm rates to new items). In the associative memory test, participants are shown intact pairs (i.e., two items that have appeared *together* during encoding) and rearranged pairs (i.e., two items that have been presented during encoding, but are taken from different study pairs). Participants are asked to recognize the original pairing of the items. In other words, their associative memory is indexed by their ability to recognize intact pairs and their ability to reject rearranged pairs (i.e., corrected associative memory score = hit rates to intact pairs minus false alarm rates to rearranged pairs).

Using the study paradigm described above, older adults typically display disproportionately larger age-related impairments in associative memory relative to item memory (see Old & Naveh-Benjamin, 2008 and Smyth & Naveh-Benjamin, 2016 for a review). Older adults show difficulties in associative memory even when they are given more time to study stimulus pairs (Naveh-Benjamin, Guez, & Shulman, 2004). Furthermore, the deficit could be generalized to a variety of study stimuli, such as word-word pairs (e.g., Naveh-Benjamin, 2000, Experiment 2; Naveh-Benjamin, Hussain et al., 2003, Experiment 2; Naveh-Benjamin, Guez, & Shulman, 2004), word-nonword pairs (e.g., Naveh-Benjamin, 2000, Experiment 1), words and their perceptual features (e.g., font, Naveh-Benjamin, 2000, Experiment 3), picture pairs (e.g., Guez & Lev, 2016; Naveh-Benjamin, Hussain et al., 2003, Experiment 1), face pairs (e.g., Bastin & Van der Linden, 2006), and face-name pairs (e.g., Hara & Naveh-Benjamin, 2015; James, Fogler, & Tauber, 2008; Naveh-Benjamin et al., 2009; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004). In contrast, older adults did not show the disproportionate deficit in associative memory when pairs of nonwords were used as stimuli (Badham & Maylor, 2011), suggesting that forming and remembering associations between nonword stimuli are equally difficult for young and older adults.

Cognitive Resource Limitation in Old Age

According to Craik and Byrd (1982), attentional resources (also referred to as "mental energy" or "processing resources") are defined as a reservoir of psychological energy that fuels cognitive functions (also see Craik & Broadbent, 1983). The researchers proposed that there is a limit to which individuals can draw attentional resources from this pool momentarily, and that the size of this resource reservoir varies with age and physical states (e.g., fatigue). Cognitive processes are often classified as automatic or controlled (e.g., Hasher & Zacks, 1979; Shiffrin & Schneider, 1977). Automatic processes can be operated involuntarily, with minimal attention, and may not involve conscious awareness. These processes are usually not affected by concurrent processes, and can be said to require few attentional resources from the individual. On the other hand, controlled processes are described as effortful processes that require conscious awareness and attention, and hence they are expected to work at the expense of mental energy. Individuals can only perform a limited number of controlled processes simultaneously. One technique to measure the amount of resources necessary for different controlled processing tasks is to have participants complete a divided attention (DA) task simultaneously with the primary task (e.g., a memory task). The purpose of the DA task is to deplete the amount of attentional resources available for the primary task. Dividing participants' attention during encoding impairs their ability to retrieve encoded information later (e.g., Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Fernandes & Moscovitch, 2000). Their performance on the DA task (i.e., secondary task) is also poorer when it is completed simultaneously with the primary task than when it is carried out alone, which serves as an index of the costs on attentional resources associated with the primary task (e.g., Anderson, Craik, & Naveh-Benjamin, 1998).

Taken together, these findings suggest that there is a limited availability of attentional resources at every moment of time.

Craik and Byrd (1982) suggested that attentional resources decline as we age. They further hypothesized that older adults' deficits in many controlled memory tasks can be explained by the declines in their attentional resources. Specifically, reduction of attentional resources makes it difficult for older adults to self-initiate deep encoding processes to remember information, and hence older adults are less likely than young adults to engage in these effortful processes unless induced by the experimental stimuli or contexts (e.g., Craik, 1986; Craik & Rose, 2012). Supporting Craik and Byrd's hypothesis, it was found that division of attention during memory tasks mimics older adults' memory deficits (e.g., Anderson et al., 2000; Johnson, Nessler, & Friedman, 2013). Craik and Byrd proposed that memory performance under divided attention and in old age is similar because in both contexts, there is a reduction in attentional resources which in turn impairs the individuals' ability to initiate and make use of deep and elaborative encoding processes. As a result, older adults and individuals completing a concurrent DA task are more likely to encode the gist of information, without learning about specific details of the information. This leads to high false alarm rates in these individuals' recognition memory, as it is hard for them to distinguish between the exact stimulus presented and a distractor that is similar to the stimulus. Evidence from neuroimaging studies converged with Craik and Byrd's hypothesis. It has been found that both aging and division of attention reduces neural activity in similar brain regions, such as the left prefrontal cortex (Anderson et al., 2000), suggesting that the same neural mechanism may underlie the two phenomena.

Relevance of Attentional Resources in Age-Related Associative Deficit

Given the evidence that aging and division of attention had similar effects on general episodic memory (e.g., Anderson et al., 2000), it follows that age-related declines in attentional resources might also mediate older adults' impairment in associative memory. As discussed in the following sections, distinctive features of ADH, including deficit in the use of encoding strategies, associative memory improvements under schematic support (using semantically related stimulus pairs), and heightened false alarm rates in associative memory tasks, have all been suggested to be related to insufficiency of attentional resources.

Deficits in Strategic Control: The Use of Encoding Strategies in Older Adults

Older adults' associative memory deficit is more pronounced and robust when tested under intentional than incidental encoding instructions (see Old & Naveh-Benjamin, 2008 for a meta-analysis review). In intentional tasks, participants are explicitly instructed that their memory will be tested, whereas in incidental tasks, they are not aware about the subsequent memory tests. Naveh-Benjamin and his colleagues (2009) found that older adults showed an associative deficit for face-name pairs when given intentional instructions, but the deficit did not appear under incidental instructions. Specifically, although older adults' overall memory was still poorer than that of young adults under incidental encoding, they did not show differentially poorer associative memory than item memory in comparison to young adults. It should be noted that the age-related associative deficit has been found in incidental tasks in some studies (e.g., Chalfonte & Johnson, 1996; Naveh-Benjamin, 2000), but the magnitude of the deficit is often smaller in comparison to that tested under intentional tasks (Old & Naveh-Benjamin, 2008). Taken together, it appears that although young adults are able to improve both item and associative memory from foreknowing about the subsequent memory tests under intentional instructions, older adults fail to show the same benefits.

According to Moscovitch's (1992) model of memory, episodic memory engages an automatic process that involves the medial temporal/hippocampal region and an effortful process that involves the frontal lobes (also see Moscovitch, 1994; Moscovitch & Winocur, 2002). He proposed that medial temporal/hippocampal regions are responsible for binding pieces of information together into cohesive episodes in memory. The frontal lobes, on the other hand, are responsible for the strategic components of memory, including elaboration and organization of information. Both of these systems have shown neurological declines with age, with changes in the frontal lobes emerging earlier and showing more noticeable impairments than changes in the medial temporal/hippocampal regions (West, 1996). It is suggested that older adults' associative deficit are driven by both of these processes (e.g., Naveh-Benjamin et al., 2009; Shing et al., 2010). That is, on top of their declines in binding information together (i.e., hippocampus-based process), older adults have an additional deficit in initiating encoding strategies relevant to the associative memory task (i.e., frontal lobe-based process) due to their declines in frontal lobe functions. Hence, they often fail to initiate appropriate strategies to support encoding of associative memory the same way as young adults.

Naveh-Benjamin and colleagues (2007) asked their young and older participants to self-report the types of encoding strategies they had used during encoding of word pairs. They found that all of their young adults reported using relational encoding strategies, such as generating a sentence or a mental image using two words of a pair. In comparison, only 11% of their older participants used the same type of encoding strategies. The rest of the older participants either used rehearsal (11%) to help them remember the word pairs, or did not use any strategies at all.

However, there is no evidence that young and older adults perceive the effectiveness of these encoding strategies differently (Bender & Raz, 2012). It is therefore unlikely that older adults used relational encoding strategies less than young adults because they underrated the effectiveness of these strategies. Interestingly, when older adults were prompted to use sentence generation as an encoding strategy by the experimenter, all of them reported using this strategy during encoding, and as a result their associative memory significantly improved (Naveh-Benjamin et al., 2007). Altogether, these findings suggest that older adults are able to use relational encoding strategies when being prompted to do so, and their associative memory performance can benefit from using these strategies. However, they are less likely than young adults to self-initiate and execute these strategies to facilitate associative memory without any environmental support.

Initiation and use of elaborative encoding strategies require attentional resources. According to Eysenck and Eysenck (1979), deep encoding processes, such as semantic and associative processing, require more effort and attention to accomplish than shallow processing, such as repetition. Moscovitch (1992) made a similar claim that strategic processes in memory are effortful and require cognitive resources. Craik and Byrd (1982) also suggested that older adults have difficulty spontaneously initiating deep encoding processes *not* because they lack insight regarding their memory deficits, but because they have limited attentional resources to contribute to these encoding processes. Hence, they are less likely to self-initiate these processes unless prompted by the experimental stimuli or task instructions (see Naveh-Benjamin et al., 2007). In line with these hypotheses, it was found that older adults require more attentional resources than young adults when using the same relational encodings strategies (e.g., sentence generation, imagery; Naveh-Benjamin, Craik, Guez, & Kreuger, 2005). Using a tracking task as a divided attention task, Naveh-Benjamin and colleagues (2005) found that older adults continued to devote resources to remember word pairs throughout the entire encoding period, whereas young adults only needed to allocate resources to the first 2 seconds of encoding. Moreover, when older adults were not instructed to use relational strategies, they showed less sustained resource costs than when they deliberately used relational strategies to learn the word pairs. Taken together, it is plausible that older adults do not initiate and make use of effective, elaborative encoding strategies readily because these encoding strategies require more cognitive resources than shallow strategies, and they do not have adequate amount of resources to allocate to these processes.

Role of Recollection and Familiarity Processes in Associative Memory

In addition to its effects on strategy use, limited availability of attentional resources might also restrict other memory processes underlying associative memory. There is evidence that older adults' associative deficit in recognition tests is primarily driven by an impairment in distinguishing and rejecting rearranged pairs that contain items from different studied pairs, but not an inability to recognize previously studied pairs (e.g., Castel & Craik, 2003; Cohn et al., 2008). In other words, their hit rates to intact pairs are often equivalent to those of young adults, but they show heightened false alarm rates to rearranged pairs, suggesting a reliance on familiarity-based memory processes without support from recollection processes (Jones & Jacoby, 2001; Rhodes, Castel, & Jacoby, 2008).

Recollection is defined as a memory process that involves remembering specific aspects of an event, such as its related perceptual, spatial, and temporal information, the source of information, or any thoughts and emotions experienced during the episode (Light, 2012). On the contrary, familiarity is defined as experiences of events that arise from activated mental representations or perceptual fluency, which lack the rich memory details characterized by recollection (Light, 2012). Recollection and familiarity are independent memory processes that work hand-in-hand. According to Yonelinas' (1994, 2001, 2002) dual process model, recollection is a threshold-retrieval or an "all-or-none" process, in which the "qualitative" information about an event is remembered. In other words, participants are either able to retrieve information associated with the studied event or not. In contrast, familiarity follows a continuous dimension based on the signal-detection theory, which reflects the "quantitative" information about the strength of the memory and is distinctive from participants' response bias in memory tasks. To illustrate, in memory tests, most stimuli (e.g., words) are familiar to participants because they have encountered them before in their lives. However, stimuli presented at encoding will be more familiar to participants because they have just been recently studied. At recognition, participants accept a stimulus as encoded if familiarity associated with the stimulus exceeds a certain response criterion. In associative memory tasks, accurate recognition for intact pairs could either be made based on recollection by remembering the exact combination of the pair, or based on familiarity by realizing that the two stimuli have appeared before, without specific memory for the actual association. On the other hand, for rearranged pairs, both items of the pairs have been studied during encoding, and hence participants will need to explicitly remember the specific item-item pairing in order to correctly reject these pairs. Older adults are able to make use of their familiarity memory processes to recognize individual items that have been presented to them earlier, but they have trouble remembering the exact associations between these items due to reduced use of recollection. As a result, they often show age-equivalent ability to recognize intact pairs, but impairment in rejecting rearranged pairs in associative recognition tests relative to young adults. In support for these premises, Cohn and colleagues (2008) found that older adults showed significantly poorer recollection than young adults in an associative memory task, whereas there was no age difference in familiarity estimates.

Recollection is considered as a controlled process that is deliberate and attention demanding (e.g., Light, 2012; Yonelinas, 2002), and is dependent on products of elaborative and reflection processes (Mandler, 1980). Familiarity, on the other hand, is an automatic process that can be executed rapidly, without taking up much attentional resources (e.g., Light, 2012; Yonelinas, 2002), as it relies more on perceptual and conceptual processing (Mandler, 1980). It is widely believed that recollection and familiarity processes can be employed flexibly, based on the individuals' cognitive control abilities and goals, the quality of information being encoded, and the way memory is tested in experiments (Benjamin & Bawa, 2004; Malmberg, 2008; Reder, 1988). In particular, recollection processes have been shown to decline with age, whereas familiarity remains relatively stable over the lifespan (Craik et al., 1996; Jacoby, Woloshyn, & Kelley, 1989; Light, 2012; Troyer, Winocur, Craik, & Moscovitch, 1999; also see Koen & Yonelinas, 2014 and Yonelinas, 2002 for a review). Craik and Byrd (1982) proposed that the general meaning, or gist, of the to-be-remembered events could be encoded automatically with minimal attentional resources. However, the encoding of specific details regarding the events requires cognitive resources and may become "optional" when attentional resources are limited. As a result, older adults and individuals under DA may not readily encode these specific details, which in turn affect their ability to retrieve these details at recognition. To illustrate, Kensinger, Clarke, and Corkin (2003) asked their participants to encode words while concurrently completing a simple or a difficult auditory discrimination task. They found that words encoded with the easy divided attention task were more likely to be recognized based on recollection than words encoded with the difficult divided attention task. Moreover, participants were more likely to rely on familiarity alone, without recruiting recollection, when they retrieved words encoded under the difficult divided attention condition. These findings imply that information retrieved based on recollection takes more attentional resources to encode relative to information retrieved based on familiarity processes. In fact, divided attention during encoding typically has small effects on familiarity-based retrieval performance (Yonelinas, 2002). Taken together, deficit in recollection processes during retrieval of associative information may be a result of declines of attentional resources with age. As familiarity processes are typically not affected by the availability of attentional resources, older adults could still rely on familiarity in associative memory tests.

Schematic Support

Schematic support is defined as the benefit of prior knowledge or schemas in enhancing encoding and retrieval memory processes, which in turn improves memory performance (Craik & Bosman, 1992). It has been found that meaningful semantic relations between words facilitates older adults' associative memory for these pairs, and as a result the associative memory deficit is reduced for semantically related pairs in comparison to unrelated pairs (Badham, Estes, & Maylor, 2012; Naveh-Benjamin, 2000, Experiment 4; Naveh-Benjamin et al., 2005; Naveh-Benjamin, Hussain et al., 2003, Experiment 2). McGillivray and Castel (2010) extended these findings to show that older adults could recall more ages of unfamiliar faces when the faces are congruent with their associated ages (e.g., an older person's face paired with an old age) in comparison to when the faces and their ages are incongruent (e.g., an older person's face paired with a younger age). These findings altogether suggest that older adults could draw from their prior experience to help them encode and retrieve associative information.

Craik and Byrd (1982) suggested that inter-item processing (i.e., the formation of associations between items) is more affected by older adults' lack of attentional resources than the processing of items in isolation, but providing schematic support (e.g., using semantically related stimuli) could attenuate this deficit. That is, providing schematic support during encoding should benefit older adults because older adults could make use of existing associations from their memory to support learning of these stimulus pairs. Encoding of unrelated pairs, on the other hand, would require more cognitive resources to create new associations between pieces of information. Naveh-Benjamin and colleagues (2005) tested this hypothesis in their study and found that although older adults showed significantly better memory for semantically related word pairs than for unrelated pairs, they did not recruit more attentional resources in order to improve their memory for related pairs, as indicated by equivalent attentional costs in a DA task. In other words, older adults did not need to put in more effort to encode these related stimulus pairs to achieve better memory outcomes, because these associations already existed prior to encoding or were easier to formulate than unrelated pairs.

Simulation of Associative Deficit in Young Adults under Divided Attention

The relationship between attentional resource limitations and older adults' associative deficits has been a popular research topic since early 2000s. Naveh-Benjamin and his lab have conducted a number of experiments to simulate older adults' associative deficit in young adults using DA tasks, but did not gain much success (e.g., Kilb & Naveh-Benjamin, 2007; Naveh-Benjamin et al., 2005; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Guez, & Shulman, 2004; Naveh-Benjamin, Hussain et al., 2003; also see Craik, Luo, & Sakuta, 2010). The common finding is that division of attention impairs both item and associative memory in young adults, but does not induce disproportionate associative memory impairment (i.e., greater impairments in associative memory than item memory) as typically shown in an age-related associative deficit. Based on these findings, Naveh-Benjamin and his colleagues concluded that age-related associative deficit is not related to older adults' lower availability of attentional resources, but a specific impairment in binding information together in memory.

Recent studies, however, have provided a different picture. In two experiments, Kim and Giovanello (2011a) asked young adults to learn pairs of unrelated words presented on the computer screen under full attention, an item detection divided attention task (DA-I), or a relation detection divided attention task (DA-R). The difference between the two DA tasks is that a DA-R task required participants to attend to and make judgments based on the relational associations between two stimuli, whereas relational processing was not required in a DA-I task. In the first experiment of their study, participants in the DA-I and DA-R conditions were both presented with pairs of faces underneath the to-be-remembered word pairs on the computer screen during encoding. Participants in the DA-I group were asked to press a key to indicate the location of a male face, whereas participants in the DA-R group were instructed to compare the two faces and indicate which face was older by pressing a key. In the second experiment, participants under both DA conditions read pairs of numbers (e.g., THREE SIX) presented under the word pairs. They were asked to indicate the location of the odd number in the DA-I task and to indicate which number was larger in the DA-R task. To summarize, DA-R conditions in both experiments required participants to compare stimuli and make a judgment based on the relation between the two stimuli. Kim and Giovanello found that young adults under DA-I conditions showed equivalent impairments in item and associative memory, as commonly demonstrated in past studies. Strikingly, young adults under DA-R conditions showed disproportionately more impairments in associative memory than item memory, which closely resembled older adults' associative deficit. In a subsequent study, Kim and Giovanello (2011b) found that when young adults encoded associative information under DA-R, they showed reduced activity in several neural regions, including the dorsolateral prefrontal cortex, ventrolateral prefrontal cortex, inferior and superior parietal cortex, and anterior hippocampus, which were related to successful associative encoding in young adults under full attention. Older adults under full attention also showed reduced activity in these same neural regions, highlighting the resemblance between aging and division of relational attention. On the other hand, the DA-I task did not impact these neural regions in young adults.

In another study, Hara and Naveh-Benjamin (2015) found that age-related associative deficit could also be simulated in young adults using a working memory divided attention task. In their first experiment, young adults were given a DA task in which they had to keep track of a series of two, three, or four letters auditorily presented to them during encoding. At the end of the presentation, they were given a probe and they had to indicate whether it had been presented as part of the series of letters they had just heard. In the second experiment, young adults were given a DA task in which they were presented two numbers auditorily, and were asked to complete an addition, subtraction, or division operation using the two numbers. These two DA tasks tapped on the storage and processing functions of working memory respectively. Hara and Naveh-Benjamin found that young adults showed disproportionately poorer associative memory under both types of DA tasks. However, there is some ambiguity in the results of the first experiment, as increasing the storage span of working memory did not further impair young adults' associative memory. Nevertheless, results of the second experiment showed a clear picture that young adults under limited processing resources performed similarly to old adults on associative memory tasks.

The studies by Kim and Giovanello (2011a, 2011b), as well as by Hara and Naveh-Benjamin (2015), are different from many of the past studies (e.g., Naveh-Benjamin, Guez, & Marom, 2003) in that the DA tasks used in these three studies involved relational processing or processing of two stimuli. This type of DA tasks engages deep, associative processing, which appears to differentially interfere with associative encoding in associative memory tasks. Consistent with these results, it has been found that the attentional system and working memory could compete with each other for cognitive resources when the two tasks tap on the same type of processing, but not when the tasks involve different types of processing (Kim, Kim, & Chun, 2005). In comparison to the studies by Kim and Giovanello, and Hara and Naveh-Benjamin, the majority of DA tasks in previous studies involved only perceptual processing. To illustrate, the choice-reaction time (CRT) task was employed as a DA task in several studies (Kilb & Naveh-Benjamin, 2007; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Guez, & Marom, 2003; Naveh-Benjamin, Hussain et al., 2003). In the auditory version of the CRT task, participants were asked to listen to tones and to respond accordingly to the frequency of the tones. In the visual version of the same task, participants were presented with four boxes on the screen while listening to word pairs during encoding, and the DA task was to press a key when an asterisk appeared in one of the boxes. The tracking task was another perceptual DA task used in previous ADH studies (Naveh-Benjamin et al., 2005; Naveh-Benjamin, Guez, Hara, Brubaker, & Lowenschuss-Erlick, 2014). This task required participants to use the computer mouse to track the movement of a dot. Taken together, the CRT and the tracking task only required participants to attend to the perceptual attributes of stimuli, without engaging in deeper, relational processing.

It is likely that these perceptual DA tasks do not recruit the same types of attentional resources as associative encoding, and hence an associative deficit could not be simulated in young adults using these tasks.

It should be noted that Castel and Craik (2003) successfully induced memory deficits for unrelated word pairs in young adults using a digit-monitoring DA task. In this task, participants were presented with a series of digits and were asked to respond when they heard three consecutive odd numbers. However, Naveh-Benjamin, Hussain et al. (2003) and Craik et al. (2010) did not find the same results despite using the same DA task. Young adults in these studies showed equivalent impairments in item and associative memory when encoding picture pairs along with the digit-monitoring DA task. It is plausible that although the digit-monitoring task is more resource demanding than perceptual-based DA tasks, it mainly involves monitoring abilities, but not relational processing. As a result, it may not specifically interfere with associative encoding in the same extent as the DA tasks in Kim and Giovanello (2011a, 2011b) and in Hara and Naveh-Benjamin (2015).

Summary

In summary, older adults show age-related impairments in associative memory, and this associative deficit is greater than their impairment in item memory. It has been suggested that older adults' associative deficit is at least partially due to their lower availability of attentional resources (e.g., Castel & Craik, 2003; Hara & Naveh-Benjamin, 2015; Kim & Giovanello, 2011a, 2011b). First, older adults' deficit is typically seen in their heightened false alarms to rearranged pairs, whereas their hit rates to intact pairs are relatively intact (e.g., Castel & Craik, 2003), suggesting a difficulty for older adults to remember exact pairing between units of information based on recollection processes. This finding is in line with Craik and Byrd's (1982) suggestion that division of attention during encoding does not allow individuals to learn information deeply, and therefore leads them to only remember the gist of information. Second, in addition to older adults' binding impairments, they also appear to have deficit in their use of strategies during encoding (e.g., Naveh-Benjamin et al., 2005). That is, they are less likely than young adults to initiate and use elaborative encoding strategies to encode associative information (Naveh-Benjamin et al., 2007), despite that they understand the effectiveness of different strategies (Bender & Raz, 2012). It is likely that they do not initiate these elaborative strategies as do young adults because they lack the attentional resources required to execute these strategies. Finally, previous research also suggests that older adults show better memory for pairs that are semantically related (e.g., Naveh-Benjamin et al., 2005), presumably because these semantic associations do not necessitate the creation of new associations in their memory, which in turn decreases the attentional resources needed for encoding (Naveh-Benjamin et al., 2005). Recent research also provides evidence that young adults under relational DA tasks show an associative deficit similar to that of older adults (Hara & Naveh-Benjamin, 2015; Kim & Giovanello, 2011a, 2011b).

Objectives of Dissertation

As reviewed in this chapter, availability of attentional resources is crucial for successful associative encoding. Associative deficit commonly seen in older adults could be mimicked using DA tasks that involve relational processing (Hara & Naveh-Benjamin, 2015; Kim & Giovanello, 2011a, 2011b). However, findings of these studies still could not identify the memory processes (e.g., recollection vs. familiarity, use of encoding strategies) that are being affected by the lack of resources for relational processing, and what could be done to alleviate these negative effects. Three studies were conducted in this Dissertation to address these research questions.

The purpose of Study 1 was to examine the role of attentional resources in associative deficit. First, associative deficit was simulated in young adults using a DA-R task described in Kim & Giovanello (2011a) to reduce participants' availability of attentional resources for relational processing. Under a DA-R task, young adults were predicted to show poorer associative memory than young adults under full attention, and their "associative deficit" would be comparable to that of older adults. Second, this study tested whether limited attentional resources for relational processing in young adults during encoding would impair their use of elaborative encoding strategies and recollection-based processes, as previous studies suggest that both of these processes are resource-demanding (e.g., Naveh-Benjamin et al., 2005; Yonelinas, 2002). Results of Study 1 would inform whether depleting younger adults' attentional resources during encoding would simulate restricted use of effective encoding strategies and recollection-based memory processes commonly seen in older adults during associative memory tasks.

Studies 2 and 3 aimed to investigate different approaches by which older adults could possibly optimize their associative memory performance. In Study 2, participants were guided to learn items and associations separately in two sequential phases to reduce competition of attentional resources between item and associative encoding. Pre-learning of items was expected to reduce demand of attentional resources for subsequent associative encoding, and thus would make it easier for older adults to engage in effective encoding strategies and recollection-based memory processes. Older adults in this study were predicted to show similar associative memory performance as young adults, as well as reduced deficit in comparison to older adults who learned items and associations together in a typical encoding paradigm (i.e., older participants in

Study 1). Finally, a value-directed learning paradigm (e.g., Castel, Benjamin, Craik, & Watkins, 2002) was adopted in Study 3 to test whether older adults are able to prioritize their attentional resources to encode associative information that is regarded as valuable. Specifically, point values were arbitrarily assigned to word pairs, and participants were motivated to remember the exact pairing between words in order to gain the points associated with each word pair. Older adults were expected to pay more attention to and encode word pairs associated with higher point values than those associated with lower point values. This would in turn strengthen their memory for high-value pairs. Results from Studies 2 and 3 would provide insight into the types of encoding contexts that are optimal for older adults to learn associations.

Chapter 2: General Method

This section outlines the overall method across all three studies in this Dissertation. Variations of procedures specific to each individual study are further described in detail in the Method section of each study. Research design in all three studies have been reviewed and approved by the Research Ethics Board at Ryerson University (REB protocol numbers: 2015-326, 2016-071, and 2016-413; See Appendix A).

Participants

Sample size. *A priori* sample size estimations for a repeated measures, within-between interaction design was conducted for all the studies in this dissertation using G*Power (Faul, Erdfelder, Lang, & Buchner, 2007). For Study 1, the sample size estimation was based on an F analysis with three groups of participants (group: young adults under full attention, young adults under DA-R, and older adults) and two measurements (memory: item vs. associative memory). Based on previous studies, the effect size f was set to be 0.50 (converted from the partial eta squared value of .20 for a similar group by memory type interaction effect in Kim & Giovanello, 2011a) and the correlation between item and associative memory was set as 0.39 (Old and Naveh-Benjamin, 2008). The values for power and alpha level were .95 and .05 respectively. Results of this analysis indicate that n = 8 per group would be sufficient to find a significant group by memory type effect. However, to be consistent with previous studies in the literature (e.g., Naveh-Benjamin, 2000; Naveh-Benjamin, Guez, Kilb, & Reedy, 2004; Naveh-Benjamin, Guez, & Shulman, 2004), the sample size was increased to 24 participants per group. The same sample size was set for Study 2, as direct statistical comparisons would be made between the older groups from the two studies.

The sample size estimation for Study 3 was based on an *F* analysis with two groups of participants (group: young and older adults) and four measurements (memory: item vs. associative memory; value: high- vs. low-value). The effect size *f* was set as .35, which was converted from a partial eta squared effect size of .11 based on a previous study that employed a similar associative memory paradigm (Naveh-Benjamin & Kilb, 2014). Power, alpha level, and correlation between item and associative memory were the same as in the sample size estimation for Study 1. Results of the analysis suggest a sample size of 12 per group, but the sample size was increased to 24 per group to be consistent with the previous two studies in this Dissertation.

Recruitment protocol. In all three studies, young adults were recruited from Ryerson University through the Undergraduate Psychology Study Participant Pool (SONA) or recruitment posters posted around campus. Older adults were recruited from the Ryerson Senior Participant Pool (RSPP). Study samples in the dissertation are independent – participants who took part in one study were not included in another study. All participants were tested at the Cognitive Aging Laboratory at Ryerson University. Young participants recruited from the Undergraduate Psychology Study Participant Pool received one course credit as compensation for their participation. Young and older participants recruited from the community received monetary reimbursement, and the amount of reimbursement varied across studies due to different session durations. Study duration for young participants was 1 hour for all three studies. For older participants, study duration was 1 hour for Study 1 and 1.5 hours for Studies 2 and 3. Participants received $10 for a 1-hour session and $15 for a 1.5-hour session for Studies 1 and 2, and $12 for a 1-hour session and $18 for a 1.5-hour session for Study 3. The pay rate for Study 3 was adjusted to match the new pay rate for other studies in the department.

Inclusion and exclusion criteria. Young adults between the age of 17 and 29 and older adults between the age of 65 and 77 were eligible for the studies. The age range of the older adult groups was specifically set to adhere to the age range of the younger groups (i.e., range of 12 years of age). Past studies have shown increased variability in cognitive performance with age (e.g., Morse, 1993). Thus, including older participants with a wide age range might lead to greater variability in the data. Participants were excluded if they (1) scored lower than 20 on the Shipley Institute of Living Vocabulary test (Shipley, 1946); (2) had uncontrolled medical conditions, such as high blood pressure or diabetes; and (3) had psychiatric or neurological disorders that might affect cognition (e.g., depression, prolonged duration of unconsciousness, dementia, and history of strokes and head injuries). Medical, psychiatric, and neurological conditions were assessed through self-reports on the background questionnaire. Older participants were excluded from the study if they scored 26 or lower on the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975), which signals dementia-related cognitive impairment. This would ensure that age differences in associative memory performance were not confounded by abnormal cognitive declines in older participants.

Selection of Word Pair Stimuli

Word pair stimuli for all experiments in this Dissertation were selected from the MRC Psycholinguistic Database (Wilson, 1988). Four hundred and eighty English nouns that consisted of four to seven letters and two to three syllables were selected. These words were then randomly paired to form 240 unrelated word pairs. A pilot study was conducted to ensure that there was no meaningful association between the two words in any of the word pairs. Ten young (age M = 19.50, SD = 3.57; years of education M = 12.75, SD = 1.27) and 10 older adults (age M = 69.40, SD = 3.98; years of education M = 15.60, SD = 2.99) were recruited to rate the associations between the words in all 240 unrelated word pairs. One hundred semantically related word pairs were also selected from the University of South Florida Free Association Norms (Nelson, McEvoy, & Schreiber, 1998) to be included in the rating task to increase variability in relatedness of the word pairs. The unrelated and related word pairs were randomly intermixed in the rating task.

All participants provided informed consent and completed the rating task individually. During this self-paced rating task, they were presented with word pairs one after each other on the computer screen. They were asked to rate the association between the two words in each pair on a scale of 1 (extremely unrelated) to 9 (extremely related) using the number keys on the right side of the keyboard. They were instructed to press the “z” key, labeled as “DK”, if they encountered a word unknown to them. They would then write down the unknown word on a piece of paper, which was placed next to the keyboard. After the rating task, participants completed the Shipley Institute of Living Vocabulary test (Shipley, 1946) to ensure that all participants had adequate vocabulary skills, as would be indicated by a score of 20 or above. All participants passed the cut-off score on the Shipley vocabulary test ($M = 28.10$, $SD = 4.15$ for young adults; $M = 36.30$, $SD = 2.00$ for older adults). Only word pairs with association rating lower than 5 were included in the final stimulus list. Furthermore, 12 word pairs were removed from the stimulus list because they contained words unknown to more than one participant. The final list included 228 word pairs, with an average association rating of 1.82 ($SD = 0.54$, ranging from 0.54 to 3.80). The association ratings did not differ between the two age groups (young adults: $M = 1.90$, $SD = 0.59$; older adults: $M = 1.73$, $SD = 1.00$), $p = .644$. It should be noted that the association ratings for related word pairs were all above 6 ($M = 7.92$, $SD = 0.62$, ranging from 6.30 to 8.85), which verifies that the unrelated word pairs in the final list were indeed given low associative ratings.

Memory Paradigms

The memory task was divided into two (Studies 1 and 2) or four (Study 3) testing blocks to avoid fatigue and floor effects in performance. In each study, the procedures of the study phase and recognition tests were explained in detail at the beginning of the task and participants were given practice trials to familiarize themselves with the procedures. They were encouraged to repeat the practice task until they fully understood the instructions. The instructions for the encoding phase, filler task, and memory tests were repeated every time before participants completed each individual phase of the memory task.

Study phase. During the study phase, participants learned pairs of words one after another on the computer screen under the general instructions to remember both the individual words and the associations between them. Specific manipulations to the encoding instructions are described in detail in the Method section of each study.

Filler tasks. The study phase was followed by a filler task. The Digit Symbol Substitution Test (DSST; Wechsler, 1958) was used as a filler task in Studies 1 and 2. Participants were presented with nine number-symbol pairs. On the same sheet of paper, there were rows of randomized numbers, without the paired symbols. Participants were asked to copy the symbol that matched with each number as quickly and accurately as they could in 2 min. The same version of the test was administered in the two memory blocks to avoid confusion. In Study 3, a modified version of the Letter Comparison task (Salthouse & Babcock, 1991) was used as a filler task. Specifically, participants were shown pairs of letter strings (e.g., RXNDJX - NXNDJX) on paper. They were instructed to compare each pair of letter strings to indicate whether they were the same or different. On the first page of the task, each letter string contained six letters, whereas the letter strings on the second page each contained nine letters. Participants were given 40 s for each page (i.e., 80 s in total), and were instructed to complete as many trials as they could in the time given without making any errors. Different versions of the task were administered in each of the four memory blocks. Only scores on the DSST and Letter Comparison task from the first memory blocks were reported and compared across participant groups in this dissertation.

Recognition tests. Item and associative memory performance was measured using the process dissociation paradigm in Studies 1 and 2 and the traditional associative recognition paradigm in Study 3.

Process dissociation paradigm. The process dissociation paradigm (Yonelinas, 2002; Yonelinas & Jacoby, 2012) allows the measurement of item and associative memory, as well as recollection and familiarity processes. There were two recognition tasks under this paradigm: an inclusion task (pair recognition) and an exclusion task (associative recognition). Both of these tasks included (1) intact pairs that participants had studied during encoding, (2) rearranged pairs that were formed using words from different studied pairs, and (3) new pairs that participants had not studied before. In the pair recognition task, participants were presented pairs of words one after another and were asked to indicate whether they had studied these words during encoding, regardless of whether the words had been presented together as a pair earlier. That is, they should respond “YES” to both intact and rearranged pairs, but “NO” to new pairs. In contrast, in the associative recognition test, they were instructed to make their memory judgments based on the original pairing of the pairs. In this case, they should only respond “YES” to intact pairs, and respond “NO” to both rearranged and new pairs. This paradigm has been used to measure recollection and familiarity processes (Yonelinas, 2002; Yonelinas & Jacoby, 2012), considering correct recognition of rearranged pairs in the pair recognition task involves both familiarity and recollection processes, whereas the failure to reject rearranged pairs in the associative recognition task indicates a reliance on familiarity, with little support from recollection.

Item memory was calculated as the difference between hit rates to rearranged pairs and false alarm rates to new pairs in the pair recognition test, whereas associative memory was derived from the difference between hit rates to intact pairs and false alarm rates to rearranged pairs in the associative recognition test (e.g., Cohn et al., 2008). Recollection estimate was calculated as the difference between hit rates to rearranged pairs in the pair recognition task and false alarm rates to rearranged pairs in the associative recognition task (Cohn et al., 2008). Familiarity estimate was calculated as a discriminability score (*d*') using the equation $\Phi(d' / 2 - c)$, in which Φ and c represent the probability of familiarity associated with an item and the response criterion measure respectively. The familiarity estimate was computed using the spreadsheet algorithm provided by Yonelinas (2015).

Traditional item and associative recognition tests. In Study 3, item and associative memory performance was tested using a recognition paradigm typically used in the associative memory literature (e.g., Naveh-Benjamin & Kilb, 2014). This paradigm includes two recognition tests: an item recognition and an associative recognition test. In the item recognition test, participants were asked to recognize individual items to measure their item memory. This is different from the process dissociation recognition procedure used in Studies 1 and 2. In the process dissociation recognition procedure, item memory was derived from the pair recognition test, in which participants were asked to accept both intact and rearranged pairs as studied items and to reject new pairs, with no emphasis placed on the pairing between the words. This procedure could not be applied to Study 3. Given that participants were rewarded points for remembering the exact pairing between words, it would be confusing to participants to include a recognition test in which pairing between words was unimportant.

In the item recognition test, participants were presented *single* words one after another. They were asked to identify the words they had studied during the study phase from new words they had not studied by pressing the "YES" or "NO" keys on the keyboard respectively. Item memory was calculated as the difference between hit rates to studied words and false alarm rates to new words. In the associative recognition test, they were given intact and rearranged word pairs. The task was to identify intact pairs from rearranged pairs by pressing the "YES" key to intact pairs and the "NO" key to rearranged pairs. Associative memory was calculated as the difference between hit rates to intact pairs and false alarm rates to rearranged pairs.

Paper-and-Pencil Questionnaires

After completion of the memory tasks, participants filled out several paper-and-pencil questionnaires measuring their vocabulary skills, mood states during the study session, as well as their demographic and medical information to screen for potential confounding factors. Participants' use of encodings strategies during the study phase of the memory task was also assessed in Studies 1 and 2. Older participants in all three studies completed an additional cognitive test (MMSE; Folstein et al., 1975) to screen for possible dementia-related cognitive impairment. All these questionnaires are described in detail in the following sections.

Personal Encoding Preference Questionnaire (PEP). The PEP was administered in Studies 1 and 2 to measure participants' use of encoding strategies during the study phase of the memory task, as well as their effectiveness rating of each strategy (see Appendix B). In the original PEP (Hertzog & Dunlosky, 2004), participants are asked to rate the effectiveness of six encoding strategies in memorizing word pairs. The six strategies are (1) rote repetition ("say the word pair over and over"), (2) attentive reading ("reading over or saying the word pair once in your mind"), (3) semantic reference ("relating the word pair to something of meaning in your life"), (4) focal attention ("focus on the word pair by looking or staring at it until you can see the word pair clearly in your mind"), (5) imagery ("imagine a scene using the two words as images in it"), and (6) sentence generation ("construct a sentence using both of the words"). The PEP was modified in the current study in that participants were asked to report *how often* they have used each strategy by providing an approximate percentage value (e.g., 0% means the participant had not used a particular strategy at all; 50% means the participant had used the strategy to memorize half of the word pairs). They were also asked to report any strategies not stated on the PEP as "other strategies". These strategies were then independently coded by the experimenter and a research assistant as high- or low-level strategies based on whether the strategy required associating the words together at a semantic level (see Results section of Study 1 for examples). On the second page of the questionnaire, participants were given the original PEP, in which they were asked to rate the effectiveness of each encoding strategy on a scale of 1 ("Least effective") to 10 ("Most effective").

To ensure that participants accurately understood and reported their use of high-level encoding strategies (i.e., imagery, semantic reference, and sentence generation), they were asked to provide an example of their use of these strategies after they completed both pages of the PEP questionnaire. Their examples were later evaluated by the experimenter and a research assistant independently, and only strategies with valid examples were counted in the final analysis. For example, a few participants reported imagining pictures of individual words, without putting the two pictures together into one image. This strategy deviated from the imagery strategy described on the PEP, whereby participants should associate the two words together by imagining a scene with pictures of *both* words. Such strategies were therefore counted as low-level strategies instead.

Positive and Negative Affect Schedule (PANAS). The PANAS (Watson, Clark, & Tellegen, 1988) measures levels of self-reported positive and negative affect during the study session. The scale contains 20 words, with half of the items representing positive affect (e.g., "Excited") and the other half representing negative affect (e.g., "Scared"). Participants were asked to rate each item using a Likert scale from 1 ("very slightly or not at all") to 5 ("extremely") to indicate the degree to which they felt the emotion or feeling described by the word. Ratings for positive and negative affect items were summed to generate respective positive and negative affect scores. Possible scores on each scale range from 10 to 50, with higher scores indicating stronger affect. The PANAS was included in the studies because mood states have been found to affect memory performance in past studies (e.g., Forgas, Goldenberg, & Unkelbach, 2009; Storbeck & Clore, 2005).

Shipley Institute of Living Vocabulary test. The Shipley Institute of Living Vocabulary test (Shipley, 1946) measures participants' vocabulary skills. The test includes 40 target items (e.g., "TALK"), each paired with four response choices (e.g., "draw, eat, speak, sleep"). Participants were asked to choose one word from the response choices that best described the target item. One score was given to each correct response. Possible scores range from 0 to 40, with higher scores indicating better vocabulary. This test was used as a screening test to exclude participants with low vocabulary skills, which could affect their ability to learn word pairs in the study. Participants would be excluded from the studies if they scored lower than 20 on the test.

Mini-Mental State Examination (MMSE). The MMSE (Folstein et al., 1975) is a 30-item cognitive assessment that is used as a screening test for dementia-related cognitive impairment in older participants. Questions on the test measure participants' orientation to time and place, attention, short-term and working memory, comprehension, language, as well as their ability to follow instructions. One score was given to each correct response. Possible scores range from 0 to 30, with higher scores indicating better cognitive functioning. A score of 26 or lower may signal dementia-related cognitive impairment, and hence participants with these scores would be excluded from the studies and replaced.

Background questionnaire. The background questionnaire inquires information related to participants' demographic characteristics (e.g., age, gender, level of education, age at which English was learned) and their health information (e.g., current physical condition, history of psychiatric or neurological disorders, medication use).

Chapter 3:

Study 1: Associative Memory Deficit under Division of Attention: Effects on Use of Encoding Strategies and Recollection and Familiarity Processes

One speculation about older adults' associative deficit is that their memory impairment is at least partially due to their limited availability of attentional resources, specifically resources that are required for processing of associative information. In particular, Kim and Giovanello (2011a, 2011b) found that when young adults encoded associative information under a relation detection DA task, they showed similar associative memory deficit as older adults. This effect could not be replicated using an item detection DA task. It was therefore suggested that older adults have limited resources for the more demanding relational processing than for item processing, and as a result are less able to allocate attentional resources to encode associative information. This speculation also explains why older adults' item memory is usually intact, while their associative memory shows greater impairment (see Old & Naveh-Benjamin, 2008 for a review). Although young adults showed similar associative deficit as older adults under a DA-R task, it is still unknown the specific mechanism that has driven this memory impairment. It is possible that the DA-R task impaired young adults' associative memory because it limited their available attentional resources to employ effective relational encoding strategies. Division of attentional resources for relational processing may also disrupt subsequent recollection memory processes, and as a result young adults under the DA-R task had to rely on familiarity processes to make recognition decisions. The purpose of this study is to examine how these memory processes (i.e., use of strategies, familiarity and recollection-based memory processes) might have been affected by limited availability of resources for relational processing.

Attentional Resources and Use of Encoding Strategies

Naveh-Benjamin et al. (2007) reported that older adults were less likely than young adults to initiate and use effective encoding strategies to study associative information. All young participants in their study, whereas only 11% of their older participants, used relational strategies (e.g., sentence generation). However, there is no evidence that older adults perceive the effectiveness of elaborative encoding strategies differently than young adults, as there was no correlation between age and subjective rating of usefulness of strategies (Bender & Raz, 2012). In addition, when older adults were encouraged to use relational strategies in Naveh-Benjamin et al. (2007), older adults were able to do so, and their associative memory deficit was greatly reduced. These findings suggest that older adults are capable of using elaborative encoding strategies to help them learn associative information, and can effectively use these strategies when prompted to do so.

Naveh-Benjamin et al.'s (2007) findings might be accounted for by age-related declines in attentional resources. Craik and Rose (2012) proposed that reduction in attentional resources in old age leads to lower use of self-initiated encoding processes. However, when given environmental support, such as prompting the use of an effective encoding strategy in this case, older adults can engage in these encoding operations and consequently improve their memory performance. There is empirical evidence that reduction of attentional resources impairs the use of effective encoding strategies in item memory in young adults. For instance, Mangels, Picton, and Craik (2001) found that when young adults encoded single words under full attention or a simple DA task, almost all of them used an elaborative, imagery strategy to aid retrieval. However, when they studied the stimuli while completing a difficult DA task, they were less able to use the same type of elaborative strategy. In fact, they started using rote rehearsal or no strategy at all. If limited resources for relational processing have deterred older adults from using elaborative encoding strategies, then young adults would be expected to use these strategies less when their resources are restrained under a DA-R task in comparison to when they complete the task under full attention.

Role of Attentional Resources in Recollection and Familiarity Processes

As discussed in the General Introduction, another factor in age-related associative deficit is older adults' reduced use of recollection processes during associative recognition tests, which might reflect a lack of details in memory necessary to retrieve accurate associative information (e.g., Cohn et al., 2008). As a result, they often display higher rates of false alarm to rearranged pairs than young adults. Castel and Craik (2003) argued that aging and division of attention have similar effects on recollection processes in memory tasks, as reduced attentional resources in both scenarios could impact recollection. Familiarity processes, on the other hand, are usually less affected by both variables (Jennings & Jacoby, 1993). There is also evidence that recollection processes might be especially affected by DA tasks that involve deep encoding in comparison to perceptual DA tasks commonly used in previous associative memory studies (e.g., Naveh-Benjamin, Guez, & Marom, 2003). For instance, Uncapher and Rugg (2008) administered two types of DA tasks to participants during encoding of single words. These young participants showed reduced recollection when they encoded the stimuli under a DA task that involved semantic judgments and executive resources, in comparison to when they completed the encoding task under a perceptual DA task or under full attention.

Although Kim and Giovanello (2011a) did not examine recollection and familiarity processes in young adults' associative memory under item and relation detection DA tasks, they mentioned that young adults in the DA-R group showed heightened false alarms to rearranged pairs similar to the performance of older adults. It should be noted, however, that increased false alarm rate might suggest a reliance on familiarity with little recruitment of recollection, but is not a direct measure of recollection or familiarity. This is because recollection and familiarity are two independent processes working simultaneously, and the false alarm measure cannot tease the two processes apart. Furthermore, response bias should be taken into account in the estimate of familiarity, as suggested by Yonelinas (Yonelinas, 2002; Yonelinas, Regehr, & Jacoby, 1995). That being said, there is still a lack of evidence whether older adults' reliance on familiarity processes in associative memory tasks could be explained by their limited availability of resources for relational processing during encoding.

The Present Study

The present study aimed to address two research objectives. The first objective was to examine whether limited availability of resources for relational processing would lead to a lower use of relational encoding strategies during learning of associative information. The second study objective was whether reduction of these resources during encoding affects recollection- and familiarity-based memory processes. Using a process dissociation paradigm, young adults were asked to study pairs of words under full attention, or when their attention was divided by a relation detection DA task. Memory performance of these young participant groups was compared with that of older adults who completed the same memory task under full attention. Recollection and familiarity estimates were also contrasted across groups.

After the memory tasks, participants were asked to report the encoding strategies they had used during the study phase. Different from past research (Naveh-Benjamin et al., 2007), participants were not just asked to report the type of strategies used, but also to indicate how consistently they had used these strategies throughout encoding. Naveh-Benjamin and colleagues found that 100% of their young participants used a relational strategy to study word pairs, but it is unknown whether they adhered to the same strategy throughout encoding. In addition, participants in the present study were also asked to rate the perceived effectiveness of different encoding strategies (e.g., sentence generation, imagery, rote repetition). It is plausible that older adults appraise the effectiveness of high-level relational strategies similarly to young adults (e.g., Bender & Raz, 2012) but are less likely to devote attentional resources to implement them.

Hypotheses of the Present Study

Based on the above literature review, the following hypotheses were generated. First, young participants who encoded word pairs while completing a relational divided attention task would show similar associative memory deficit as full attention older adults, with disproportionately poorer associative memory than item memory relative to full attention young participants. Second, divided attention during encoding would selectively impair recollection processes, while leaving familiarity processes intact. As a result, divided attention young adults and full attention older adults would show reduced recollection relative to full attention young adults, while familiarity would be comparable across groups. Finally, division of resources for relational processing was expected to deplete resources to execute relational encoding strategies and thus impair the use of these strategies. That is, young adults under divided attention would be less likely to use relational encoding strategies than young adults tested under full attention.

Method

Participants

Twenty-four older (15 females) and 48 young adults were included in this study. The young adults were randomly and evenly assigned into the full attention (FA; 19 females) and divided attention conditions (DA; 18 females). Eight young participants not included in the above sample size were replaced – four (three FA and one DA) for having a neurological/psychiatric condition, three (one FA and two DA) for failing to follow instructions, and one FA participant for lack of language proficiency (i.e., scored lower than the cut-off score of 20 on the Shipley Institute of Living Vocabulary test). One additional older participant was replaced because he did not meet the cut-off score (i.e., a score of 27) on the MMSE. Participants' demographic characteristics are summarized in Table 1. The two young groups did not differ in age, $t(46) = 0.65$, $p = .517$, $d = 0.19$. Results from one-way ANOVAs suggested that the three groups did not differ in the level of education, the age at which they learned English, or their subjective health rating (all ps > .05, η^2s < .07). The three groups did differ in their performance on the Shipley Institute of Living Vocabulary test, $F(2, 69) = 23.96$, $p < .001$, $\eta^2 = .41$. Bonferroni post-hoc analyses revealed that older adults scored higher on the vocabulary test than both full attention and divided attention young adults (ps < .001), with the two young groups not differing from each other ($p = .508$). Participants also differed in their positive affect, $F(2, 69) = 15.33$, $p < .001$, $\eta^2 = .31$, and negative affect scores, $F(2, 69) = 3.55$, $p = .034$, $\eta^2 = .09$, on the PANAS. Bonferroni post-hoc analyses indicate that older adults showed higher positive affect than the two young adult groups, both ps < .001, and lower negative affect than the DA group, $p = .029$. On the other hand, the two young adult samples did not differ in their PANAS ratings, all ps > .40. In addition, there were group differences in scores on the Digit Symbol Substitution test, $F(2, 69) = 20.66$, $p < .001$, $\eta^2 = .37$. Bonferroni post-hoc analyses showed that older adults performed significantly poorer on the task than both young adult groups, both ps < .001, but there was no difference between the two younger groups, $p = 1.00$. Despite these group differences, correlation analyses indicate that there was no correlation between Shipley, PANAS, and Digit Symbol scores and item memory, association memory, and recollection estimates within each participant group, all *p*s > .07.

Table 1

Participant Characteristics in Study 1

Measure	FA Young Adults *M*(*SD*)	DA Young Adults *M*(*SD*)	Older Adults *M*(*SD*)	Group Differences
Age **	22.00 (3.67)	21.33 (3.40)	71.42 (2.96)	YA[f] < OA[g]
Years of Formal Education	15.27 (2.22)	14.60 (2.18)	16.46 (3.95)	-
Age Learned English	2.06 (3.03)	2.00 (3.31)	0.63 (2.24)	-
Health Rating[a]	8.17 (1.00)	8.04 (0.98)	8.60 (1.01)	-
Shipley Vocabulary[b] **	30.04 (4.03)	28.50 (3.99)	35.79 (3.50)	YA < OA
PANAS: Positive[c] **	29.13 (7.41)	28.42 (7.83)	38.13 (4.63)	YA < OA
PANAS: Negative[c] *	12.71 (2.87)	14.25 (4.97)	11.54 (2.13)	DA[h] > OA
DSST[d] **	87.79 (16.54)	83.79 (17.55)	61.75 (10.20)	YA > OA
MMSE[e]	-	-	28.88 (0.90)	-

Note. *$p < .05$. **$p < .001$. [a]Self-reported based on a scale from 1 (“poor”) to 10 (“excellent”). [b]Shipley Vocabulary = Shipley Institute of Living Vocabulary test. [c]PANAS = Positive and Negative Affect Schedule. [d]DSST = Digit Symbol Substitution Test. [e]MMSE = Mini-Mental State Examination. [f]YA = young adults. [g]OA = older adults. [h]DA = DA young adults.

Materials

One hundred and twenty word pairs were selected from the word pair stimulus set in the pilot study described in Chapter 2. Twelve of these word pairs served in the practice trials. The actual memory task contained two blocks, with 54 word pairs in each block. Word pairs in the two memory blocks were matched in terms of relatedness rating of the word pairs, letter and syllable length of the words, as well as frequency, familiarity, meaningfulness, imageability, and concreteness ratings of each word (MRC Psycholinguistic Database; Wilson, 1988). In each memory block, six word pairs served as buffers at the beginning (three pairs) and the end (three pairs) of the encoding phase. In between these buffers were 32 word pairs, with half as intact pairs and the other half as rearranged pairs in the subsequent recognition tests. The word pairs were pseudo-randomly presented during encoding, with the restriction that word pairs from the same recognition condition (pair or associative recognition tests; intact or rearranged pairs) would not appear consecutively for more than two trials. There were two recognition tests in each block, a pair recognition and an associative recognition test. Sixteen new word pairs were included in each memory block, with eight in the pair recognition test and the other eight in the associative recognition test. The word pairs in the recognition tests were also pseudo-randomly presented, such that word pairs from the same stimulus type (intact, rearranged, or new pairs) did not appear more than three times in a row. None of the word pairs were repeated in the two memory blocks.

A number comparison task was used as a secondary task during memory encoding in the DA condition. Numbers in the task ranged from one to ten and were written in capitalized English (e.g., "FIVE"). In each trial, an odd number was always paired with an even number.

Procedure

All participants provided informed consent (see Appendix C) at the beginning of the experiment and completed the experiment individually. The stimuli in computer tasks were presented using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA), and were shown in Calibri with a font size of 18. The text was white against a black background. Participants in the DA condition first completed the number comparison task under full attention for the same duration as would be in the memory encoding phase (approximately 3 min) to obtain baseline performance on the DA task. They viewed pairs of numbers (e.g., "THREE

TEN") on the screen, at a rate of 2 s each with an inter-stimulus interval of 500 ms after every two trials. This trial duration matched with that in the memory encoding phase. Participants were instructed to indicate which number was larger in numerical value by pressing the corresponding left ("v" key) and right ("m" key) keys on the keyboard.

All participants then completed two blocks of memory task, each containing an encoding phase, a filler task, and two recognition tests. Participants were instructed that their task was to memorize word pairs during the study phase, and their memory would be tested in two subsequent recognition tests. Participants studied 38 word pairs, each presented on the screen for 4 s, with an inter-stimulus interval of 500 ms between pairs (as illustrated in Figure 1). In the DA condition, participants were asked to complete the number comparison task while studying the word pairs at the same time. Specifically, a pair of numbers appeared underneath the word pair, at a rate of 2 s each with an inter-stimulus interval of 500 ms after every two DA trials. That is, participants in the DA condition needed to complete two number comparison trials during the encoding of one word pair. Participants in this condition were asked to pay equal attention to memorizing the word pairs and to the DA task, whereas young and older adults under FA only needed to focus on the encoding of word pairs.

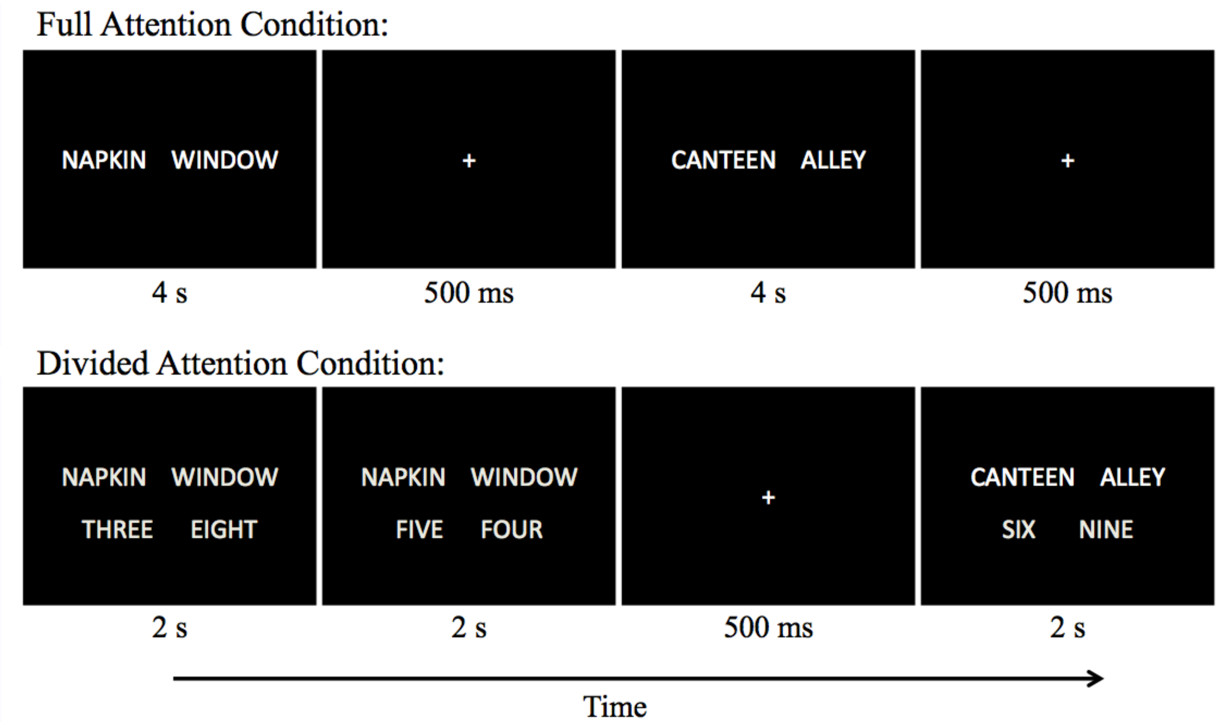

Figure 1. Illustration of encoding procedures in full attention and divided attention conditions.

After the encoding phase, all participants were given the DSST (Wechsler, 1958) as a filler task for 2 min. They then completed a pair and an associative recognition test, with the order of the two tests counterbalanced across participants. Both recognition tests included eight intact pairs and eight rearranged pairs from the encoding phase, and eight new pairs. In the pair recognition test, participants were asked to indicate whether they have studied the words during encoding, regardless of whether the words had been presented together as a pair earlier. They should respond “YES” to both intact and rearranged pairs, but “NO” to new pairs. In the associative recognition test, they should make their memory judgments based on the original pairing of the pairs, and respond “YES” to intact pairs and “NO” to both rearranged and new pairs. The “YES” and “NO” responses were made by pressing the “z” and “/” keys, with the keys counterbalanced across participants (i.e., “z” was used as the “YES” key for half of the participants, and "/" served as the "YES" key for the other half of the participants). Responses were self-paced, with an inter-stimulus interval of 500 ms between trials.

After the memory blocks, all participants completed the PEP to assess their use of encoding strategies during the study phase, as well as participants' appraisal of the effectiveness of different strategies. Older participants were then administered the MMSE (Folstein et al., 1975). Next, all participants filled out the PANAS (Watson et al., 1998), the Shipley Institute of Living Vocabulary test (Shipley, 1946), and a background questionnaire. Finally, participants were fully debriefed (see Appendix D) and compensated.

Results

Secondary Task Performance in Divided Attention Condition

The number comparison task was used as a secondary task to divide young adults' attention during memory encoding. To acquire baseline performance on this task, DA young adults completed the same task under full attention prior to the memory task. As expected, they showed significantly lower accuracy and slower reaction times when they completed the number comparison task under divided attention during encoding of word pairs (proportion accuracy: $M = .90$, $SD = .07$; reaction time: $M = 1192.75$ ms, $SD = 121.68$ ms) than when they completed the task alone under full attention (proportion accuracy: $M = .96$, $SD = .02$; reaction time: $M = 920.33$ ms, $SD = 118.56$ ms), $t(23) = -4.38$, $p < .001$, $d = -1.00$ and $t(23) = 10.13$, $p < .001$, $d = 2.07$, respectively. These results provide evidence that completing the encoding and number comparison tasks simultaneously was cognitively demanding.

Memory Performance

Item memory, associative memory, recollection and familiarity scores of young adults in FA and DA conditions, as well as older adults, are presented in Table 2.

Table 2

Memory Scores of FA Young Adults, DA Young Adults, and Older Adults

Memory Score	FA Young Adults $M(SD)$	DA Young Adults $M(SD)$	Older Adults $M(SD)$
Item Memory[a]	.69 (.23)	.52 (.19)	.58 (.18)
Associative Memory[a]	.61 (.30)	.30 (.25)	.32 (.29)
Recollection[a]	.59 (.29)	.33 (.22)	.32 (.31)
Familiarity[b]	0.58 (1.19)	0.26 (0.58)	0.64 (0.74)

Note. [a]Proportion score. [b]Discriminability score.

Item and associative memory scores. A 3 (group: FA young adults vs. DA young adults vs. older adults) x 2 (memory: item vs. associative memory) mixed model ANOVA was conducted to compare item and associative memory across the three participant groups, with group as a between-subjects variable and memory as a within-subjects variable. Overall, participants showed better memory for items than for associations, $F(1, 69) = 37.61$, $p < .001$, $\eta_p^2 = .35$. There was also significant differences in memory performance across groups, $F(2, 69) = 9.13$, $p < .001$, $\eta_p^2 = .21$. These main effects were further qualified by a significant group by memory interaction effect (see Figure 2), $F(2, 69) = 3.19$, $p = .048$, $\eta_p^2 = .09$.

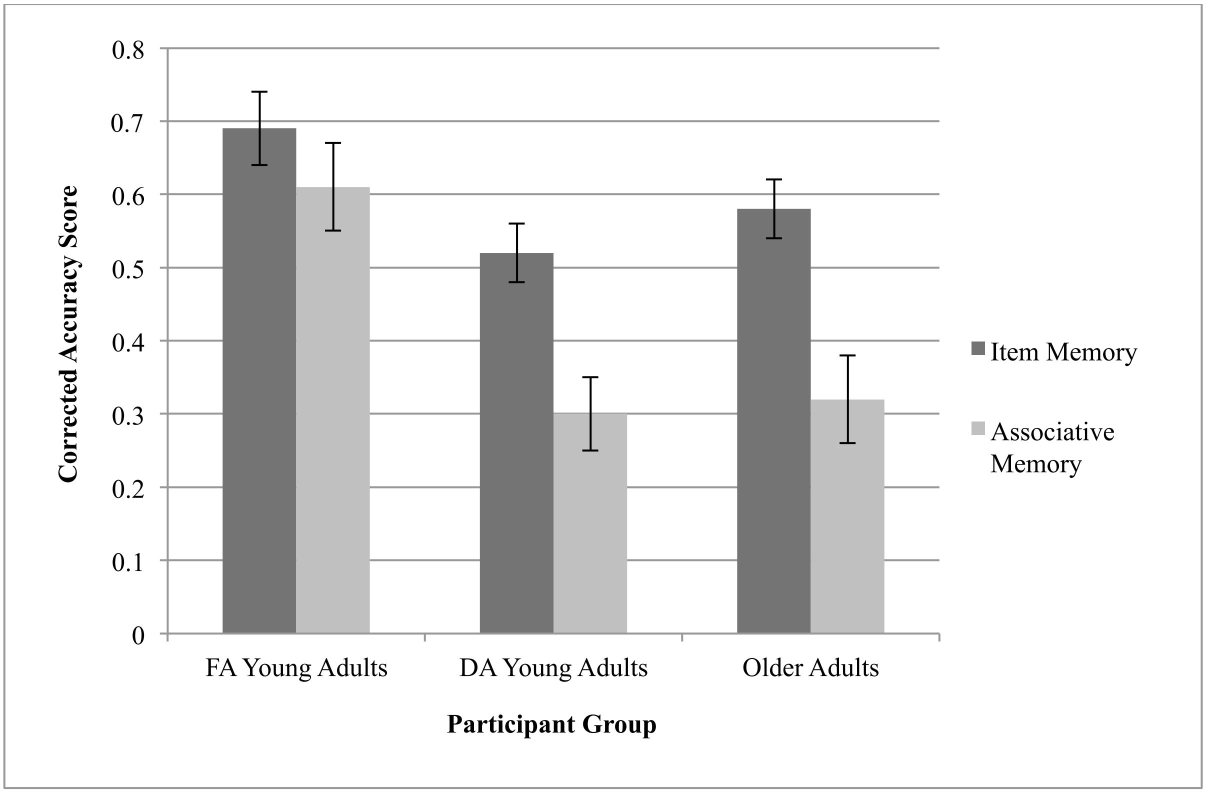

Figure 2. Item and associative memory performance of FA young adults, DA young adults, and older adults in Study 1. Error bars represent standard errors.

Follow-up ANOVAs were conducted to further examine the group by memory interaction effect. First, a 2 (group: FA young adults vs. older adults) x 2 (memory) mixed model ANOVA revealed age differences in associative memory consistently found in previous studies (e.g., Naveh-Benjamin, 2000; Old & Naveh-Benjamin, 2008). There were significant main effects of memory, $F(1, 46) = 20.71$, $p < .001$, $\eta_p^2 = .31$, and group, $F(1, 46) = 9.76$, $p = .003$, $\eta_p^2 = .18$, which were qualified by a significant group and memory interaction effect, $F(1, 46) = 5.74$, $p = .021$, $\eta_p^2 = .11$. There was a significant age difference in associative memory, $t(46) = 3.37$, $p = .002$, $d = 0.97$, whereas age difference in item memory was only marginally significant, $t(46) = 1.82$, $p = .075$, $d = 0.53$. These results replicated the age-related associative deficit, which

Naveh-Benjamin (2000) defined as disproportionally greater age differences in associative memory than item memory.

Next, a 2 (group: FA vs. DA young adults) x 2 (memory) mixed model ANOVA was conducted to examine differences in memory performance between young adults in the two attention conditions. There was again a significant main effect of memory, $F(1, 46) = 15.44$, $p < .001$, $\eta_p^2 = .25$, and a main effect of group, $F(1, 46) = 16.00$, $p < .001$, $\eta_p^2 = .26$. Specifically, participants showed better memory for items than for associations, and young participants under full attention performed better in the memory tasks than those under divided attention. There was also a marginally significant interaction effect of group and memory, $F(1, 46) = 3.14$, $p = .083$, $\eta_p^2 = .06$. Although young participants in the DA condition showed poorer memory than those under FA for both items, $t(46) = 2.84$, $p = .007$, $d = 0.82$, and associations, $t(46) = 3.88$, $p < .001$, $d = 1.13$, the group difference was larger for associative memory than item memory, as indicated by their respective effect sizes.

Finally, a 2 (group: DA young adults vs. older adults) x 2 (memory) mixed model ANOVA was conducted to investigate differences in memory performance between young adults under DA and older adults. Again, there was a significant main effect of memory, $F(1, 46) = 43.78$, $p < .001$, $\eta_p^2 = .49$, whereby participants scored higher on the item memory test than the associative memory test. However, both the main effect of group and the group by memory interaction effect were non-significant, $F(1, 46) = 0.54$, $p = .465$, $\eta_p^2 = .01$ and $F(1, 46) = 0.43$, $p = .516$, $\eta_p^2 = .01$, respectively. These results suggest that young adults under DA performed similarly to older adults in the item and associative memory tests.

Finally, dependent *t*-tests were conducted to compare item and associative memory scores within each participant group. Young adults under FA showed equivalent item and associative memory, $t(23) = 1.46$, $p = .157$, $d = 0.30$. On the other hand, both young adults in the DA condition and older adults showed significantly poorer associative memory in comparison to their own memory for items, $t(23) = 4.22$, $p < .001$, $d = 0.88$, and $t(23) = 5.14$, $p < .001$, $d = 1.14$, respectively. Taken together, young adults under FA performed equivalently in the item and associative memory tasks, whereas young adults under DA and older adults showed similar associative deficit, as indexed by significantly poorer associative memory than item memory.

Recollection and familiarity estimates. Participants' recollection and familiarity estimates (see Table 2) were compared across the three sample groups using two separate one-way ANOVAs, with group (FA young adults vs. DA young adults vs. older adults) as a between-subjects variable. There was a significant difference in recollection estimates across groups, $F(2, 69) = 7.91$, $p < .001$, $\eta^2 = .19$. Bonferroni post-hoc multiple comparisons revealed that FA young adults showed better recollection than both DA young adults, $p = .003$, and older adults, $p = .003$, whereas there was no significant difference in recollection between DA young adults and older adults, $p = 1.000$. On the other hand, there was no significant difference in familiarity estimates across the three samples, $F(2, 69) = 1.30$, $p = .278$, $\eta^2 = .04$.

Correlation analyses revealed that for all three groups of participants, recollection estimate scores were positively correlated with better item memory (rs = .74, .72, and .55 for FA young adults, DA young adults, and older adults respectively, all ps < .01) and associative memory performance (rs = .85, .74, and .89 for FA young adults, DA young adults, and older adults respectively, all ps < .001). These results indicate that regardless of age and attention conditions, participants with better recollection showed better memory overall. Familiarity was only positively correlated with item memory in DA young adults, $r = .58$, $p = .003$, but not in FA young adults and older adults. In addition, familiarity did not correlate with association memory performance in any participant group, which is in line with findings that recollection, but not familiarity, supports recognition of associative information (Yonelinas, 2002).

Use of Effective Encoding Strategies

Only one FA young adult, one DA young adult, and two older adults reported only using one strategy throughout the encoding phase. All other participants reported using at least two strategies, and approximately 80% of participants in each group reported using three or more different encoding strategies. These findings suggest that participants, regardless of age and attention conditions, typically do not adhere to only one strategy to memorize associative information, as has been assumed in previous studies (e.g., Naveh-Benjamin et al., 2007).

The percentage use of different encoding strategies across participant groups is presented in Table 3. These strategies were further categorized into high-level (elaborative) and low-level strategies, following Bender and Raz’s (2012) factor analysis. A few participants (three FA young adults, three DA young adults, and seven older adults) also reported using other strategies not listed on the PEP. These strategies were independently classified into high- and low-level strategies by the experimenter and a research assistant. Strategies were categorized as high-level strategies if participants demonstrated an attempt to connect the two words in a word pair together based on the semantic meaning of the words. For instance, one participant reported making a comment or a joke about the word pair. On the other hand, strategies were classified as low-level strategies if participants made associations of the two words by linking perceptual characteristics of the words, or without taking into account the semantic meaning of the words. To demonstrate, a few participants memorized the word pairs by focusing on the first one or two letters of both words. The two coders reached 100% agreement on the classification of these strategies into high- and low-level strategies.

Table 3

Frequency of Use of High- and Low-Level Strategies in FA Young Adults, DA Young Adults, and Older Adults

Strategy	FA Young Adults *M*	DA Young Adults *M*	Older Adults *M*
		High-Level Strategy	
Semantic Reference	9.80%	13.00%	8.10%
Imagery	35.30%	20.30%	18.30%
Sentence Generation	15.00%	5.30%	13.50%
Others	1.90%	2.10%	1.50%
Total (*SD*)	62.00% (35.48%)	40.67% (32.69%)	41.46% (35.46%)
		Low-Level Strategy	
Rote Repetition	16.00%	26.40%	27.30%
Attentive Reading	12.40%	22.30%	15.20%
Focal Attention	7.50%	8.00%	9.00%
Others	2.10%	2.70%	7.10%
Total (*SD*)	38.00% (35.48%)	59.33% (32.69%)	58.54% (35.46%)

One-way ANOVA only revealed a marginally significant difference in use of high-level strategies across the three participant groups, $F(2, 69) = 2.94$, $p = .060$, $\eta^2 = .08$. Visual inspection of the data in Table 3suggests that FA young adults were more likely than the other two groups to use high-level encoding strategies. However, high variance in strategy use might have led to the non-significant result in the ANOVA analysis. To resolve this issue, participants were categorized into consistent high-level strategy users if they had used these strategies more than 50% of the time; otherwise, they were classified as low-level strategy users. The number of high- and low-level strategy users in each sample group is presented in Table 4. Chi-square analysis indicates a difference in the number of consistent high- and low-strategy users across participant groups, χ^2 (2, N = 72) = 8.14, p = .017. Specifically, there was a higher number of FA young adults who used high-level strategy consistently relative to DA young adults and older adults. In fact, the number of high-level strategy users in DA young adults and older adults was comparable.

Table 4

Number of Consistent High- and Low-Level Strategy Users in FA Young Adults, DA Young Adults, and Older Adults

Strategy User	FA Young Adults	DA Young Adults	Older Adults
High-Level Strategy	17	9	8
Low-Level Strategy	7	15	16

Correlations between use of strategies and memory. Correlation analyses revealed that frequency of use of high-level strategies did not affect memory performance of the three sample groups equally (see Table 5). Specifically, using these strategies improved FA young adults' general memory performance, including their item memory, associative memory, and recollection. Even for DA young adults, using high-level strategies improved their associative memory and recollection, whereas it did not significantly improve their item memory. Interestingly, older adults' memory performance did not seem to benefit from using high-level encoding strategies, as there were no significant correlations between frequency of strategy use and any of their memory scores. These findings suggest that older adults might not be able to use these strategies as effectively as young adults, and hence did not show the same improvements in memory relative to their younger counterparts.

Table 5

Correlations between Use of High-Level Strategies and Memory Performance in FA Young Adults, DA Young Adults, and Older Adults

Measure	FA Young Adults	DA Young Adults	Older Adults
Item Memory Score	.56**	.38	.12
Associative Memory Score	.72**	.56**	.38
Recollection Estimate	.66**	.46*	.26
Familiarity Estimate	-.10	.27	.36

Note. $^{*}p < .05$. $^{**}p < .01$.

Appraisal of Encoding Strategies

Participants' subjective ratings of the effectiveness of each strategy on the PEP were compared across the three groups using a one-way ANOVA (see Table 6 for their ratings). There was no group difference in their ratings of each strategy (ps > .10, η_p^2s < .06). To further examine whether the three groups of participants appraised the effectiveness of high- and low-level strategies similarly, these individual ratings were combined. Specifically, their effective ratings of semantic reference, imagery, and sentence generation were averaged to derive an overall effectiveness rating for high-level encoding strategies. Similarly, their effectiveness ratings for rote repetition, attentive reading, and focal attention were averaged to form an overall effectiveness rating for low-level encoding strategies. Effective ratings for high- and low-level strategies were compared in a 3 (group) x 2 (strategy: high vs. low) ANOVA, with group as a between-subjects variable and strategy as a within-subjects variable. Results indicate that participants in general rated high-level encoding strategies as more effective in helping them remember word pairs than low-level strategies, $F(1, 69) = 28.79$, $p < .001$, $\eta_p^2 = .29$. Neither the main effect of group nor the group by strategy interaction was statistically significant (both ps >

.20, η_p^2s < .05). In other words, these results show no age difference in participants' appraisal of the effectiveness of high- and low-level encoding strategies in facilitating associative encoding. Hence, lower use of high-level encoding strategies in older adults (and DA young adults) is unlikely to be due to lower appraisal of the effectiveness of these strategies.

Table 6

Effectiveness Ratings of Each Encoding Strategy in FA Young Adults, DA Young Adults, and Older Adults

Strategy	FA Young Adults *M*(*SD*)	DA Young Adults *M*(*SD*)	Older Adults *M*(*SD*)
		High-Level Strategy	
Semantic Reference	7.17 (2.10)	7.96 (2.27)	6.67 (2.46)
Imagery	7.58 (2.17)	7.21 (2.72)	7.04 (2.27)
Sentence Generation	6.33 (2.53)	6.38 (2.65)	6.46 (2.47)
Average	7.03 (1.69)	7.18 (2.05)	6.72 (1.99)
		Low-Level Strategy	
Rote Repetition	5.13 (2.56)	6.38 (2.06)	5.96 (2.94)
Attentive Reading	3.96 (2.20)	4.67 (2.28)	5.46 (2.75)
Focal Attention	4.17 (2.01)	5.25 (2.66)	5.42 (2.60)
Average	4.42 (1.74)	5.43 (1.57)	5.61 (2.21)

Discussion

This study examined the role of attentional resources in age-related associative deficit, particularly whether depletion of attentional resources during encoding would impair the use of effective encoding strategies and recollection memory processes in associative memory tasks. It was hypothesized that young adults who learned word pairs under a relational DA task would show the associative deficit commonly seen in older adults (e.g., Naveh-Benjamin, 2000). In addition, similar to their older counterparts, they would be less likely to use high-level encoding strategies and engage in recollection-based memory processes in comparison to young adults under FA. These hypotheses were all supported by the findings of this study.

First, results of this study replicated Kim and Giovanello's (2011a, 2011b) findings. Young adults who learned word pairs while simultaneously engaging in a relational DA task showed an associative deficit similar to that of older adults tested under full attention in the same study. Specifically, both groups showed significantly poorer associative memory than item memory. When compared to young adults in the FA group, both DA young adults and older adults showed disproportionately greater impairment in their associative memory relative to item memory.

In addition, results of this study provided further insight into the specific memory processes that are impaired by the reduction of attentional resources. Young adults in the DA condition were less likely than young adults under FA to rely on recollection processes during the memory task. In fact, their recollection estimate score was comparable to that of older adults. Familiarity processes were not affected by division of attention during encoding or aging. In other words, recollection processes were impaired in DA young adults and older adults in this study, whereas their familiarity memory processes remained intact. Although item memory could be supported by both recollection and familiarity processes, successful associative memory is primarily dependent on recollection processes (Yonelinas, 2002). In this study, participants' recollection estimates were moderately correlated with their item memory scores and strongly correlated with their associative memory scores. Participants who had higher recollection showed better performance in both item and associative memory than those who engaged in recollection less. Familiarity abilities, however, were only correlated with item memory in DA young adults, and were not related to associative memory performance in any of the participant groups. Taken together, depletion of attentional resources weakens individuals' use of recollection processes, which in turn contributes to poor associative memory performance.

Lack of attentional resources also impaired the use of effective encoding strategies for learning associations between items. When their attentional resources were depleted, young adults' pattern of strategy use during the study phase was comparable to that of older adults. There was a trend for DA young adults and older adults to use high-level encoding strategies less than FA young adults. Furthermore, there were significantly fewer DA young adults and older adults who consistently used high-level strategies (more than 50% of the time) during encoding than FA young adults. These differences in strategy use could not be attributed to group differences in appraisal of the effectiveness of these strategies. All three groups of participants rated high-level strategies as more effective than low-level strategies in remembering word pairs, with no group difference in the effectiveness rating of each encoding strategy. Thus, it is reasonable to infer that having low availability of attentional resources, whether due to division of attention or normal aging, limits individuals' ability to use effective strategies to bind associative information together in memory. However, it should be noted that although use of high-level encoding strategies was positively related to item memory, associative memory, and recollection estimates in the two young adult samples, the same correlations were weak in the older group. In other words, older adults' memory performance did not appear to benefit from using effective encoding strategies more frequently, which might suggest a lower *quality* of use of these strategies relative to young adults.

In sum, when attentional resources during encoding were exhausted in young adults, they displayed similar associative deficit to older adults. They also showed reduced use of recollection processes and effective encoding strategies, which both support successful associative memory. These findings suggest that lack of attentional resources could at least partly explain the associative deficit in old age, and the underlying mechanism involves both reduced use of recollection processes and effective encoding strategies.

Chapter 4:

Study 2: The Effect of Resource Reservation on Older Adults' Associative Memory

In associative memory tasks, associative learning can be argued to rely on the initial processing and encoding of items. That is, participants can only learn about associations between items after they have encoded these individual items. In fact, item and associative memory performance are significantly correlated ($r = .39$, Old & Naveh-Benjamin, 2008), suggesting that they are not independent of each other. In addition, although there is evidence that associative memory could be specifically impaired by a relational DA task (Study 1 of Dissertation; Kim & Giovanello, 2011a, 2011b), to my knowledge there is yet to be a scenario in which a DA task could specifically target item memory while giving lesser influence to associative memory. When young adults studied associative information under an item-based DA task that theoretically does not tap into relational attentional resources, their associative memory also suffered along with the decline of their item memory (e.g., Kim & Giovanello, 2011a). These findings suggest that associative encoding is dependent on item encoding, as memory for these items serve as the building blocks for memory for the associations between them.

Results of Study 1 suggest that older adults lack relational attentional resources to efficiently learn associations between items, and as a result show poorer associative memory than young adults. In Study 1, young participants' item memory was also affected by the depletion of relational attentional resources, despite the magnitude of impairment in item memory being smaller than that in associative memory. These findings suggest that encoding of items also consumes similar resources as encoding of associations, and may compete for resources during the study phase. In typical associative memory tasks, participants are asked to learn items and associations simultaneously during the study phase (e.g., Naveh-Benjamin, 2000), but encoding of items presumably occurs before encoding of associations. If both item and associative encoding require attentional resources, then one would expect these resources to be spent on item encoding before leftover resources could be allocated to association encoding. It is possible that when attentional resources are scarce, older adults are more likely to prioritize allocating resources to learning of items, which precedes associative encoding and is less resource-demanding. In the current study, young and older participants studied items and associations in isolation, with item learning preceding encoding of associations. Having the opportunity to learn items before making associations between them should allow older adults to reserve attentional resources specifically for associative encoding. As a result, they should have sufficient resources to use effective encoding strategies and recollection memory processes, which would in turn reduce their associative deficit.

Isolating Item and Associative Encoding

There is evidence that learning items and associations in isolation improves associative memory in young adults. In Dennis, Turney, Webb, and Overman's (2015) study, young adults viewed items from half of the to-be-encoded picture pairs prior to the associative learning task. In comparison to pictures that contain new items, participants showed improved associative memory for pairs composed of previously viewed items. Moreover, they showed reduced neural activity in the hippocampus, parahippocampal regions, and superior frontal gyrus during encoding of these pairs, suggesting that fewer resources were needed to encode pairs with familiar items than pairs with new items. They also showed increased activity in the parietal cortex, such as the bilateral inferior parietal cortex and the precuneus, when encoding pairs with familiar items. These regions are involved in goal-directed attention, as well as the binding of information into a unified whole. These findings support the speculation that item encoding takes up resources, and prior learning of items allow participants to spend more attentional resources to study associations.

Based on Dennis et al.'s (2015) study, it is expected that older adults would also show better associative memory for stimulus pairs if they have seen the items of these pairs earlier. In Kilb and Naveh-Benjamin (2011), young and older participants were presented with individual pictures (items) or picture pairs three times during a training phase before an associative memory task. At the encoding phase of the subsequent associative memory task, participants studied three types of picture pairs: (1) pairs that contained items they had seen at the training phase (item repetition condition), (2) exact pairs they had seen at the training phase (pair repetition condition), and new pairs (study only condition). Consistent with the results in Dennis et al., young adults in this study showed better associative memory for picture pairs in both the item and pair repetition conditions in comparison to the study only condition. Specifically, they showed increased hit rates to intact pairs and reduced false alarm rates to rearranged pairs in the associative memory task. However, older adults did not show the same benefits. Older adults' memory for pairs that contained previously studied items did not improve over pairs that they had only studied once: although they showed improvements in hit rates to intact pairs, their false alarm rates to rearranged pairs also increased. In other words, older adults were able to recognize more intact pairs in the item repetition condition, but this manipulation also impaired their ability to reject rearranged pairs that contained pictures that have been shown to them multiple times in the training phase. Older adults showed relatively better associative memory performance under the pair repetition condition than under the study only condition, but the effect was mainly due to their increased hit rates; their false alarm rates to rearranged pairs were unchanged. In a follow-up experiment, Kilb and Naveh-Benjamin found that item and pair repetitions increased older adults' familiarity to items and pairs respectively, without any effect on their recollection of the materials. As familiarity to stimuli was increased, older adults found it more difficult to reject picture pairs that were recombined. This was especially problematic in the item repetition condition as familiarity to individual items was increased but the binding between items was not strengthened, whereas increased familiarity to picture pairs could at least help older adults recognize these pairs when they were shown in their exact pairing (i.e., intact pairs).

Kilb and Naveh-Benjamin's (2011) findings suggest that older adults' associative memory does not benefit from learning of individual items prior to studying of associations between them. Specifically, their item repetition paradigm led to heightened familiarity of individual items, with little recollection supporting memory for associations. However, it is possible that learning all items together in one block would increase interference and unnecessary clustering between items. Unintentional clustering of items might make it difficult for older adults to form new associations assigned by the experimenter during the associative memory phase. In several studies, Campbell and her colleagues have found that older adults are more likely than young adults to automatically and implicitly bind unrelated information, such as target and distracting information, together in their memory even when they are not instructed to do so (i.e., hyper-binding effect; e.g., Biss, Campbell, & Hasher, 2013; Campbell, Hasher, & Thomas, 2010; Campbell, Zimmerman, Healey, Lee, & Hasher, 2012). For instance, in Weeks, Biss, Murphy, and Hasher's (2016) study, older adults first completed a selective attention task in which they were asked to attend to faces and ignore names that were superimposed on these faces. After a delay, they either studied the exact same face-name pairs from the selective attention task, or pairs containing recombined faces and names that had appeared in the selective attention task. Older adults showed better memory for the exact face-name pairs that they had seen in the selective attention task than rearranged face-name pairs in a subsequent cued-recall task. These findings indicate that once older adults have hyper-bound, or clustered, items together implicitly, it becomes difficult for them to form new associations between these items. That being said, older adults' associative memory might show more benefits if item and associative encoding take place in two difference phases *within the same trial*. This procedure would allow older adults to allocate resources specifically for item and associative encoding, but at the same time eliminate the possibility of unintentional clustering of items during the item learning phase.

The Present Study

The study phase in the current experiment contained encoding trials that were divided into two stages – an item learning and an associative learning phase. During the item learning phase, participants were sequentially presented the two items of a word pair on the screen. They were asked to think about the semantic meaning of each word when it was shown on the screen. Presentation of the two words was immediately followed by the associative learning phase, during which both words were presented together on the screen. At this time, participants would put the two words together in their memory and remember that the two words go together as a pair. Young and older participants' item and associative memory would then be assessed using the same process dissociation recognition paradigm as in Study 1. It was expected that this encoding paradigm would eliminate age-related associative deficit in older adults, such that they would show similar memory performance as young adults in the same study. The process dissociation paradigm would also allow for the measurement of recollection and familiarity processes to provide insight into whether older adults' associative memory was supported by recollection or merely through a reliance on familiarity. In addition, participants' use of encoding strategies would also be inquired upon the completion of the memory task to compare the percentage of use of high-level encoding strategies between the two age groups.

To further examine whether inclusion of an item learning phase would provide a better encoding environment for older adults to learn associative information, a secondary analysis was conducted to compare memory performance of older adults in Studies 1 and 2. In Study 1, older adults learned item and associative information together during the study phase (traditional encoding condition), without any exposure to the items prior to associative encoding. If inclusion of the item learning phase allowed older adults to allocate more attentional resources specifically for item and associative encoding, then older adults in the current study would show greater use of high-level encoding strategies and recollection processes, as well as better associative memory performance, than older adults in Study 1. The young adult samples from the two studies would not be included in this secondary analysis because the primary focus of this analysis was to examine the difference in memory performance of older adults under the two different encoding conditions. In addition, young adults could already learn associative information efficiently under the traditional encoding paradigm as reflected in their equivalent item and associative memory performance in Study 1. Thus, it does not add much value to include young participants in this analysis.

Hypotheses of the Present Study

First, older participants in the current study were predicted to show similar memory performance as young participants. Having the opportunity to study individual items before learning their associations should decrease the attentional resource load needed for associative encoding (e.g., Dennis et al., 2015). If older adults' associative deficit can be explained by their limited availability of resources available for associative learning, addition of the item learning phase during encoding should allow them to reserve more attentional resources to study associations. Specifically, they were predicted to use high-level encoding strategies readily similar to young adults. Furthermore, based on the finding that division of attention during encoding impairs recollection processes (e.g., Study 1 of Dissertation; Yonelinas, 2002), having a greater availability of attentional resources for associative encoding should also lead to better recollection performance, and hence older adults should show similar recollection performance as their younger counterparts. Second, in comparison to older participants in Study 1 who studied the two words of each word pair together without the item learning phase, older participants in the current study should show better associative memory, which in turn eliminates the associative deficit. Moreover, they were predicted to show increased use of high-level encodings strategies, as well as recollection processes to remember word pairs.

Method

Participants

Twenty-four young (16 females) and 24 older adults (20 females) were included in this study. One young participant was replaced due to failure to follow task instructions, and three older participants were replaced because they did not meet the cut-off score (score of 27) on the MMSE. Participants' demographic characteristics are presented in Table 7. Young and older participants did not differ in the age at which they learned English, as well as their subjective health rating, *p*s > .08. All participants passed the cut-off score on the Shipley Institute of Living Vocabulary test, but older adults scored higher on the test than young adults, $t(37.60)$[1] = 7.59, $p < .001$, $d = 2.26$. Older adults also had higher education than young adults, $t(37.92)$[1] = 2.69, $p = .01$, $d = 0.80$. Young participants showed higher negative affect scores on the PANAS than older

[1] Degrees of freedom was adjusted due to unequal variances between groups.

participants, $t(29.08)^1 = 4.75$, $p < .001$, $d = 1.51$. Finally, older adults were slower on the DSST than their younger counterparts, $t(46) = 5.90$, $p < .001$, $d = 1.71$.

Table 7

Participant Characteristics in Study 2

Measure	Young Adults *M*(*SD*)	Older Adults *M*(*SD*)
Age **	21.96 (3.14)	69.88 (3.88)
Years of Formal Education *	15.06 (1.95)	17.13 (3.21)
Age Learned English	2.50 (4.11)	0.83 (1.86)
Health Rating[a]	8.38 (1.24)	8.06 (1.16)
Shipley Vocabulary[b] **	29.42 (3.88)	36.42 (2.32)
PANAS: Positive[c]	32.38 (8.89)	35.83 (6.27)
PANAS: Negative[c] **	13.13 (2.54)	10.50 (0.93)
DSST[d] **	90.04 (16.72)	62.58 (15.50)
MMSE[e]	-	28.79 (0.93)

Note. $*p < .05$, $**p < .001$. [a]Self-reported, with scores ranging from 1 (“poor”) to 10 (“excellent”). [b]Shipley Vocabulary = Shipley Institute of Living Vocabulary test. [c]PANAS = Positive and Negative Affect Schedule. [d]DSST = Digit Symbol Substitution Test. [e]MMSE = Mini-Mental State Examination.

Materials and Procedure

All word stimuli used in the present study were the same as in Study 1. All participants were tested individually and provided informed consent (see Appendix E) at the beginning of the experiment. Participants then completed two blocks of memory task, each containing an encoding phase, a filler task, and two recognition tests. Similar to Study 1, participants were instructed to memorize pairs of words during the encoding phase, and their memory for the words and their pairings would be tested in two recognition tests. During the encoding phase, participants studied 38 word pairs, in which six pairs served as buffers at the beginning and end of the encoding phase. In each trial, participants saw two words presented on the screen one after the other for 2 s each (see Figure 3). To encourage active learning, participants were asked to think about the meaning of the word (i.e., what the word is or what it means) when each word appeared. Next, there was a blank screen for 500 ms and then the two words were presented as a pair together on the screen for 4 s. At this time, participants would put the two words together in their memory and remember the pairing between these words. After each trial, there was an inter-stimulus interval of 500 ms before the next trial began. After the encoding phase, participants completed the DSST (Wechsler, 1958) as a 2-minite filler task between the study phase and the memory tests. They were then given the pair and associative recognition tests, with the order of the two tasks counterbalanced across participants. The instructions and procedures for the filler task and the two recognition tasks were identical to those in Study 1.

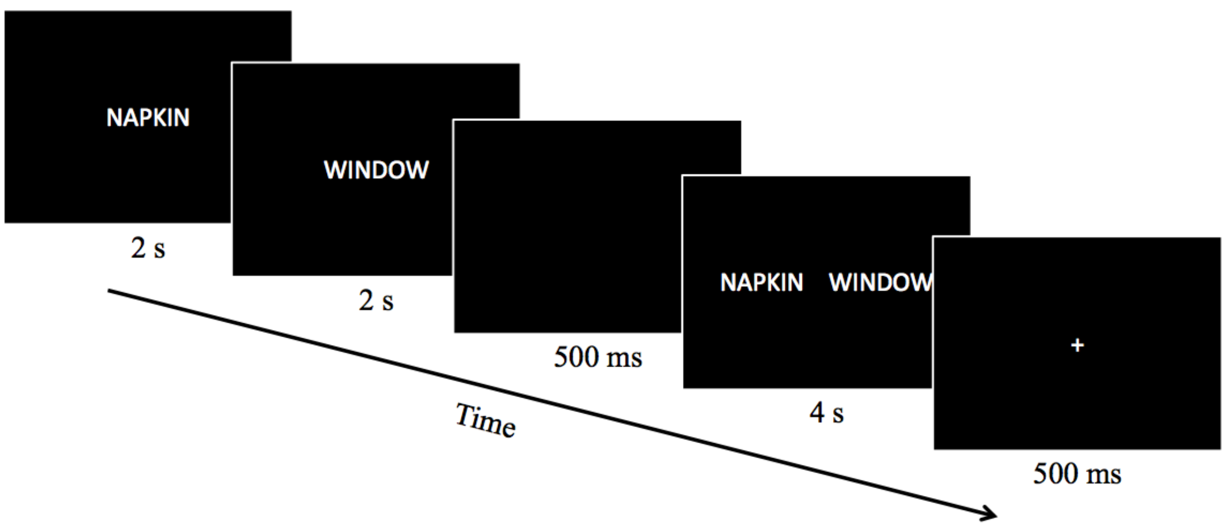

Figure 3. Illustration of the item learning encoding condition in Study 2.

Immediately after the completion of the two memory blocks, participants filled out the PEP, which assesses their frequency of use of different encoding strategies, as well as their appraisal of the effectiveness of these strategies. Participants were further inquired at which point during the study phase did they start making associations between the two words of each word pair. Specifically, they were asked whether they put the two words together in their memory when both words were shown together on the screen, or immediately after they had read the second word of the word pair. Response to this question would provide insight on the approximate duration of associative encoding for each participant, as participants who started engaging in associative learning once they had read the second word would have longer learning time than those who waited till they saw both words together to make associations between the two. In addition, participants were inquired whether they thought of the meaning of the words (either in words or as images) when the words were presented individually on the screen during the item learning phase; if the participant responded yes, they were further prompted to provide an approximate percentage of words for which they generated meanings. Next, older participants were administered the MMSE (Folstein et al., 1975) to screen for possible dementia-related cognitive deficiencies. Both young and older participants then filled out the PANAS (Watson et al., 1998), Shipley Institute of Living Vocabulary test (Shipley, 1946), and a background questionnaire. Finally, all participants were debriefed (see Appendix F) and reimbursed for their participation.

Results

Age Differences in Memory Performance and Use of Encoding Strategies

Item and associative memory scores, as well as recollection and familiarity estimates, were derived using the same procedures as described in Study 1 and are presented in Table 8.

Table 8

Memory Scores of Young and Older Adults in Study 2

Memory Score	Young Adults $M(SD)$	Older Adults $M(SD)$
Item Memory[a]	.80 (.20)	.76 (.18)
Associative Memory[a]	.67 (.26)	.58 (.32)
Recollection[a]	.70 (.23)	.60 (.27)
Familiarity[b]	0.82 (1.23)	0.79 (1.29)

Note. [a]Proportion score. [b]Discriminability score. The familiarity scores were obtained from 23 young and 23 older adults.

Item and associative memory scores were compared across the two age groups using a 2 (age: young vs. older adults) x 2 (memory: item vs. associative memory) mixed-model ANOVA, with age as a between-subjects variable and memory as a within-subjects variable. The results revealed a main effect of memory, $F(1, 46) = 15.36$, $p < .001$, $\eta_p^2 = .25$, whereby participants across both age groups showed better item memory than associative memory (see Figure 4). Nevertheless, there was no age difference in memory performance, $F(1, 46) = 1.18$, $p = .283$, $\eta_p^2 = .03$. The interaction effect of age and memory was also non-significant, $F(1, 46) = 0.41$, $p = .528$, $\eta_p^2 = .01$. These results suggest that both young and older adults showed significantly better item memory than associative memory, which is likely due to longer exposure to the individual items during encoding than previous studies (e.g., Naveh-Benjamin, 2000). In this study, individual words were first presented separately before they were shown together as a pair, and hence learning of these items should be stronger in comparison to learning in a traditional encoding paradigm as in Study 1.

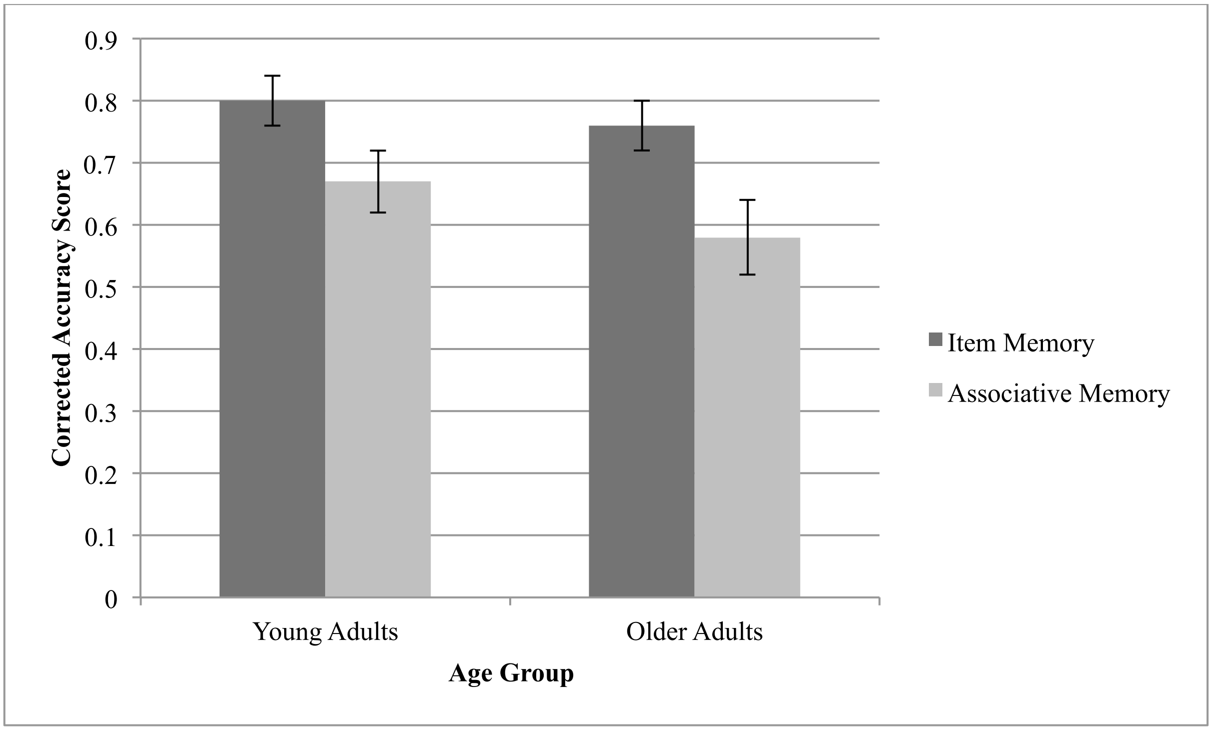

Figure 4. Item and associative memory performance of young and older adults in Study 2. Error bars represent standard errors.

Next, young and older participants' recollection and familiarity estimate scores (see Table 8) were compared using two separate independent *t*-tests. There was no age difference in recollection in the current study, $t(46) = 1.26$, $p = .215$, $d = 0.36$. The two groups also did not differ in their familiarity estimates, $t(44) = .08$, $p = .940$, $d = 0.02$. Familiarities scores were obtained from 23 young and 23 older adults. One participant from each age group was removed from this analysis because they did not show any false alarms in the memory task and as a result their familiarity abilities could not be accurately defined. Replicating the results of Study 1, recollection estimate scores were positively correlated with item and associative memory scores in both young (rs = .85 and .77 respectively, ps < .001) and older adults (rs = .54 and .91 respectively, ps < .01). For young adults, familiarity scores were positively correlated with item memory performance, $r = .56$, $p = .006$, but were not related to associative memory performance,

p = .861, which is in line with previous findings that familiarity could facilitate memory for items, but associative memory requires recollection. For older adults, familiarity scores were not associated with item memory scores, but were negatively correlated with their associative memory performance, r = -.47, p = .024. That is, greater dependence on familiarity was related to poorer associative memory in older adults.

Encoding strategies. Replicating findings of Study 1, it was rare for participants to rely only on one encoding strategy when studying word pairs. Only two older adults in the current study reported using one strategy throughout the two study phases. The remaining participants used at least two strategies. In fact, 91.66% of young participants and 87.5% of older participants reported using at least 3 different types of encoding strategies in this study. Participants' percentage use of different encoding strategies, as well as their overall percentage use of high- and low-level strategies, is reported in Table 9. For participants who reported using other strategies not listed on the PEP, their strategies were independently coded as high- or low-level strategies by the experimenter and a research assistant, following the same coding guidelines described in Chapter 2. Young and older adults' overall percentage use of high-level encoding strategies were compared using an independent t-test. Older adults in the current study were just as likely as young adults to use high-level encoding strategies to remember word pairs, $t(46)$ = 0.12, p = .909, d = 0.03.

Table 9

Frequency of Use of High- and Low-Level Strategies in Young and Older Adults in Study 2

Strategy	Young Adults *M*	Older Adults *M*
	High-Level Strategy	
Semantic Reference	15.72%	14.04%
Imagery	42.31%	34.79%
Sentence Generation	12.00%	23.00%
Others	3.00%	0.00%
Total (*SD*)	72.82% (19.67%)	71.96% (30.97%)
	Low-Level Strategy	
Rote Repetition	8.00%	10.00%
Attentive Reading	9.00%	8.00%
Focal Attention	7.00%	6.00%
Others	3.47%	3.75%
Total (*SD*)	27.18% (19.67%)	28.04% (30.97%)

In adherence to the analyses conducted for Study 1, participants were categorized into consistent high-level strategy users and consistent low-level strategy users based on whether they reported using these respective strategies for more 50% of the time during the experiment. Twenty young and 19 older adults were classified as consistent high-level strategy users. Chi-square analysis indicates no difference in the number of high- or low-level strategy users between the two age groups, χ^2 (1, N = 48) = .14, p = .712. Taken together, older adults in the current study used high-level encoding strategies as frequently as did young adults. In addition, there was also no age difference in the number of participants who consistently used high-level strategies during the experiment.

Finally, Pearson's correlation analyses were conducted to examine the associations between participants' percentage use of high-level encoding strategies and different memory performance scores (see Table 10). For young adults, although there were small to moderate associations between their use of high-level strategies and their item and associative memory performance, these correlations did not reach significance. On the other hand, older adults' use of encoding strategies was significantly correlated with their item and associative memory scores, as well as their recollection estimate scores, all *p*s < .01.

Table 10

Correlations between Use of High-Level Strategies and Memory Performance in Young and Older Adults in Study 2

Measure	Young Adults	Older Adults
Item Memory Score	.22	.52*
Associative Memory Score	.29	.58*
Recollection Estimate	.06	.60*
Familiarity Estimate	-.24	-.06

Note. *$p < .01$

Appraisal of encoding strategies. Young and older adults' effectiveness ratings of each encoding strategy and the overall effectiveness ratings of high- and low-level strategies are presented in Table 11. Independent *t*-tests revealed that young participants gave higher ratings to rote repetition and imagery as effective encoding strategies for learning associations than did older adults, $t(46) = 2.01$, $p = .050$, $d = 0.58$, and $t(38.79)$[1] $= 2.29$, $p = .027$, $d = 0.68$, respectively. However, the two age groups did not differ in their ratings of the remaining strategies, as well as their overall averaged effectiveness ratings of high- and low-level strategies, both *p*s > .16.

Table 11

Effective Ratings of Each Encoding Strategy in Young and Older Adults in Study 2

Strategy	Young Adults *M(SD)*	Older Adults *M(SD)*
	High-Level Strategy	
Semantic Reference	7.46 (2.30)	6.33 (3.05)
Imagery*	8.83 (1.71)	7.33 (2.71)
Sentence Generation	6.58 (2.92)	7.00 (3.05)
Average	7.63 (1.83)	6.89 (2.35)
	Low-Level Strategy	
Rote Repetition*	4.71 (1.83)	3.63 (1.91)
Attentive Reading	3.67 (2.51)	3.54 (2.06)
Focal Attention	4.04 (2.31)	3.71 (2.42)
Average	4.14 (1.37)	3.63 (1.60)

Note. $^*p < .05$.

Meaning generation during item-learning. Participants self-reported whether they generated meanings of the individual words during the item-learning phase. All but two older participants reported generating meanings, either as images or in short phrases. They then reported an approximate percentage of words for which they had generated meanings. This percentage was marked as 0% if participants did not come up with any word meanings. One young participant indicated that she had generated meanings for the words, but did not report a percentage of words she generated meanings for. For the remaining participants, there was no age difference in the percentage of words with meanings generated, $t(45) = -0.60$, $p = .549$, $d = -0.18$ (young adults: $M = 76.09\%$, $SD = 28.56\%$; older adults: $M = 81.67\%$, $SD = 34.44\%$).

Summary. In general, both age groups showed significantly better memory for items than for associations. This is likely due to the longer exposure to individual items during encoding, which consequently strengthened participants' memory for these items. That being said, this effect should not be regarded as the typical associative deficit commonly found in older adults. More importantly, there was no age difference in various memory performance measures. Older participants did not show disproportionately greater associative memory deficit than item memory in comparison to young participants. They also showed similar uses of recollection processes and high-level encoding strategies as their younger counterparts in the memory task.

Comparisons of Older Adults' Memory Performance between Studies 1 and 2

To examine the benefits of the item learning phase to older adult's associative memory over a traditional encoding paradigm, older participants' memory performance in this study was compared with that of older participants in Study 1. In Study 1, participants learned the same word pairs using the traditional encoding paradigm, in which they were shown the word pairs for 4 s each without an item learning phase. Table 12 presents the demographic characteristics of older participants in the two studies. Participants in Study 2 reported lower negative affect on the PANAS than those in Study 1, $t(31.53)$[1] = -2.20, $p = .035$, $d = -0.68$. However, there was no correlation between negative affect scores and any of the memory measures, ps > .230. There was no difference in any of the other measures between the two age groups, ps > .092.

Table 12

Participant Characteristics of Older Adults in Study 1 (Traditional Encoding) and Study 2 (Item Learning)

Measure	Study 1 (Traditional) *M*(*SD*)	Study 2 (Item Learning) *M*(*SD*)
Age	71.42 (2.96)	69.88 (3.88)
Years of Formal Education	16.46 (3.95)	17.13 (3.21)
Age Learned English	0.63 (2.24)	0.83 (1.86)
Health Rating[a]	8.60 (1.01)	8.06 (1.16)
MMSE[b]	28.88 (0.90)	28.79 (0.93)
Shipley Vocabulary[c]	35.79 (3.50)	36.42 (2.32)
PANAS: Positive[d]	38.13 (4.63)	35.83 (6.27)
PANAS: Negative[d] *	11.54 (2.13)	10.50 (0.93)
DSST[e]	61.75 (10.20)	62.58 (15.50)

Note. *$p < .05$. [a] Self-reported, with scores ranging from 1 (“poor”) to 10 (“excellent”). [b]MMSE = Mini-Mental State Examination. [c]Shipley Vocabulary = Shipley Institute of Living Vocabulary test. [d]PANAS = Positive and Negative Affect Schedule. [e]DSST = Digit Symbol Substitution Test.

Memory performance. Participants’ item and associative memory scores, as well as their recollection and familiarity estimates are presented in Table 13. A 2 (encoding condition: traditional vs. item learning) x 2 (memory: item vs. associative memory) mixed model ANOVA was conducted, with encoding condition as a between-subjects variable and memory as a within-subjects variable. There was a main effect of memory, $F(1, 46) = 29.00$, $p < .001$, $\eta_p^2 = .39$, in which item memory was in general better than associative memory (see Figure 5). Critically, older participants under the item learning condition showed better overall memory than their counterparts who received the traditional encoding condition, $F(1, 46) = 13.46$, $p = .001$, $\eta_p^2 = .23$, but this effect did not interact with memory type. These results suggest that the inclusion of an item learning phase during encoding is beneficial to both item and associative memory performance.

Table 13

Memory Scores of Older Adults in Study 1 (Traditional Encoding) and Study 2 (Item Learning)

Memory Score	Study 1 (Traditional) *M*(*SD)*	Study 2 (Item Learning) *M*(*SD)*
Item Memory[a]	.58 (.18)	.76 (.18)
Associative Memory[a]	.32 (.29)	.58 (.32)
Recollection[a]	.32 (.31)	.60 (.27)
Familiarity[b]	0.64 (0.74)	0.79 (1.29)

Note. [a]Proportion score. [b]Discriminability score. The familiarity scores were obtained from 23 older adults in Study 2 (Item learning condition).

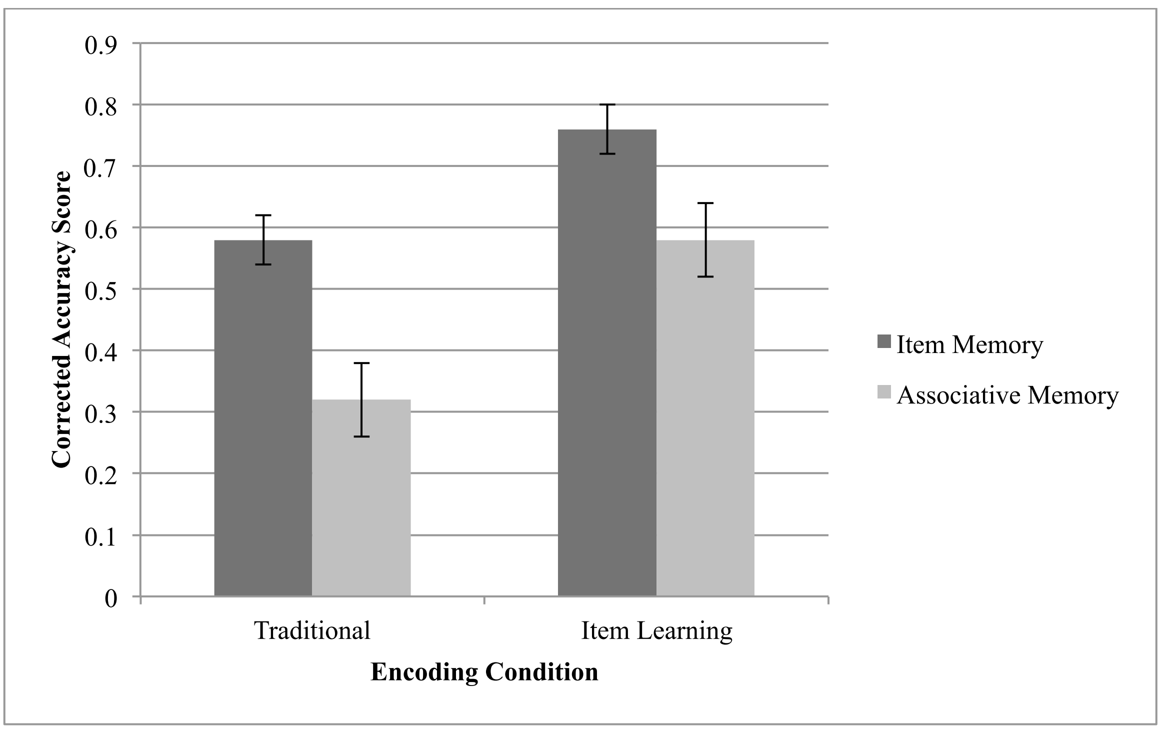

Figure 5. Item and associative memory performance of older adults in Study 1 (traditional encoding) and Study 2 (item learning). Error bars represent standard errors.

To examine whether the benefits of the item learning manipulation was specific to improvements on hit rates, false alarm rates, or both, further analyses were conducted to compare hit and false alarm rates between older participants from the two encoding conditions (see Table 14). Hit and false alarm rates in item memory were proportion hits to rearranged pairs and proportion false alarms to new pairs in the pair recognition test respectively. For associative memory, hit rates were proportion hits to intact pairs and false alarm rates were proportion false alarms to rearranged pairs in the associative recognition test. Independent *t*-test comparisons indicate that older participants under the item learning encoding paradigm showed fewer false alarms in both their item and associative memory than those under the traditional encoding condition, $t(46) = -2.96$, $p = .005$, $d = -0.87$, and $t(46) = -2.84$, $p = .007$, $d = -0.82$, respectively. There was also a trend for participants in the item learning condition to show higher hit rates in item memory than those in the traditional encoding condition, but the effect did not reach statistical significance, $t(46) = 1.73$, $p = .09$, $d = 0.49$. However, the two groups did not differ in their hit rates in the associative memory task, $t(46) = 1.40$, $p = .20$, $d = 0.38$. Taken together, these results suggest that the effects of the item learning manipulation primarily manifested in reduced false alarm rates, but not heightened hit rates.

Table 14

Hit and False Alarm Rates in Item and Associative Memory Tests in Older Adults in Study 1 (Traditional Encoding) and Study 2 (Item Learning)

Memory Score	Study 1 (Traditional) *M*(*SD)*	Study 2 (Item Learning) *M*(*SD)*
	Item Memory	
Hit Rates	.78 (.15)	.85 (.14)
False Alarm Rates*	.20 (.14)	.09 (.10)
	Associative Memory	
Hit Rates	.77 (.14)	.83 (.13)
False Alarm Rates*	.45 (.26)	.24 (.25)

Note. $^*p < .01$.

Recollection and familiarity estimates are presented in Table 13, and were analyzed using independent *t*-tests. The analyses revealed that older participants in the item learning condition showed significantly better recollection than their counterparts in the traditional encoding condition, $t(46) = 3.36$, $p = .002$, $d = 0.97$. However, familiarity estimate scores did not differ between the two groups, $t(34.84)$[1] $= 0.50$, $p = .622$, $d = 0.15$.

Encoding strategies. Older participants' percentage use of high-level encoding strategies during the study phase was analyzed using an independent *t*-test. Participants in the item learning condition ($M = 71.96\%$, $SD = 30.97\%$) used high-level encoding strategies more often than those in the traditional encoding condition ($M = 41.45\%$, $SD = 35.46\%$), $t(46) = 3.17$, $p = .003$, $d = 0.92$. Chi-square analyses were conducted to compare the number of consistent high-level and low-level encoding strategy users (i.e., participants who used high- or low-level strategies for more than 50% of the time) under the two encoding conditions (see Table 15). Significantly more participants in the item learning condition used high-level strategies consistently throughout the study phase than in the traditional encoding condition, χ^2 (1, N = 48) = 10.24, p = .001.

Table 15

Number of Consistent High- and Low-Level Encoding Strategy Users in Older Adults in Study 1 (Traditional Encoding) and Study 2 (Item Learning)

Strategy User	Study 1 (Traditional)	Study 2 (Item Learning)
High-Level Strategy	8	19
Low-Level Strategy	16	5

Summary. Relative to participants in the traditional encoding condition (Study 1), older participants in the item learning condition (Study 2) showed overall better item and associative memory, which was primarily driven by reduced false alarm rates in memory tests. In addition, participants in the item learning condition showed increased use of high-level encoding strategies and recollection memory processes than those in the traditional encoding condition, whereas reliance of familiarity processes was not affected by encoding manipulations.

The Role of Study Time Duration in Memory Performance

An alternative explanation for the better memory performance in the item learning condition relative to the traditional encoding condition is the difference in stimulus exposure time during the study phase. In Study 1, participants learned each word pair for 4 s each. In the current study, participants first saw each word for 2 s each, and were then given 4 s to study the two words together as a pair. That being said, participants could start learning associations between the two words of a word pair once they had seen the second word, which would give them a total of 6 s to learn the associations.

In this study, after participants completed the memory tasks, they were asked at which point during the presentation of the word pairs did they start putting the two words together in their memory. Half of the participants reported learning associations once they had read the second word (14 young and 10 older participants), whereas the other half of the sample waited until both words were presented together on the screen (10 young and 14 older participants). There were relatively equal number of young and older participants in each category, $\chi^2(1, N = 48) = 1.33$, $p = .248$. To examine whether learning time impacted participants' memory performance, a 2 (age: young vs. older adults) x 2 (memory: item vs. associative memory) x 2 (encoding time: second vs. both words) mixed-model ANOVA was conducted, with memory type as a within-subjects variable, and age and encoding time as between-subjects variables (see Table 16). The only significant effect was the main effect of memory, $F(1, 44) = 16.56$, $p < .001$, $\eta_p^2 = .27$, as item memory was in general better than associative memory. The main effect of encoding time was not significant and did not interact with the effect of age or memory type, *p*s > .20. To increase power, a 2 (memory) x 2 (encoding time) mixed model ANOVA was conducted on all participants in the study, but the results remained the same. These results are also consistent with the literature that longer study time does not eliminate the age-related associative deficit, as older participants still showed disproportionately greater deficits in associative memory than item memory relative to young adults even when given longer encoding time than young adults in previous studies (e.g., encoding time of 4 s for young participants vs. 10 s for older participants in Naveh-Benjamin et al., 2007; also see Naveh-Benjamin, Guez, & Shulman, 2004 and Naveh-Benjamin, Hussain et al., 2003).

Table 16

Item and Associative Memory Scores in Young and Older Adults who Studied Word Pair Associations at Different Time Points (When Both Words Were Presented vs. When the Second Word Was Presented)

	Young Adults *M*(*SD*)		Older Adults *M*(*SD*)	
Memory Score	Both Words	Second Word	Both Words	Second Word
Item Memory	.80 (.18)	.79 (.22)	.78 (.17)	.75 (.19)
Associative Memory	.71 (.24)	.61 (.29)	.53 (.33)	.62 (.31)

Discussion

In Study 2, young and older adults studied word pairs under an item learning encoding condition, in which they learned individual words and the associations between these words in two different phases. This paradigm allowed older participants to devote their attentional resources specifically to item and associative encoding by reducing competition between attentional resources for the two components of encoding. Older participants in this study showed equivalent memory performance to that of young participants, and significantly better overall memory performance than older adults who studied the same associative information under a traditional encoding paradigm (Study 1). Moreover, there is also evidence that their better memory was driven by their reliance on effective encoding strategies and recollection-based memory processes.

First, older adults under the item learning condition were more likely to initiate and execute high-level encoding strategies than those who learned the same word pairs under a traditional encoding paradigm. In fact, there was no age difference in the percentage use of high-level encoding strategies between young and older participants in Study 2. These findings suggest that separating item and associative encoding into two separate phases could minimize resource competition between item and associative encoding, and thus enable older adults to initiate the use of effective encoding strategies to facilitate associative memory. When attentional resources are scarce, even young adults are less able to employ the same encoding strategies (Study 1). Furthermore, there were moderate correlations between use of high-level encoding strategies and memory performance, including item and associative memory and recollection performance, among older adults in this study. That is, older participants who engaged more in high-level encoding strategies showed better memory performance than those who did not. On the other hand, increased use of high-level encoding strategies had no correlation with older adults' memory performance in Study 1. These findings may suggest that older participants' *quality* of encoding strategies was better when they had sufficient resources during encoding than when resources were limited under a traditional encoding paradigm. In addition, the same correlations between use of encoding strategies and memory performance were not significant in the younger sample in this study, which might be due to the relatively low variance in their percentage use of high-level encoding strategies.

Findings from Study 1 demonstrated that lack of attentional resources during encoding limits the use of recollection processes in associative memory tasks. It was therefore predicted that older adults' use of recollection processes would be higher when competition of attentional resources between item and associative learning was minimized. This hypothesis was supported. Under the item learning encoding paradigm, older adults were able to recruit recollection memory processes as efficiently as young adults. In particular, older participants showed equivalent recollection estimates as their younger counterparts, and their recollection score almost doubled that of older participants from Study 1. Furthermore, their efficient use of recollection processes was also reflected in their relatively low false alarm rates. In comparison to older adults in Study 1, older adults in the current study had significantly fewer false alarms in both item and associative memory tests. In contrast, although older adults in Kilb and Naveh-Benjamin's (2011) study also learned items prior to associations between them, they did not show any improvements in recollection and false alarm rates relative to the control condition. In particular, older adults in Kilb and Naveh-Benjamin's study showed higher hit rates in the subsequent associative memory, but at the same time their false alarm rates also increased, hence their overall associative memory performance (i.e., hit rates to intact pairs minus false alarm rates to rearranged pairs) did not improve. As described in the Introduction section of this chapter, Kilb and Naveh-Benjamin's paradigm might have increased implicit clustering between items in older adults because all items were learned together in one block, and as a result, it was difficult for older adults to form new associations with these items. In the current paradigm, items and associations between items were learned in two phases within the same trials. This manipulation reduced familiarity specific to items, and at the same time allowed sufficient resources for old adults to form stronger associative memory via recollection processes.

It should be noted that item memory scores of both young and older participants in Study 2 appeared to be inflated by the encoding paradigm. Given that participants were exposed to the individual words for a longer period of time than participants in Study 1, it is not surprising that they displayed heightened memory for items in comparison to their memory for associations. However, this should not be interpreted as an associative deficit, which was illustrated by significantly poorer associative memory than item memory in older adults in Study 1. Benefits of the item learning phase on associative memory could also be demonstrated in their age-equivalent strategy use efficiency, recollection estimates and false alarm rates, as these abilities typically decline in the case of an age-related associative deficit (e.g., Cohn et al., 2008; Naveh-Benjamin et al., 2007).

In summary, findings of Study 2 suggest that the item learning paradigm could reduce older adults' associative deficit. This learning condition helps older adults reserve and concentrate their attentional resources to focus on item and associative encoding in isolation. This would allow them to initiate and execute high-level encoding strategies during each study phase, which is less likely to happen when resources are scarce. Deep encoding of associative information also leads to higher use of recollection processes during retrieval. As a result, older adults show higher ability to reject rearranged pairs than older adults tested under a traditional encoding paradigm, which in turn leads to better memory performance.

Chapter 5:

Study 3: The Effect of Value-Directed Learning on Older Adults' Associative Memory

Results of Study 1 suggest that older adults' associative deficit could be explained by their lower availability of attentional resources for encoding of associative information (also see Kim & Giovanello, 2011a, 2011b). However, when older adults were motivated to use encoding strategies, they could direct their processing resources to encode associative information, which in turn facilitated their associative memory (e.g., Naveh-Benjamin et al., 2007). These results suggest that although older adults have a limited pool of resources to encode associative information, they are able to allocate their resources towards associative encoding when directed to. Given that their attentional resources are limited, it is plausible that they typically prefer not to spend their resources on associative encoding as it takes up more resources than item encoding (Study 1 of Dissertation; Kim & Giovanello, 2011a, 2011b). This may be especially true when the information being encoded is not relevant or important to older participants. Following this speculation, the purpose of this study was to examine whether increasing extrinsic motivation through value-directed learning could affect how older adults allocate their resources during associative encoding, and subsequently enhance their associative memory performance.

Strategic and Selective Control Theory

Castel (2007) proposed the strategic and selective control theory, which posits that older adults could compensate for their declines in memory by strategically directing their limited attentional resources to information that is important or valuable to them. According to the theory, older adults are able to use strategic control during memory encoding, in which strategic control is defined as the ability to direct resources to and prioritize learning of information associated with high value. Specifically, it is assumed that individuals engage in evaluative processing during encoding, by which they assess the value of the to-be-remembered information. Value refers to the importance associated with the to-be-remembered information, either externally assigned by the experimenter or internally generated by the participant based on his/her current goals. Value can also be determined by the situation (i.e., the goal of the task) or by personal experience (e.g., what is considered as important to know). The participant then selectively allocates resources to items and events that are considered as important at the expense of limiting resources for less important information.

An example of value-directed learning is older adults' memory for emotionally positive information over negative information. In her socioemotional selectivity theory, Carstensen (1995) proposed that older adults focus more on goals associated with emotional gratification, whereas young adults put more emphasis on goals associated with acquisition of knowledge. As a result, older adults are more likely than young adults to remember emotionally positive over negative information. Furthermore, it was found that encoding of positive information is not automatic, and it requires cognitive resources to accomplish (Knight et al., 2007; Mather & Knight, 2005). This means that although encoding of both positive and negative information requires resources, older adults strategically allocate their resources to study positive information, presumably because learning of positive information matches with their goals towards emotional gratification. In Castel's (2007) terms, higher value is assigned to positive information in comparison to negative information, and as a result older adults shift their attentional resources to encode positive information.

Older adults' bias towards learning positive information over negative information can be viewed as an example of value-directed learning in which the value of the to-be-remembered information is largely dependent on participants' personal goals. Value could also be assigned externally by the experimenter to neutral stimuli (e.g., Castel et al., 2002; McGillivray & Castel, 2011). Castel and his colleagues (2002) used a selectivity paradigm to examine older adults' memory for information arbitrarily assigned with high and low values. Young and older participants in this study learned 48 lists of words, each containing 12 words. Every word in each word list was paired with a point value, ranging from 1 to 12. Participants would receive the score associated with the word if they could later recall the word. They were told that the goal of the task was to maximize the score and they should try to recall words associated with higher value. To examine whether participants would selectively remember high-value words, Castel and colleagues calculated the selectivity index (SI) score, whereby the scores participants received from the recall task were compared with the ideal scores, while controlling for chance scores. The ideal score is the maximum score the participant could get, whereas the chance score is the average of all possible scores.

In a number of experiments, Castel et al. (2002) found that although older adults still recalled fewer words than young adults, they showed a higher, or at least equivalent, SI score as young adults. This suggests that older adults had a preference to learn and recall words associated with higher value. In fact, their memory for high-value words was comparable to that of young adults. It was further demonstrated that this higher selectivity was not due to older adults ignoring words of low value. The same effect was shown even when the associated point value was presented *after* participants had read and processed the words (Castel et al., 2002), ruling out the possibility that older adults did not read low-value words and just paid attention to high-value words. Castel and his colleagues suggested that older adults might have dedicated more resources and rehearsal to high-value words, leading to better recall of these items. This is a strategic mechanism to help them maximize their performance on the task (i.e., to receive higher points), as they realized that they could not possibly remember all the information.

Value-Directed Learning in Associative Memory

Castel (2007) suggested that older adults' associative memory could be influenced by the perceived value of the to-be-remembered information. In his study, he asked young and older adults to study grocery items and their associated prices (Castel, 2005). Half of the prices associated with the items were similar to market price, whereas the other half of the prices were unrealistic prices that did not match the market price. It was found that whereas young adults were better than older adults in recalling unrealistic item-price pairs, there was no age difference in memory for realistic item-price pairs. Castel suggested that when the item-price pairs were realistic, older adults viewed the information as more self-relevant and plausibly used their prior knowledge about item prices during encoding of these item-price pairs. This in turn led to deeper encoding of the information, and hence they showed age-equivalent memory for realistic item-price pairs. These findings suggest that older adults could use evaluative processing to assess the value or importance of information during encoding, which consequently improved their memory for high-value information. However, given that older adults in this study were likely to have used prior knowledge to support their memory for high-value information, it is not clear whether they needed to selectively allocate their cognitive resources to encode the item-price pairs that they were already familiar with in their daily lives. In other words, results of this study could not explain whether older adults showed better memory for realistic than unrealistic item-price pairs because they devoted more attentional resources to the former pairs, or because their prior knowledge about prices had helped them bind the information together in a meaningful way, supporting later retrieval. Moreover, they might have more experience with grocery prices than young adults, making it difficult to use grocery prices as unbiased stimuli to measure age-differences in memory.

In a more recent study, Ariel, Price, and Hertzog (2015) investigated the effect of value-directed learning on associative memory using unrelated word pairs as stimuli, which should not be particularly more familiar to older adults than young adults. Young and older participants in this study were given six word pairs to remember in each study trial, with each pair assigned with a point value from 2 to 12. Participants would gain the point value associated with the word pair if they could recall the pair in the cued-recall test administered after the presentation of all study trials. During encoding, the six word pairs were presented on the screen together but were each concealed by a black box. The word pairs were only visible to participants when the mouse cursor was placed on the boxes. Hence, they could only study one word pair at a time. There was a time limit for each study trial, thus it was optimal for participants to evaluate the point value of each word pair and allocate their study time on each pair accordingly. All three experiments in this study showed that both young and older participants selectively learned high-value word pairs over low-value word pairs by allocating longer study time and using more effective encoding strategies (e.g., sentence generation, imagery) for high value pairs. As a result, both age groups showed better associative memory for high-value than low-value pairs. Nevertheless, although older adults regulated study time and their use of encoding strategies as efficiently as young adults, their associative memory for high-value word pairs was still poorer than that of young participants. In other words, manipulation of value in this study did not reduce the associative deficit in older adults.

Ariel et al.'s (2015) study paradigm might pose a disadvantage for older participants. First, older adults typically show a greater associative deficit when their associative memory is tested using recall tests in comparison to recognition tests (Old & Naveh-Benjamin, 2008). This occurs because recall tests require them to retrieve learned information from their memory without any environmental support, which becomes difficult with age (Naveh-Benjamin, 2000; also see Craik & McDowd, 1987; Danckert & Craik, 2013). Furthermore, item memory was not measured in Ariel and colleagues' study. It is critical to control for item memory performance in associative memory studies, as older adults' reduced associative memory could be driven by a low ability to remember information in general (poor memory for both items and associations), or a specific deficit in binding items together in memory (disproportionately poorer associative memory than item memory). Due to these limitations, it is still difficult to draw solid conclusions as to whether value-directed learning could reduce associative deficit in older adults.

The Present Study

The present study aimed to investigate whether older adults could flexibly prioritize their attentional resources to remember associative information with high importance over less important associative information. In this study, young and older participants were asked to remember word pairs that were either associated with high or low value. Both their item and associative memory was then tested using recognition tests. At the beginning of the study, participants were instructed that the goal of the study was to maximize the points they could receive at the associative recognition test. To motivate participants to attend to and remember the associations between words, they were awarded points not only when they could correctly recognize the intact pairing at the associative memory test, but also when they could successfully reject rearranged pairs.

The current study paradigm is different from Ariel et al.'s (2015) study in several ways. First, to reduce test difficulty, recognition tests were used to measure memory performance instead of cued-recall tests. Another benefit of using recognition tests is that participants' memory for intact pairs and their ability to reject rearranged pairs could be contrasted. As discussed in the General Introduction section, older adults' associative deficit is primarily driven by their poor ability to reject rearranged pairs, rather than their ability to accept intact pairs (e.g., Castel & Craik, 2003; Cohn et al., 2008). Therefore, it would be meaningful to examine whether value-directed learning could improve both hit and false alarm rates. Second, item memory measurement was included as a comparison to associative memory performance, which would allow a more valid measure of age-related associative deficit. Finally, encoding time was controlled by the experimenter, but not the participant in the present study. Participants were exposed to high- and low-value word pairs for the same amount of time, and were not allowed to skip the low-value pairs. This design ensures that participants had equal opportunity to view both types of stimuli, and any difference in memory performance between high- and low-value word pairs would be driven by the amount of encoding resources they put in during each study trial.

Hypotheses

Given older adults' limited availability of attentional resources, they would likely allocate more resources to encode high-value associative information than low-value information. Older participants in this study were predicted to show better memory for high-value than low-value word pairs. On the other hand, young adults should have sufficient resources to encode most, if not all, of the information and hence their associative memory for the two types of word pairs would not differ. Furthermore, based on the assumption that older adults could flexibly allocate more resources to learn high-value associations, associative deficit (i.e., difference between item and associative memory performance) was hypothesized to be smaller for high-value relative to low-value information. Deeper encoding of high-value word pairs would lead to both increased hit rates and reduced false alarm rates for high-value word pairs in comparison to low-value pairs.

Method

Participants

Twenty-four young (22 females) and 24 older adults (17 females) were included in this study. One older participant, not included in the above sample, was replaced because she scored lower than the cut-off score (score of 27) on the MMSE. Participants' demographic characteristics are shown in Table 17. There were more female participants in the young adult group than in the older adult group, but the difference was only marginally significant, χ^2 (1, N = 48) = 3.42, p = .064. Older participants had more years of education, $t(46) = 3.72$, $p = .001$, d = 1.08, and higher scores on the Shipley Institute of Living Vocabulary test, $t(46) = 7.20$, $p < .001$, $d = 2.09$, than young participants. In addition, they scored higher on the positive affect scale, $t(45.37)$[1] = 6.24, $p < .001$, $d = 1.80$, and lower on the negative affect scale, $t(46) = -2.33$, p = .025, $d = -0.67$, of the PANAS in comparison to their younger counterparts. They also had slower reaction time than young adults, as reflected in their lower scores on the letter comparison tasks, $t(46) = -4.88$, $p < .001$, $d = -1.41$ for the 6-letters task and $t(46) = -4.01$, $p < .001$, $d = -1.16$ for the 9-letters task. On the other hand, the two age groups did not differ in the age at which they learned English and their subjective health rating, ps > .934, $d < 0.02$.

Table 17

Participant Characteristics in Study 3

Measure	Young Adults *M*(*SD*)	Older Adults *M*(*SD*)
Age **	21.17 (3.00)	69.96 (4.05)
Years of Formal Education *	14.58 (2.28)	17.29 (2.74)
Age Learned English	1.71 (3.64)	1.63 (3.27)
Health Rating[a]	8.15 (1.14)	8.15 (1.08)
Shipley Vocabulary[b] **	27.79 (4.41)	36.17 (3.61)
PANAS: Positive[c] **	27.92 (5.04)	37.58 (5.67)
PANAS: Negative[c] *	14.38 (3.15)	12.42 (2.67)
Letter Comparison: 3-Letters **	16.75 (3.15)	12.33 (3.12)
Letter Comparison: 6-Letters **	9.42 (2.08)	7.21 (1.72)
MMSE[d]	-	29.17 (1.01)

Note. $*p < .05$. $**p < .001$. [a]Self-reported, with scores ranging from 1 ("poor") to 10 ("excellent"). [b]Shipley Vocabulary = Shipley Institute of Living Vocabulary test. [c]PANAS = Positive and Negative Affect Schedule. [d]MMSE = Mini-Mental State Examination.

Materials

For this experiment, 153 word pairs were selected from the stimulus set finalized in the pilot study described in Chapter 2. In addition, 43 single words were selected from the same stimulus set to serve as new items in the item memory task. Of these stimuli, 9 word pairs and 3 single words were used in the practice trials and the remaining stimuli were used in the actual task. There were four blocks of memory tasks. Word pairs were matched across these memory blocks in terms of relatedness rating of the word pairs, letter and syllable length of the words, as well as frequency, familiarity, meaningfulness, imageability, and concreteness ratings of each word (MRC Psycholinguistic Database; Wilson, 1988). At the study phase of each block, there were six buffer pairs, with three presented at the beginning and three presented at the end of the study phase. In between the buffers were 30 to-be-tested word pairs. These pairs were randomly divided into three 10-pair sets (Set A, Set B, and Set C). Each word pair was randomly assigned a point value. Half of the pairs were associated with a high point value (point values of 9 or 10), whereas the other half of the pairs was associated with a low point value (point values of 1 or 2). To control for the possibility that word pairs that were easier to learn were assigned to either high or low point values by chance, the point value of each word pair within the stimulus sets was counterbalanced across participants, such that each word pair was equally likely to be learned as high- or low-value information. Word pairs in the study phase were pseudo-randomly presented, with the restriction that word pairs from the same set (Set A, B, or C) and value condition (high- or low-value) would not appear twice in a row.

The traditional associative recognition tests were used. There were two recognition tests: an item recognition and an associative recognition test. The item recognition test contained ten studied and ten new words. The studied words consisted of one word from each encoded word pair in Set A, whereas the new words were words that had not been presented during encoding. The associative recognition test contained ten intact word pairs and ten rearranged word pairs. The intact pairs were the exact word pairs in Set B during encoding. The rearranged pairs were created by combining words from Set C with words from Set A that had not been presented in the item recognition test. In addition, only words with the same assigned point values were re-paired together. To illustrate, if the word pair A-B from Set A and C-D from Set C had both been assigned a point value of 9 during encoding, then the word A would be used as a studied word in the item recognition test, whereas the words C and B would be paired to create a rearranged word pair for the associative recognition test. Word pairs were pseudo-randomly presented in each recognition test, with no more than three consecutive trials containing words/word pairs from the same set (Set A, B, or C) and condition (intact or rearranged pairs in the associative recognition test; old or new words in the item recognition test).

Procedure

All participants were tested individually and provided informed consent (see Appendix G) prior to testing. There were four blocks of memory tasks, each consisting of an encoding task, a filler task, and two recognition tests (item and associative). At encoding, participants learned 36 word pairs presented on the computer screen one after another, at a rate of 4 s each, followed by a blank screen for 500 ms and an inter-stimulus interval for 500 ms. The words were presented in black Calibri font of 18 point size against a white background using E-Prime 2.0 software (Psychology Software Tools, Pittsburgh, PA). Below each word pair was a number in red colour indicating the point value assigned to the word pair (see Figure 6). Participants were instructed that each word pair was assigned a point value. Some word pairs were assigned high point values (points 9 or 10), whereas some assigned low point values (points 1 or 2). Word pairs with higher point values were more valuable than word pairs with lower point values. If they remembered the exact pairing of the words (hits to intact pairs) at the subsequent associative recognition test, they would receive the point associated with the pair. During the recognition test, there would also be word pairs that contain words that had appeared at encoding, but presented in different combinations. If participants were able to reject these rearranged pairs correctly (correct rejection), they would also gain the associated points. It was emphasized that their goal was to try to gain as many points as possible in the associative recognition tests. Points would not be rewarded in the item recognition tests to emphasize the importance of learning of associations. Nevertheless, participants were told to still try their best to give as many correct responses as they could.

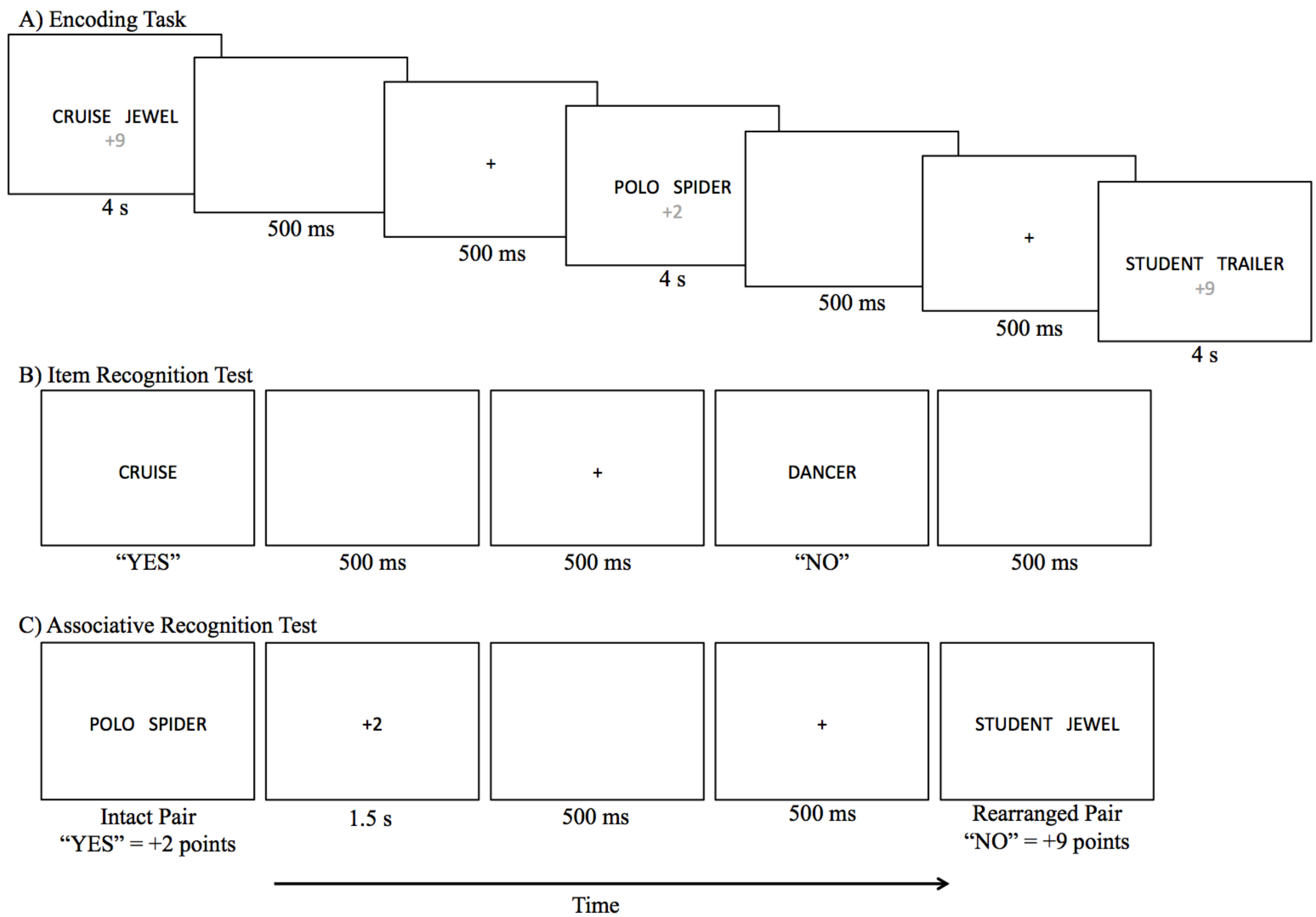

Figure 6. Encoding and recognition procedures in Study 3. Point values in encoding task were presented in red (grey in diagram).

After the encoding task, participants completed a modified version of the letter comparison task (Salthouse & Babcock, 1991) as a filler task for approximately 1.5 min. Then, participants completed an item and an associative recognition test (see Figure 6), with the order of the two tests counterbalanced across participants. In the item recognition test, participants had to distinguish between the words they had studied during the study phase from new words they had not studied by pressing the "YES" or "NO" keys on the keyboard respectively ("z" or "/" keys, with the two keys counterbalanced across participants). In the associative recognition test, they were asked to identify intact pairs from rearranged pairs by pressing the same "YES" and

"NO" keys. Both recognition tests were self-paced with a blank screen for 500 ms and a 500 ms inter-stimulus interval in-between trials. For the associative recognition test, participants were shown the point value they had earned immediately after they had made each response. A total score for all the trials in the same memory block was given at the end of the block so participants could keep track of their performance. A practice task was provided to all participants prior to the first memory block.

After the memory task, participants were asked whether they felt that word pairs with higher point values were more important than word pairs with lower point values, and whether they tried to memorize more of these high-value word pairs than low-value word pairs. Next, all participants completed the PANAS (Watson et al., 1998), the Shipley Institute of Living Vocabulary test (Shipley, 1946), and a background questionnaire. Older participants were also administered the MMSE (Folstein et al., 1975). All participants were debriefed (see Appendix H) and reimbursed at the end of the study session.

Results

Item and associative memory scores for young and older participants are presented in Table 18. Given that new words in the item recognition tests were not assigned point values, the same false alarm rates to new words were used to calculate item memory for high- and low-value information. Inclusion of false alarm rates is necessary to control for guesses and to allow for comparisons between item and associative memory scores (which also corrects for false alarm rates to rearranged pairs).

Table 18

Proportion Memory Scores of Young and Older Adults in Study 3

	Young Adults *M(SD)*		Older Adults *M(SD)*	
Memory Score	High-value	Low-value	High-value	Low-value
Item Memory	.61 (.20)	.54 (.21)	.56 (.20)	.52 (.21)
Associative Memory	.54 (.27)	.52 (.32)	.56 (.23)	.51 (.28)

A 2 (age: young vs. older adults) x 2 (memory: item vs. associative memory) x 2 (value: high vs. low) mixed model ANOVA was conducted, with age as a between-subjects variable and memory type and value as within-subjects variables. The results revealed a main effect of value, $F(1, 46) = 6.83$, $p = .012$, $\eta_p^2 = .13$, whereby high-value information was in general better recognized than low-value information (see Figure 7). However, this effect did not interact with age or memory type, all *p*s > .48, η_p^2s < .01. Strikingly, neither the main effect of age nor the interaction between age and memory type was significant, *p*s > .38, η_p^2s < .02. That is, the typical age-related deficit in associative memory was not found in the current study. In fact, older participants in this study performed as well as their younger counterparts, with no significant difference between their item and associative memory performance. It is also important to note that the value of the word pairs did not affect older adults' memory in the predicted direction. Based on the hypothesis that older adults would selectively allocate their limited attentional resources to learn valuable information during encoding (Castel, 2007), older adults in this study were predicted to show little age-related associative deficit for high-value word pairs, but the deficit should still appear for low-value word pairs. However, the data show absence of associative deficit for both high- and low-value word pairs.

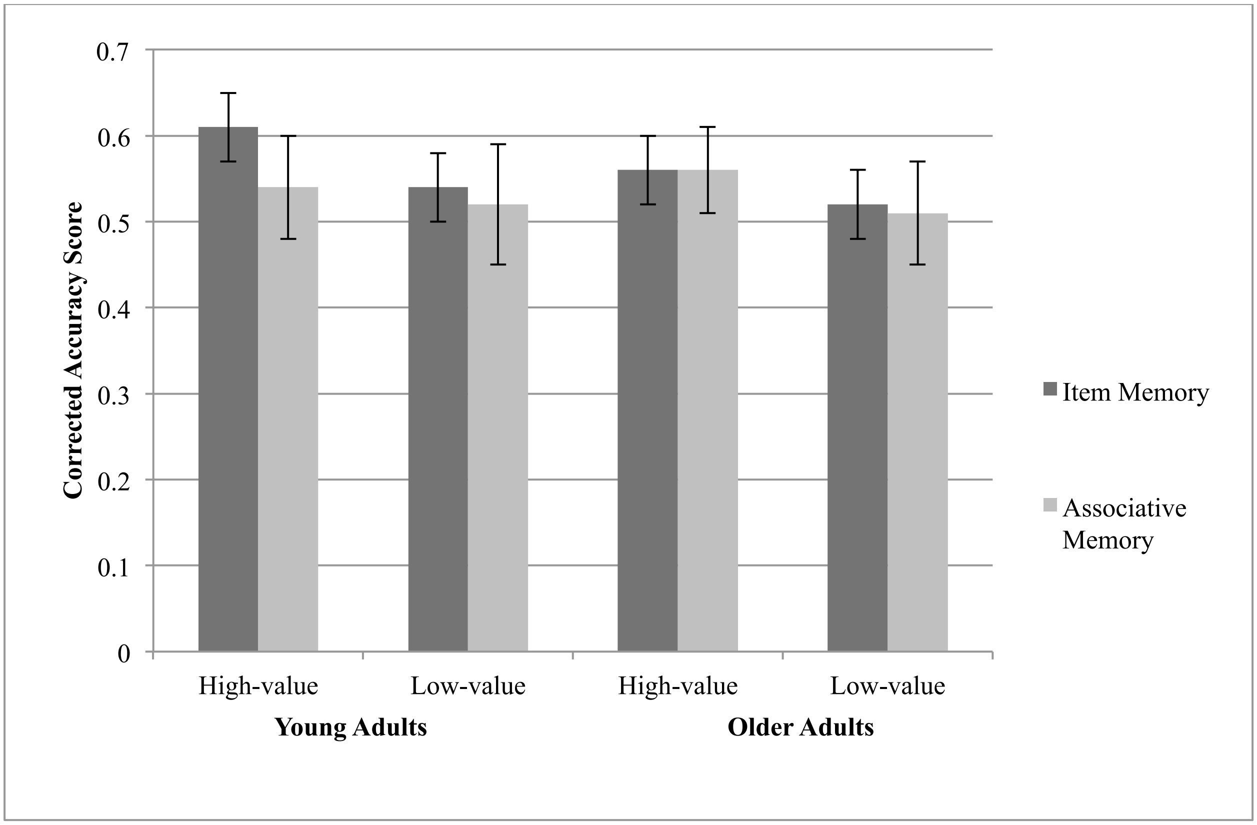

Figure 7. Item and associative memory scores for high- and low-value information in young and older adults in Study 3. Error bars represent standard errors.

The next analyses aimed to further examine the effect of value on hit and false alarm rates in associative memory in young and older participants (see Table 19). Two separate 2 (age) x 2 (value) mixed-model ANOVAs were conducted on hit rates and false alarm rates in the associative memory tests respectively. For hit rates, there was a marginally significant effect of value, $F(1, 46) = 3.98$, $p = .052$, $\eta_p^2 = .08$. Participants in general showed higher hit rates for intact pairs assigned with higher value than those with lower value. Furthermore, there was a main effect of age, $F(1, 46) = 5.00$, $p = .03$, $\eta_p^2 = .10$. Unexpectedly, older participants showed higher overall hit rates in the associative memory test than young participants. For false alarm rates to the rearranged pairs, there was only a marginally significant effect of age, $F(1, 46) = 3.23$, $p = .079$, $\eta_p^2 = .07$, with a trend for older adults to show higher false alarm rates than young adults. However, neither the main effect of value nor the interaction effect of age and value was significant, ps > .58, η_p^2s < .01.

Table 19

Hit and False Alarm Rates in Associative Memory in Young and Older Adults in Study 3

	Young Adults *M(SD)*		Older Adults *M(SD)*	
Memory Score	High-value	Low-value	High-value	Low-value
Hit Rates	.72 (.14)	.70 (.22)	.84 (.12)	.77 (.17)
False Alarm Rates	.18 (.18)	.19 (.18)	.28 (.17)	.26 (.17)

Changes in Associative Memory Performance across Blocks

In previous studies, older adults have shown increasingly stronger selectivity for learning of high-value information over low-value information across study blocks (e.g., Castel, Balota, & McCabe, 2009). To examine whether participants in this study demonstrated similar learning selectivity, a 2 (age: young vs. older adults) x 2 (value: high- vs. low-value) x 4 (blocks: Blocks 1, 2, 3, vs. 4) mixed model ANOVA was conducted, with age as a between-subjects variable, and value and blocks as within-subjects variables. The dependent variable in this analysis was corrected associative memory score. The data are presented in Table 20. None of the main or interaction effects in this analysis were significant, all ps > .19, all η_p^2s < .37. In other words, there was no evidence that young and older participants showed increasingly higher selectivity for learning high-value word pairs over low-value word pairs across the different blocks. However, it is important to note that each associative memory score in the current analysis was generated from the difference between hit rates to five intact pairs and false alarm rates to five rearranged pairs. The low number of trials in each cell might have limited the power of the current analysis.

Table 20

Associative Memory Scores Across Four Memory Blocks in Young and Older Adults

	Young Adults *M(SD)*		Older Adults *M(SD)*	
Block	High-value	Low-value	High-value	Low-value
Block 1	.55 (.32)	.58 (.33)	.53 (.35)	.53 (.32)
Block 2	.50 (.41)	.54 (.37)	.55 (.27)	.51 (.33)
Block 3	.58 (.33)	.48 (.43)	.59 (.29)	.55 (.36)
Block 4	.53 (.33)	.46 (.46)	.58 (.28)	.48 (.39)

Saliency of Point Values

After the completion of the memory task, participants were asked whether they felt that high-value word pairs were more important to remember than low-value word pairs during the study phase. Out of 24 participants in each age group, 10 young and 12 older adults thought that the high-value word pairs were more important to remember, whereas the remaining participants felt that the two types of word pairs were equally important to remember. The number of participants who held these views did not significantly differ between the two age groups, χ^2 (1, N = 48) = 0.34, p = .562. Participants who did not perceive high-value word pairs as more important reported that they were trying to remember all of the pairs regardless of value, and/or that they did not pay attention to the value at all so that they could focus on memorizing the words. In addition, all participants were asked whether they tried to remember more high-value word pairs than low-value word pairs. Nine of 24 young participants and eight of 24 older participants reported strategically memorizing more high-value word pairs than low-value pairs, with no significant difference in these numbers between the two age groups, χ^2 (1, N = 48) = 0.09, p = .763. Taken together, although participants showed better memory for high-value than low-value information in this study, only about one-third of participants explicitly focused on learning of high-value information. Many participants tried to remember both types of information, plausibly as a strategy to gain as many points as they could, without the trade-off of losing points from not remembering low-value information.

Discussion

According to Castel (2007), older adults could flexibly allocate their limited attentional resources during encoding based on the importance of the to-be-remembered information. In the context of the current study paradigm, they were expected to devote more resources on studying associative information with high importance in the expense of spending fewer resources on learning low-value information. Consequently, they should show better memory for high-value than low-value word pairs. It was also hypothesized that their associative deficit for high-value pairs should be reduced in comparison to that for low-value pairs. These benefits in memory performance should be reflected in both increased hit rates to intact pairs and reduced false alarm rates to rearranged pairs in high-value word pairs.

The results of this study revealed that high-value information was remembered better than low-value information. However, this effect did not interact with age or memory type. Young and older adults remembered both high-value items and associations better than low-value ones. For associative recognition, higher value leads to improved hit rates to intact pairs, but participants' ability to reject rearranged pairs was not affected by the assigned value of the stimuli.

An interesting finding is that older participants in general performed just as well as their younger counterparts in this study. Older adults did not show any associative deficit, which was indicated by their equivalent item and associative memory performance for both high- and low-value information. It was predicted that older adults would shift their attentional resources towards learning high-value word pairs, and hence would show reduced associative deficit for these pairs than low-value word pairs. However, the typical age-related associative deficit commonly found in previous studies (e.g., Old & Naveh-Benjamin, 2008) was still expected to appear in memory for low-value word pairs. Hence, older participants' absence of associative deficit for low-value information is surprising.

Age-related associative deficit was found in Study 1 of this Dissertation. Different memory paradigms were used in Study 1 and the present study, but there is no reason to believe that the current paradigm was easier for older adults than that in Study 1. First, word pair stimuli from both studies were selected from the same stimulus database finalized in the pilot study described in Chapter 2. Second, the number of word pairs participants learned in each study phase was comparable between the two studies (38 word pairs in Study 1 and 36 word pairs in Study 3). Third, associative memory scores were calculated as the difference between hit rates to intact pairs and false alarm rates to rearranged pairs in both memory paradigms. Fourth, participants completed four blocks of memory tasks in Study 3, whereas there were only two blocks in Study 1. Finally, although encoding time in both studies was 4 s for each word pair, participants in Study 3 had to process both the word pair and its assigned point value within that time duration, which should be more resource demanding than learning the word pair alone in Study 1. Despite that the memory paradigm is arguably more challenging than that in Study 1, older participants in this study did not display any associative deficit and showed similar item and associative memory performance as young participants. In fact, their hit rates to intact pairs in the associative memory tests were significantly better than that of young adults. In addition, although there was still a trend for older adults to have more false alarms to rearranged pairs than did young adults in this study (Older adults: $M = .27$, $SD = .16$; Young adults: $M = .18$, $SD = .16$; $d = .52$, a medium effect size), the magnitude of this age difference was smaller compared to that in Study 1 (Older adults: $M = .45$, $SD = .26$; Young adults: $M = .22$, $SD = .24$; $d = .91$, a large effect size).

A plausible explanation for the unexpected age-equivalent memory performance for the low-value items in this study is that the present task instructions posed greater emphasis on remembering associations between words than in Study 1. Although participants were still instructed to memorize both individual words and their pairings and to try their best in both item and associative recognition tests as in Studies 1 and 2, correct associative memory responses were specifically rewarded in the present study. In a typical encoding condition as in Study 1, participants might have prioritized their attentional resources on item encoding, which left them few resources for associative encoding. This speculation was supported by results in Study 2. When older adults were directed to allocate their resources to item and associative encoding in two separate phases, they could successfully use effective encoding strategies to remember associations and perform as well as young adults in the recognition tests. In addition, Hockley and Cristi (1996) showed that young adults displayed an “associative deficit”, as indexed by their significantly poorer associative memory than item memory, when task instructions emphasized learning of items during encoding of word pairs. However, their associative memory was equivalent to their item memory when they were instructed to focus on associative encoding. In other words, even in young adults, associative memory suffers when item learning is prioritized. In the present study, accurate memory for associations was rewarded and therefore associative encoding was more salient and valuable to participants than item encoding. Consistent with Castel’s (2007) strategic and selective control theory, it is likely that older participants prioritized their attentional resources to associative encoding in this study, and hence showed age-equivalent associative memory performance. In addition, the scoring system in the associative memory tests might have also further promoted deep encoding of associations. Specifically, points were not only given to correct recognition of intact pairs, but also correct rejection of rearranged pairs. As described in the General Introduction, correct rejection of rearranged pairs is more challenging for older adults than correct recognition of intact pairs (e.g., Cohn et al., 2008), because the former requires memory for the exact pairing between items whereas the latter could be accomplished without recollecting the exact pairing between them. To optimize their scores in this study, older adults would need to reduce their false alarm rates to rearranged pairs. This requirement might further motivate them to focus their resources on remembering the exact pairing between words.

It is also important to note that two-thirds of young and older participants did not try to remember more high-value pairs than low-value pairs. Many of them reported that they tried to remember all word pairs regardless of value, as they did not want to give up the opportunity to gain points from low-value stimuli. It is plausible that despite their lower availability of attentional resources in comparison to young adults, older adults still have sufficient attentional resources to engage in efficient associative encoding. However, because their resources are more limited, they might be less likely than young adults to devote their resources on associative encoding unless the to-be-remembered information is meaningful. In the current study, older participants perceived high- and low-value word pairs as equally important to remember, hence they allocated attentional resources to encode both high- and low-value associations and as a result did not display any age-related declines in their memory for these associations.

In sum, young and older participants in general remembered more high-value than low-value information, and this effect appeared in both item and associative memory. Unexpectedly, older participants performed as well as young participants in the memory tests, and did not show any associative deficit for either high- or low-value word pairs. In this study, accurate memory for associations was rewarded with points, but there was no extrinsic motivation to remember the individual items. The emphasis on associative encoding in the task instructions directed older adults to allocate their limited attentional resources to focus on associative encoding. In contrast, they might likely prioritize their resources to item learning over associative encoding in a typical associative memory paradigm as in Study 1.

Chapter 6: General Discussion

The overall purpose of this Dissertation was to investigate the role of reduced attentional resources in age-related associative deficit, and to explore whether the deficit could be alleviated through different manipulations during encoding. Study 1 tested the impacts of limited attentional resources during encoding on associative memory performance, particularly individuals' ability to use effective encoding strategies and recollection memory processes to support successful associative memory. Studies 2 and 3 examined the effectiveness of two different encoding manipulations to facilitate associative memory in older adults. Specifically, item and associative learning were separated into two sequential phases to alleviate attentional resource load during associative encoding in Study 2. In Study 3, value was assigned to to-be-remembered word pairs to motivate participants to prioritize their attentional resources towards encoding of important associative information. The overall results of these studies and their implications in associative memory research are discussed in this chapter.

Attentional Resources and Associative Deficit

According to Craik, many age-related problems in memory stem from the reduction of attentional resources with advancing age (e.g., Craik & Byrd, 1982; Craik & Rose, 2012). In particular, older adults lack the attentional resources needed to self-initiate and engage in effortful mental processes such as deep elaborative encoding operations that normally support successful memory performance in young adults. Kim and Giovanello (2011a, 2011b) provided evidence that young adults display an associative deficit similar to older adults when they learn associative information while completing a relational divided attention task at the same time. In the present Dissertation, results of Study 1 replicate Kim and Giovanello's findings, and more importantly offer further insights into the mechanisms underlying the effect of reduced attentional resources on associative memory.

The critical finding of Study 1 is that reduction of attentional resources involved in relational processing impairs memory performance similarly to the effect of aging. Specifically, both DA young adults and older adults showed disproportionately poorer associative memory than item memory in comparison to young adults under full attention. Furthermore, resource depletion during the study phase leads to lower use of effective encoding strategies and recollection-based memory processes. Young adults under divided attention and older adults tended to rely on low-level encoding strategies (e.g., rote repetition) to remember associations, whereas young adults under full attention were more likely to use high-level strategies (e.g., sentence generation) consistently throughout the study phase, despite that all three participant groups understood that high-level strategies were more effective than low-level strategies to help one remember word pairs. These results suggest that the use of effective strategies is resource-demanding, and is less likely to be executed under insufficient attentional resources. Because attentional resources are limited in older adults (due to normal aging) and young adults under divided attention, both groups were less able to self-initiate and carry out these effortful encoding strategies in the associative memory task.

Memory retrieval in both young adults under divided attention and older adults was less dependent on recollection-based processes than that in young adults under full attention. Familiarity, on the other hand, was not affected by reduction of attentional resources during encoding, which replicates previous findings (e.g., Yonelinas, 2002). These results suggest that when attentional resources are insufficient during encoding, either induced by a DA task or as an effect of aging, the memory trace tends to lack details and is more gist-like. As discussed previously, accurate item memory could be supported by familiarity processes, whereas successful associative memory strongly depends on recollection of details (Yonelinas, 1997). Hence, with little support from recollection, associative memory was particularly impaired in both DA young adults and older adults.

It has been well documented that older adults' failure to self-initiate effective encoding strategies and their weaker reliance on recollection processes are two major contributing factors in their associative deficit (e.g., Cohn et al., 2008; Naveh-Benjamin et al., 2007). Recent studies also revealed that the deficit is related to reduced attentional resources in old age (Kim & Giovanello, 2011a, 2011b). However, there was yet to be a study to connect these concepts together. Findings of Study 1 thus added a novel contribution to the literature by suggesting the underlying mechanism of the associative deficit – reduced attentional resources during encoding makes it challenging to initiate effortful encoding strategies and for memory to support recollection of associative information.

Effects of Encoding Manipulations on Older Adults' Associative Memory

Findings from Study 1 demonstrate that insufficient attentional resources during encoding could impair associative memory performance. A less resource-demanding encoding environment might hence alleviate older adults' associative deficit. This speculation was supported by Study 2. In this study, resource load during encoding was alleviated by having participants learn items and associations separately in two sequential phases. Pre-learning of items reduces the attentional resource load needed for the subsequent associative learning, and as a result, older adults did not show any signs of associative deficit and their memory performance was equivalent to that of young adults. In comparison to older adults who studied the same word pairs in a traditional encoding paradigm (Study 1), older adults in Study 2 showed more frequent use of high-level encoding strategies and there were a greater number of consistent high-level strategy users relative to those in Study 1. The finding that older adults could self-initiate high-level encoding strategies without explicit instructions is fascinating. Although Naveh-Benjamin et al. (2007) showed that older adults could use sentence generation to improve their associative memory, strategy use was explicitly prompted by the experimenters. In Study 2 of this Dissertation, older adults were instructed to think of the meaning of each word during the item learning phase to ensure that they would actively study the words before learning their associations. Nevertheless, they were not provided additional guidance to use any particular strategy to form associations between the words. The finding that they used high-level encoding strategies more readily than older adults in Study 1 suggests that older adults are able to self-initiate effective, relational encoding strategies, but this may only happen when they have sufficient attentional resources during encoding of associations.

In addition, when resource load during encoding was reduced in Study 2, older adults showed higher reliance on recollection memory processes than older adults in Study 1. Their false alarm rates to rearranged pairs in the associative recognition tests significantly decreased in comparison to older adults in Study 1. It is likely that deep encoding of the word pairs through the use of effective encoding strategies led to recollection of details that were necessary for the retrieval of associative information. This speculation is supported by the moderate correlation between recollection and use of high-level strategies in older adults in Study 2.

In Study 3, value was assigned to word pairs to motivate older adults to direct their limited attentional resources towards important stimuli during encoding. Although older adults were expected to prioritize learning of high-value pairs over low-value pairs, the results showed age-equivalent memory performance for both types of associations. Given that participants were only rewarded for accurate associative memory but not for item memory, the instructions placed stronger emphasis on associative encoding over item encoding. As a result, older adults likely shifted their attentional resources to encode associations, possibly by using more effective encoding strategies. However, because the use of encoding strategies was not assessed in Study 3, it is not certain how older adults improved their associative memory performance.

Integrating the findings from all three studies in this Dissertation, older adults' associative deficit could be explained by a lower availability of attentional resources. With limited resources, they might be more likely than young adults to prioritize item encoding, because encoding of items is less resource demanding and it precedes associative encoding. Thus under a traditional associative encoding paradigm (e.g., Naveh-Benjamin, 2000), older adults usually show disproportionately poorer associative memory than item memory in comparison to young adults. According to Craik and Rose (2012), although older adults lack attentional resources to self-initiate effortful mental processes, these processes could still be performed when there is environmental support. An example of an environmental support is to provide pictorial stimuli instead of verbal stimuli during encoding, as pictures are highly meaningful and tend to encourage deeper encoding than verbal stimuli (Craik & Byrd, 1982). It can be argued that the encoding manipulations in Studies 2 and 3 of this Dissertation also provided environmental support for older adults. In Study 2, older adults were guided to encode items and associations sequentially. The pre-learning of items should eliminate resource competition between item and associative encoding and thus ensure that older adults devote their available resources fully to associative encoding. That is, older adults in this paradigm did not have to prioritize item learning in the expense of engaging shallow encoding of associations, which might be more likely to happen when they had to learn items and their associations simultaneously (e.g., Study 1 of Dissertation). The encoding instructions of Study 3 prompted older adults to focus on associative encoding, because they would be specifically rewarded for accurate memory of associations. In this situation, prioritizing item encoding over associative encoding would work against the requirement of the task. As a result, older adults showed similar memory performance for the word pairs as young adults in this study.

Correlations between Use of Encoding Strategies and Associative Memory Performance

It might be perplexing that there was a significant positive correlation between use of high-level encoding strategies and associative memory scores in older adults in Study 2, but the same correlation did not reach significance in Study 1. In Study 1, there were only eight older participants who reported using high-level encoding strategies consistently (more than 50% of the time) in the memory task, whereas the majority of participants used low-level strategies consistently. A closer examination of the data indicated high variance in memory performance among the consistent high-level strategy users. That being said, failure to find correlation between strategy use and associative memory performance might be due to small sample size and high variability in memory performance in high-level strategy users. When this participant subgroup was removed from analysis, a significant correlation between strategy use and associative memory was revealed, $r = .69$, $p = .003$, providing evidence that higher use of effective encoding strategies could contribute to better associative memory performance which is consistent with findings in Study 2. It is worthy to note that the high variance in memory performance in consistent high-level strategy users in Study 1 suggests that not all older participants benefitted equally from using effective encoding strategies. It is therefore important to explore in future studies whether lack of attentional resources could also affect the *quality* of strategy use, and more importantly, whether encoding conditions that promote efficient allocation of attentional resources, such as that in Study 2, could improve older adults' quality of strategy use.

Limitations and Future Directions

Despite the positive findings in this Dissertation, a few limitations should be addressed. First, the role of attentional resources in associative memory was deduced using behavioural measures, which may not serve as a direct measure of attentional resources. Kim and Giovanello (2011b) found that when young adults encoded associative information under divided attention, they showed reduced activity in the dorsolateral and ventrolateral prefrontal cortex, the inferior and superior parietal cortex, and anterior hippocampus similar to older adults. Hence, it may be meaningful to examine whether older adults are able to activate these brain areas under an encoding paradigm requiring lower resource load (Study 2) or a paradigm emphasizing associative learning (Study 3). It should be noted, however, that older adults might also show activation in other brain areas or other activation patterns. Previous studies have revealed that older adults may activate more brain regions than young adults to accomplish a cognitive task as compensation against declines in brain functions. For instance, whereas young adults show lateralized frontal activity during successful encoding of words, older adults may activate the same regions bilaterally (e.g., Morcom, Good, Frackowiak, & Rugg, 2003).

Second, encoding strategy use was not assessed trial-by-trial in Studies 1 and 2, thus the reported percentage use of strategy could only be an estimate. That being said, participants' self-reported strategy use should still serve as a close account of their experience during encoding, given that percentage use of high-level encoding strategies was positively correlated with memory performance in both studies. In addition, the modified PEP questionnaire used in this Dissertation is a more sensitive measure of encoding strategy use than the open-ended questionnaire used in Naveh-Benjamin et al. (2007). Naveh-Benjamin et al. reported that 100% of young adults in their study used elaborative encoding strategies, whereas findings of this Dissertation revealed that it is not uncommon for young adults to use low-level strategies, such as rote repetition. In fact, some young adults switched between high- and low-level strategies during encoding. Hence, Naveh-Benjamin et al.'s finding that all young adults used relational strategies during encoding might be a misrepresentation of their encoding experience.

Finally, older adults showed age-equivalent associative memory for both high- and low-value information, despite that they were expected to only show improved memory for high-value information. The speculation is that the task instructions emphasized associative encoding, and hence prompted older adults to focus their attentional resources on learning of associations. However, the current data do not provide direct evidence on how they achieved their good performance. It is possible that they engaged in elaborative encoding strategies more than under a traditional encoding paradigm as in Study 1. The PEP questionnaire was not administered in Study 3 because participants were expected to use different encoding strategies for high- and low-value information and it might therefore be difficult for them to report their strategy use for the two respective types of information. A direction for a follow-up study is to highlight the importance of associative encoding over item encoding in the instructions, without assigning value to the stimuli. Older adults should still show age-equivalent associative memory in this paradigm if their performance in Study 3 was due to the emphasis on associative encoding in the instructions. Without a distinction between high- and low-value pairs, the PEP questionnaire could then be used to assess older adults' use of encoding strategies and test whether they are more likely to use elaborative strategies when associative encoding is emphasized in comparison to a traditional encoding paradigm as in Study 1.

Conclusion

In summary, findings of this Dissertation indicate that lack of attentional resources (i.e., "mental energy"; Craik & Byrd, 1982) required for relational processing during encoding impairs the use of elaborative encoding strategies and recollection-based memory processes, which both contribute to the age-related associative deficit. However, despite their limited attentional resources, older adults could still devote resources to learn associative information when resource competition between item processing and associative encoding was minimized by sequentially learning items and associations in separate phases (Study 2) or when being guided/rewarded to prioritize associative encoding (Study 3). That is, although older adults typically show poorer associative memory than young adults, their deficit could be alleviated if given sufficient environmental support during encoding.

These results have great practical implications. It may be fruitful to educate older adults about different encoding situations that promote successful memory encoding. In fact, this approach should be more effective than training older adults on using effortful encoding strategies, as it has been found that older adults show larger memory improvements when given encoding environments that prompt them to self-generate encoding strategies than when they are instructed to employ specific strategies (Flegal & Lustig, 2016). In addition, because the encoding manipulations tested in this Dissertation are not specific to learning of word pairs, the same memory benefits should also be transferrable to associative memory for other stimuli, such as pictures.

Appendix A: Ryerson REB Approval Letters

Ryerson University RESEARCH ETHICS BOARD

To: Brenda Wong
Psychology
Re: REB 2015-326: Attentional Resources and Associative Memory
Date: October 26, 2015

Dear Brenda Wong,

The review of your protocol REB File REB 2015-326 is now complete. The project has been approved for a one year period. Please note that before proceeding with your project, compliance with other required University approvals/certifications, institutional requirements, or governmental authorizations may be required.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. If this is a funded project, access to research funds may also be affected.

Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible with an indication from the Principal Investigator as to how, in the view of the Principal Investigator, these events affect the continuation of the protocol.

Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

Please quote your REB file number (REB 2015-326) on future correspondence.

Congratulations and best of luck in conducting your research.

Lynn Lavallée, Ph.D.
Chair, Research Ethics Board

Ryerson University Research Ethics Board

To: Brenda Iok Wong
Psychology
Re: REB 2016-071: Age differences in item and associative learning
Date: March 16, 2016

Dear Brenda Iok Wong,

The review of your protocol REB File REB 2016-071 is now complete. The project has been approved for a one year period. Please note that before proceeding with your project, compliance with other required University approvals/certifications, institutional requirements, or governmental authorizations may be required.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. If this is a funded project, access to research funds may also be affected.

Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible with an indication from the Principal Investigator as to how, in the view of the Principal Investigator, these events affect the continuation of the protocol.

Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

Please quote your REB file number (REB 2016-071) on future correspondence.

Congratulations and best of luck in conducting your research.

Lynn Lavallée, Ph.D.
Chair, Research Ethics Board

Ryerson University Research Ethics Board

To: Brenda Wong
Psychology
Re: REB 2016-413: Age differences in value-directed learning
Date: December 21, 2016

Dear Brenda Wong,

The review of your protocol REB File REB 2016-413 is now complete. The project has been approved for a one year period. Please note that before proceeding with your project, compliance with other required University approvals/certifications, institutional requirements, or governmental authorizations may be required.

This approval may be extended after one year upon request. Please be advised that if the project is not renewed, approval will expire and no more research involving humans may take place. If this is a funded project, access to research funds may also be affected.

Please note that REB approval policies require that you adhere strictly to the protocol as last reviewed by the REB and that any modifications must be approved by the Board before they can be implemented. Adverse or unexpected events must be reported to the REB as soon as possible with an indication from the Principal Investigator as to how, in the view of the Principal Investigator, these events affect the continuation of the protocol.

Finally, if research subjects are in the care of a health facility, at a school, or other institution or community organization, it is the responsibility of the Principal Investigator to ensure that the ethical guidelines and approvals of those facilities or institutions are obtained and filed with the REB prior to the initiation of any research.

Please quote your REB file number (REB 2016-413) on future correspondence.

Congratulations and best of luck in conducting your research.

Lynn Lavallée, Ph.D.
Chair, Research Ethics Board

Appendix B: Personal Encoding Preference (PEP) Questionnaire

We would like to know the strategies you might have used to learn the associations of word pairs in the memory task. Listed below are some possible strategies for learning word pairs. Some strategies are followed by a specific example using the word pair *clown: paper* to demonstrate how these strategies works.

Please indicate how often you have used each strategy during the study phase of the memory task to learn the associations. For example, if you have used a particular strategy to memorize 60% of the word pairs, please write "60" on the line next to that strategy. If a particular strategy has never been used in this study, please write "0".

Strategy	**Percentage of Use**
1. ***Rote repetition:*** Say the word pair over and over. *For example:* clown: paper, clown: paper, clown: paper, etc.	___________%
2. ***Attentive reading:*** Reading over or saying the word pair once in your mind	___________%
3. ***Semantic reference:*** Relate the word pair to something of meaning in your life. *For example:* My grandmother gave me a paper clown for my sixth birthday.	___________%
4. ***Focal attention:*** Focus on the word pair by looking or staring at it until you can see the word pair clearly in your mind.	___________%
5. ***Imagery:*** Imagine a scene using the two words as images in it. *For example:* imagining a scene where the tall clown jumped out of the paper car tearing the paper door off the hinges.	___________%
6. ***Sentence generation:*** Construct a sentence using both of the words. *For example:* "The clown wore a red and orange paper hat."	___________%
7. ***Other strategy (Please explain):*** ____ ____ ____	___________%

Using the following scale, please evaluate how effective you think each strategy should be for us to learn word pairs, regardless of your own use of strategies in this study.

1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Least effective				*Moderately effective*					*Most effective*

1. *Rote repetition:* Say the word pair over and over.
For example: clown: paper, clown: paper, clown: paper, etc.

1 2 3 4 5 6 7 8 9 10

2. *Attentive reading:* Reading over or saying the word pair once in your mind

1 2 3 4 5 6 7 8 9 10

3. *Semantic reference:* Relate the word pair to something of meaning in your life.
For example: My grandmother gave me a paper clown for my sixth birthday.

1 2 3 4 5 6 7 8 9 10

4. *Focal attention:* Focus on the word pair by looking or staring at it until you can see the word pair clearly in your mind.

1 2 3 4 5 6 7 8 9 10

5. *Imagery:* Imagine a scene using the two words as images in it.
For example: imagining a scene where the tall clown jumped out of the paper car tearing the paper door off the hinges.

1 2 3 4 5 6 7 8 9 10

6. *Sentence generation:* Construct a sentence using both of the words.
For example: "The clown wore a red and orange paper hat."

1 2 3 4 5 6 7 8 9 10

7. *Other strategy (Please explain):*

____

____

1 2 3 4 5 6 7 8 9 10

Appendix C: Consent Forms in Study 1

Consent Form for Young Adults from SONA (Study 1)

Ryerson University
Consent Agreement

You are being invited to participate in a research study. Please read this consent form so that you understand what your participation will involve. Before you consent to participate, please ask any questions to be sure you understand what your participation will involve.

STUDY TITLE: Attentional Resources and Associative Memory
Consent Form for Young Adults (SONA)

INVESTIGATORS: This research study is being conducted by Brenda Wong, PhD Candidate (Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor) from the Department of Psychology at Ryerson University.

This study is funded by Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (RGPIN-2014-06153) awarded to Dr. Lixia Yang.

If you have any questions or concerns about the research, please feel free to contact Brenda Wong at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987.

PURPOSE OF THE STUDY: The purpose of this cognitive psychology study is to examine the relations between attention and our memory for associations between pieces of information. For this study, 144 healthy individuals will be recruited, including 96 Ryerson students from PSY 102/202 and 48 older adults. The results of this study will contribute to a dissertation.

WHAT YOU WILL BE ASKED TO DO: If you volunteer to participate in this study, you will be asked to do the following things: First, you will read and sign the consent form so that you understand the procedures of this experiment. Next, you will be asked to complete a memory task on the computer. In this task, you will be asked to remember pairs of words, and then to recognize these word pairs in two memory tests. Detailed instructions and practice trials will be provided to familiarize you with the task. Following the computerized tasks, you will fill out a few paper-and-pencil questionnaires to assess your mood, your vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition), to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. The entire study will take approximately 1 hour, and will take place at the South Bond Building at 105 Bond Street, Toronto. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.
WHAT IS EXPERIMENTAL IN THIS STUDY: None of the procedures used in this study is experimental in nature – they have all been used by other researchers and found to be useful experimental procedures. However, part of this study is considered “experimental”. By following

the procedure described above, the study examines the impact of one variable (called the "independent variable"; e.g., aging) on another variable (called the "dependent variable"; e.g., memory). More information about the independent and dependent variables will be provided at the end of the session.

POTENTIAL BENEFITS: Although you may not benefit directly from participating in this study, the benefits of participation in this study may include: (1) gaining knowledge in psychological experiments; (2) learning about the effect of aging on associative memory; and (3) contributing to scientific research in aging.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT: The potential risks in this study are very low. Some minor risks may include fatigue and discomfort from answering some questions given their personal nature. You will be offered to take breaks throughout the testing session. You may choose to refuse participation in any aspect of the research (e.g., responding to a particular question on the questionnaire). Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. If any aspect of the study makes your uncomfortable, you may skip a question or stop participation, either temporarily or permanently, without any penalty. You will still be fully compensated in this case.

CONFIDENTIALITY: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. We will not be collecting personal identifying information on the computer tasks. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity. All the data collected from you will be kept in a locked cabinet in a locked laboratory or on a password protected computer for up to 10 years. The data will only be accessible by the investigators of this study and associated lab personnel. After the stated period of time, the data will be destroyed.

INCENTIVES FOR PARTICIPATION: You will receive one participation credit towards your PSY 102/202 course at Ryerson University. If you prefer to "walk through" the study (i.e., to observe the research process without providing any personal data), you will still receive one credit under the condition that you have not already received the maximum allotted for research participation.

VOLUNTARY PARTICIPATION AND WITHDRAWAL: Participation in this study is completely voluntary. You can choose whether to be in this study or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time and you will still be given the incentives and reimbursements described above. If you choose to stop participating, you may also choose to not have your data included in the study. Your choice of whether or not to participate will not influence your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research.

QUESTIONS ABOUT THE STUDY: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

This study has been reviewed by the Ryerson University Research Ethics Board. If you have questions regarding your rights as a participant in this study please contact:

Research Ethics Board
c/o Office of the Vice President, Research and Innovation
Ryerson University
350 Victoria Street
Toronto, ON M5B 2K3
416-979-5042; rebchair@ryerson.ca

If you any have questions about receiving your Psychology 102/202 credit for participation please contact: thepool@psych.ryerson.ca

Attentional Resources and Associative Memory

CONFIRMATION OF AGREEMENT:

Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to participate in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement. You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Participant (please print)

____________________________________ __________________
Signature of Participant Date

____________________________________ __________________
Signature of Researcher Date

Consent Form for Young Adults from the Community (Study 1)

Ryerson University
Consent Agreement

You are being invited to participate in a research study. Please read this consent form so that you understand what your participation will involve. Before you consent to participate, please ask any questions to be sure you understand what your participation will involve.

STUDY TITLE: Attentional Resources and Associative Memory
Consent Form for Young Adults (Community)

INVESTIGATORS: This research study is being conducted by Brenda Wong, PhD Candidate (Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor) from the Department of Psychology at Ryerson University.

This study is funded by Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (RGPIN-2014-06153) awarded to Dr. Lixia Yang.

If you have any questions or concerns about the research, please feel free to contact Brenda Wong at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987.

PURPOSE OF THE STUDY: The purpose of this cognitive psychology study is to examine the relations between attention and our memory for associations between pieces of information. For this study, 144 healthy individuals will be recruited, including 96 young adults and 48 older adults. The results of this study will contribute to a dissertation.

WHAT YOU WILL BE ASKED TO DO: If you volunteer to participate in this study, you will be asked to do the following things: First, you will read and sign the consent form so that you understand the procedures of this experiment. Next, you will be asked to complete a memory task on the computer. In this task, you will be asked to remember pairs of words, and then to recognize these word pairs in two memory tests. Detailed instructions and practice trials will be provided to familiarize you with the task. Following the computerized tasks, you will fill out a few paper-and-pencil questionnaires to assess your mood, your vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition), to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. The entire study will take approximately 1 hour, and will take place at the South Bond Building at 105 Bond Street, Toronto. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.

POTENTIAL BENEFITS: Although you may not benefit directly from participating in this study, the benefits of participation in this study may include: (1) gaining knowledge in psychological experiments; (2) learning about the effect of aging on associative memory; and (3) contributing to scientific research in aging.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT: The potential risks in this study are very low. Some minor risks may include fatigue and discomfort from answering some questions given their personal nature. You will be offered to take breaks throughout the testing session. You may choose to refuse participation in any aspect of the research (e.g., responding to a particular question on the questionnaire). Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. If any aspect of the study makes your uncomfortable, you may skip a question or stop participation, either temporarily or permanently, without any penalty. You will still be fully compensated in this case.

CONFIDENTIALITY: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. We will not be collecting personal identifying information on the computer tasks. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity. All the data collected from you will be kept in a locked cabinet in a locked laboratory or on a password protected computer for up to 10 years. The data will only be accessible by the investigators of this study and associated lab personnel. After the stated period of time, the data will be destroyed.

INCENTIVES FOR PARTICIPATION: As an appreciation for your time and effort, you will receive $10 for your participation in this study.

VOLUNTARY PARTICIPATION AND WITHDRAWAL: Participation in this study is completely voluntary. You can choose whether to be in this study or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time and you will still be given the incentives and reimbursements described above. If you choose to stop participating, you may also choose to not have your data included in the study. Your choice of whether or not to participate will not influence your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research.

QUESTIONS ABOUT THE STUDY: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

This study has been reviewed by the Ryerson University Research Ethics Board. If you have questions regarding your rights as a participant in this study please contact:

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Attentional Resources and Associative Memory

CONFIRMATION OF AGREEMENT:

Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to participate in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement. You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Participant (please print)

____________________________________ __________________
Signature of Participant Date

____________________________________ __________________
Signature of Researcher Date

Consent From for Older Adults (Study 1)

Ryerson University
Consent Agreement

You are being invited to participate in a research study. Please read this consent form so that you understand what your participation will involve. Before you consent to participate, please ask any questions to be sure you understand what your participation will involve.

STUDY TITLE: Attentional Resources and Associative Memory
Consent Form for Older Adults

INVESTIGATORS: This research study is being conducted by Brenda Wong, PhD Candidate (Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor) from the Department of Psychology at Ryerson University.

This study is funded by Natural Sciences and Engineering Research Council of Canada (NSERC) Discovery Grant (RGPIN-2014-06153) awarded to Dr. Lixia Yang.

If you have any questions or concerns about the research, please feel free to contact Brenda Wong at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987.

PURPOSE OF THE STUDY: The purpose of this cognitive psychology study is to examine the relations between attention and our memory for associations between pieces of information. For this study, 144 healthy individuals will be recruited, including 96 young adults and 48 older adults. The results of this study will contribute to a dissertation.

WHAT YOU WILL BE ASKED TO DO: If you volunteer to participate in this study, you will be asked to do the following things: First, you will read and sign the consent form so that you understand the procedures of this experiment. Next, you will be asked to complete a memory task on the computer. In this task, you will be asked to remember pairs of words, and then to recognize these word pairs in two memory tests. Detailed instructions and practice trials will be provided to familiarize you with the task. Following the computerized tasks, you will fill out a few paper-and-pencil questionnaires to assess your mood, your attention and memory, your vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition), to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. The entire study will take approximately 1 hour, and will take place at the South Bond Building at 105 Bond Street, Toronto. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.

POTENTIAL BENEFITS: Although you may not benefit directly from participating in this study, the benefits of participation in this study may include: (1) gaining knowledge in psychological experiments; (2) learning about the effect of aging on associative memory; and (3) contributing to scientific research in aging.

WHAT ARE THE POTENTIAL RISKS TO YOU AS A PARTICIPANT: The potential risks in this study are very low. Some minor risks may include fatigue and discomfort from answering some questions given their personal nature. You will be offered to take breaks throughout the testing session. You may choose to refuse participation in any aspect of the research (e.g., responding to a particular question on the questionnaire). Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. If any aspect of the study makes your uncomfortable, you may skip a question or stop participation, either temporarily or permanently, without any penalty. You will still be fully compensated in this case.

CONFIDENTIALITY: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. We will not be collecting personal identifying information on the computer tasks. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity. All the data collected from you will be kept in a locked cabinet in a locked laboratory or on a password protected computer for up to 10 years. The data will only be accessible by the investigators of this study and associated lab personnel. After the stated period of time, the data will be destroyed.

INCENTIVES FOR PARTICIPATION: As an appreciation for your time and effort, you will receive $10 for your participation in this study.

VOLUNTARY PARTICIPATION AND WITHDRAWAL: Participation in this study is completely voluntary. You can choose whether to be in this study or not. If any question makes you uncomfortable, you can skip that question. You may stop participating at any time and you will still be given the incentives and reimbursements described above. If you choose to stop participating, you may also choose to not have your data included in the study. Your choice of whether or not to participate will not influence your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research.

QUESTIONS ABOUT THE STUDY: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

This study has been reviewed by the Ryerson University Research Ethics Board. If you have questions regarding your rights as a participant in this study please contact:

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416-979-5042; rebchair@ryerson.ca

Attentional Resources and Associative Memory

CONFIRMATION OF AGREEMENT:

Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to participate in the study and have been told that you can change your mind and withdraw your consent to participate at any time. You have been given a copy of this agreement. You have been told that by signing this consent agreement you are not giving up any of your legal rights.

____
Name of Participant (please print)

____________________________________ __________________
Signature of Participant Date

____________________________________ __________________
Signature of Researcher Date

Appendix D: Debriefing Form in Study 1

Thank you for your participation! This document explains the issues investigated in this study.

Previous research findings suggest that older adults experience more difficulties remembering associations between pieces of information (i.e., associative memory) than young adults (Old & Naveh-Benjamin, 2008). Several factors might play a role in this age difference. First, older adults are less likely than young adults to use effective strategies, such as creating a sentence linking the word pair, when learning associations (Naveh-Benjamin, Brav, & Levy, 2007). Second, older adults are also less likely to engage in recollection-based memory processes, which refer to the remembering of details associated with an experienced event (e.g., remembering where you met your friend; Light, 2002). In real life, older adults often experience a feeling that someone looks familiar, but have difficulty recalling specific details about him/her.

The use of effective strategies and recollection-based memory processes both require attentional resources (Naveh-Benjamin, Craik, Guez, & Kreuger, 2005; Yonelinas, 2002), which can be defined as a pool of "mental energy" used to complete mental activities at the present moment. Attentional resources decline with age, and also when one's attention is divided (e.g., it is hard to complete two difficult tasks at the same time). It is not clear, however, whether older adults are less likely than young adults to use effective strategies and recollection-based memory processes in associative memory tasks because of a lower availability of attentional resources. This study was designed to investigate this possibility.

In this study, we included two groups of young adults and one group of older adults. All participants completed a memory task in which they learned pairs of words for later memory tests. One group of young adults completed the memory tasks while simultaneously engaging in a digit comparison task, as a means to divide their attention and to limit the availability of attentional resources devoted to the memory task. Specifically, these participants saw two numbers appearing on the computer screen underneath the word pair. They were asked to indicate which number was bigger, while learning the word pairs at the same time. The remaining participants completed the memory task alone without distraction. Participants' associative memory performance, as well as their use of recollection-based memory processes could be derived from their responses in the two memory tests. Their use of strategies during the learning phase was measured using a questionnaire.

We predicted that young adults who completed the memory task while completing the digit comparison task will perform similarly as older adults in the memory task. Specifically, in comparison to young adults completing the same memory task under full attention, these participants will be less likely to use effective strategies during the learning phase, and to use recollection-based memory processes less often. As a result, they will show poorer associative memory than young adults under full attention.

For more information, you can consult the following sources:

Light, L. L. (2012). Dual-process theories of memory in old age: An update. In M. Naveh-Benjamin & N. Ohta (Eds.), *Memory and Aging: Current Issues and Future Directions* (pp. 97-124). New York: Psychology Press.

Old, S. R. & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging, 23*(1), 104-118. doi: 10.1037/0882-7974.23.1.104

Feel free to contact the investigator, Brenda Wong, at (416) 979-5000 ext. 4987 if you have any questions regarding this project.

If you having questions regarding your rights as a human subject in this study, you may contact the Ryerson University Research Ethics Board: Lynn Lavallée, Ph.D., Chair, Research Ethics Board at (416) 979 5000 ext. 4791 or lavallee@ryerson.ca.

Appendix E: Consent Forms in Study 2

Consent Form for Young Adults from SONA (Study 2)

Ryerson University
Consent Agreement

Age Differences in Item and Associative Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

Investigators: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto.

Purpose of the Study: The purpose of this cognitive study is to examine age differences in memory for pieces of information and the associations between them. 24 young adults enrolled in PSY 102/202 at Ryerson University and from the community will be invited to participate in this research. 24 older adults will also be recruited from the community. The results of this study will contribute to a dissertation.

Description of the Study: If you decide to participate in the research, your visit will last approximately 60 minutes. During your visit, you will be asked to do the following: Read and sign a consent form, complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember individual words, as well as the associations between these words. Your memory for the words and the associations between them will be tested in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood, vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.

What is Experimental in this Study: None of the procedures used in this study is experimental in nature – they have all been used by other researchers and found to be useful experimental procedures. However, part of this study is considered "experimental". By following the procedure described above, the study examines the impact of one variable (called the "independent variable"; e.g., aging) on another variable (called the "dependent variable"; e.g., memory). More information about the independent and dependent variables will be provided at the end of the session.
Risks or Discomforts: This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a

typical day. Participants may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your participation credit.

Benefits of the Study:
There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. Participants may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: You will receive 1 participation credit to use towards your PSY 102/202 course at Ryerson. If you would prefer to 'walk through' the study (that is, if you would like to observe the research process but not provide any personal data), you will still be given the 1 credit assuming you have not already received the maximum allotted for research participation in a given term.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your grades or academic status. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be given your 1 credit.

Data Storage and Dissemination of Results
The data from this study will be held in a locked cabinet in a locked laboratory and saved on a password-protected computer for up to 10 years. After this period, the data will be destroyed. It is possible that a third party (e.g., graduate students, senior undergraduate students) may have access to the data for a purpose that was not originally identified in this study. As well, results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

If you any have questions about receiving your Psychology 102/202 credit for participation, please contact: thepool@psych.ryerson.ca.

<u>Agreement:</u> Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

______________________________ _________________________

Signature of Participant Date

______________________________ _________________________

Signature of Investigator Date

Consent Form for Young Adults from the Community (Study 2)

Ryerson University
Consent Agreement

Age Differences in Item and Associative Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

Investigators: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto.

Purpose of the Study: The purpose of this cognitive study is to examine age differences in memory for pieces of information and the associations between them. 24 young and 24 older adults will be recruited for this study. The results of this study will contribute to a dissertation.

Description of the Study: If you decide to participate in the research, your visit will last approximately 60 minutes. During your visit, you will be asked to do the following: Read and sign a consent form, complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember individual words, as well as the associations between these words. Your memory for the words and the associations between them will be tested in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood, vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.

Risks or Discomforts: This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. Participants may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your compensation.

Benefits of the Study:
There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. Participants may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: As an appreciation for your time and effort, you will receive $10 for your participation in this study.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be fully compensated.

Data Storage and Dissemination of Results
The data from this study will be held in a locked cabinet in a locked laboratory and saved on a password-protected computer for up to 10 years. After this period, the data will be destroyed. It is possible that a third party (e.g., graduate students, senior undergraduate students) may have access to the data for a purpose that was not originally identified in this study. As well, results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

______________________________ ________________________
Signature of Participant Date

______________________________ ________________________
Signature of Investigator Date

Consent Form for Older Adults (Study 2)

Ryerson University
Consent Agreement

Age Differences in Item and Associative Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

<u>Investigators</u>: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto.

<u>Purpose of the Study</u>: The purpose of this cognitive study is to examine age differences in memory for pieces of information and the associations between them. 24 young and 24 older adults will be recruited for this study. The results of this study will contribute to a dissertation.

<u>Description of the Study:</u> If you decide to participate in the research, your visit will last approximately 90 minutes. During your visit, you will be asked to do the following: Read and sign a consent form, complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember individual words, as well as the associations between these words. Your memory for the words and the associations between them will be tested in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood, attention and memory, vocabulary skills, as well as your experience during the testing session. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study.

<u>Risks or Discomforts:</u> This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. Participants may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your compensation.

<u>Benefits of the Study:</u>
There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. Participants may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: As an appreciation for your time and effort, you will receive $15 for your participation in this study.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be fully compensated.

Data Storage and Dissemination of Results
The data from this study will be held in a locked cabinet in a locked laboratory and saved on a password-protected computer for up to 10 years. After this period, the data will be destroyed. It is possible that a third party (e.g., graduate students, senior undergraduate students) may have access to the data for a purpose that was not originally identified in this study. As well, results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

______________________________ _________________________
Signature of Participant Date

______________________________ _________________________
Signature of Investigator Date

Appendix F: Debriefing Form in Study 2

Thank you for your participation! This document explains the issues investigated in this study.

Previous research findings suggest that older adults experience more difficulties remembering associations between pieces of information (i.e., associative memory) than young adults (Old & Naveh-Benjamin, 2008). One possible explanation for this age difference is older adults' declines in attentional resources, which can be defined as a pool of "mental energy" used to complete mental activities at the present moment (Craik & Bryd, 1982). In one study, young participants were asked to learn pairs of words while completing another task simultaneously (Kim & Giovanello, 2011). This manipulation divided their attention and drained their attentional resources. As a result, young adults' associative memory performance was comparable to that of older adults.

In typical experiments on associative memory (e.g., Naveh-Benjamin, 2000), young and older participants are shown pairs of words and are asked to memorize the words as well as the associations between them at the same time. Learning of individual words and studying their associations both require attentional resources (Dennis, Turney, Webb, & Overman, 2015). Moreover, it is arguable that learning of associations follows the learning of individual items. For example, we need to study the words "clown" and "paper" before we can memorize that these two words go together as a pair. In this case, one would expect attentional resources to be spent on learning of items before leftover resources could be allocated to learning of associations. That being said, resources for associative encoding might be especially scarce for older adults in comparison to young adults.

The purpose of the study is to examine whether young and older adults' associative memory could be improved by learning items and associations separately. In each memory trial, participants were asked to study each word in a word pair individually first. Next, the two words in each word pair were presented together on the screen, and at this time participants were asked to put the two words together in memory. Young and older adults' associative memory performance in this study would be compared with results from a previous study conducted in our lab, in which young and older adults studied the same word pairs without the opportunity to learn each individual word before learning the associations between them.

We are predicting that having the opportunity to learn individual words first should free up attentional resources for the later associative learning phase, during which participants will only need to focus on remembering the associations between the words. Hence, participants who are given prior exposure to the individual words are predicted to show better associative memory than those without this exposure. This effect might benefit older adults more than young adults, given that older adults have lower availability of attentional resources than young adults when learning associations.

For more information, you can consult the following sources:

Dennis, N. A., Turney, I. C., Webb, C. E., & Overman, A. A. (2015). The effects of item familiarity on the neural correlates of successful associative memory encoding. *Cognitive, Affective, & Behavioural Neuroscience.* Advance online publication. doi: 10.3758/s13415-015-0359-2

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging, 23*(1), 104-118. doi: 10.1037/0882-7974.23.1.104

Feel free to contact the investigator, Brenda Wong, at brendaiok.wong@psych.ryerson.ca or (416) 979-5000 ext. 4987 if you have any questions regarding this project.

If you having questions regarding your rights as a human subject in this study, you may contact the Ryerson University Research Ethics Board: Lynn Lavallée, Ph.D., Chair, Research Ethics Board at (416) 979 5000 ext. 4791 or rebchair@ryerson.ca.

Appendix G: Consent Forms in Study 3

Consent Form for Young Adults from SONA (Study 3)

Ryerson University
Consent Agreement

Age Differences in Value-Directed Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

Investigators: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto. The results of this study will contribute to the partial fulfillment of the dissertation of Brenda Wong.

Purpose of the Study: The purpose of this cognitive study is to examine age differences in memory for associations between pieces of information. 24 young adults (ages 17 to 29) enrolled in PSY 102/202 at Ryerson University and from the community will be invited to participate in this research. 24 older adults (ages 65 to 77) will also be recruited from the community.

Description of the Study: If you decide to participate in the research, your visit will last approximately 60 minutes. During your visit, you will be asked to do the following: Read and sign the consent form, and complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember pairs of words, and then to recognize these word pairs in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood and vocabulary skills. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study. This study is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC).

What is Experimental in this Study: None of the procedures used in this study is experimental in nature – they have all been used by other researchers and found to be useful experimental procedures. However, part of this study is considered “experimental”. By following the procedure described above, the study examines the impact of one variable (called the “independent variable”; e.g., aging) on another variable (called the “dependent variable”; e.g., memory). More information about the independent and dependent variables will be provided at the end of the session.

Risks or Discomforts: This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. You may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your participation credit.

Benefits of the Study: There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. You may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: You will receive 1 participation credit to use towards your PSY 102/202 course at Ryerson. If you would prefer to 'walk through' the study (that is, if you would like to observe the research process but not provide any personal data), you will still be given the 1 credit assuming you have not already received the maximum credits allotted for research participation in a given term.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your grades or academic status. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be given your 1 credit.

Data Storage and Dissemination of Results: Data on the computer will be transported with an encrypted USB key and will be stored on Ryerson computers that are password protected. Paper-and-pencil questionnaire data will be held in a locked cabinet in a locked laboratory. All data will be stored for up to 10 years. After this period, the data will be destroyed. Results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University, 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

If you any have questions about receiving your Psychology 102/202 credit for participation, please contact: thepool@psych.ryerson.ca.

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

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Signature of Participant Date

______________________________ ____________________________

Signature of Investigator Date

Consent Form for Young Adults from the Community (Study 3)

Ryerson University
Consent Agreement

Age Differences in Value-Directed Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

<u>Investigators</u>: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto. The results of this study will contribute to the partial fulfillment of the dissertation of Brenda Wong.

<u>Purpose of the Study</u>: The purpose of this cognitive study is to examine age differences in memory for associations between pieces of information. 24 young (ages 17 to 29) and 24 older adults (Ages 65 to 77) will be recruited for this study.

<u>Description of the Study:</u> If you decide to participate in the research, your visit will last approximately 60 minutes. During your visit, you will be asked to do the following: Read and sign the consent form, and complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember pairs of words, and then to recognize these word pairs in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood and vocabulary skills. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study. This study is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC).

<u>Risks or Discomforts</u>: This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. You may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your compensation.

<u>Benefits of the Study</u>: There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. You may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: As an appreciation for your time and effort, you will receive $12 for your participation in this study.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be fully compensated.

Data Storage and Dissemination of Results: Data on the computer will be transported with an encrypted USB key and will be stored on Ryerson computers that are password protected. Paper-and-pencil questionnaire data will be held in a locked cabinet in a locked laboratory. All data will be stored for up to 10 years. After this period, the data will be destroyed. Results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

______________________________ ________________________
Signature of Participant Date

______________________________ ________________________
Signature of Investigator Date

Consent Form for Older Adults (Study 3)

Ryerson University
Consent Agreement

Age Differences in Value-Directed Learning

You are being asked to participate in a research study. Before signing this consent form, it is important that you read the following information. You may ask as many questions as necessary to be sure that you understand what the study entails.

Investigators: Brenda Wong (PhD Student; Principle Investigator) and Dr. Lixia Yang (Graduate Supervisor), Department of Psychology, Ryerson University, Toronto. The results of this study will contribute to the partial fulfillment of the dissertation of Brenda Wong.

Purpose of the Study: The purpose of this cognitive study is to examine age differences in memory for associations between pieces of information. 24 young (ages 17 to 29) and 24 older adults (ages 65 to 77) will be recruited for this study.

Description of the Study: If you decide to participate in the research, your visit will last approximately 90 minutes. During your visit, you will be asked to do the following: Read and sign the consent form, and complete a computerized memory task and several paper-and-pencil questionnaires. During the computer task, you will be asked to remember pairs of words, and then to recognize these word pairs in two recognition tasks. Detailed instructions and practice trials will be provided to familiarize you with the task. The paper-and-pencil questionnaires will be used to assess your mood, attention and memory, and vocabulary skills. Some basic demographic and health information will also be collected on a background questionnaire (e.g., age, gender, education level, medication use, and health condition) to help us understand the factors that might affect the results of this study. At the end of the study, you will be debriefed and compensated for your participation. Research findings (i.e., group results) will be available to you upon request, and will be sent to you via email or mail after the completion of the study. The study is funded by the Natural Sciences and Engineering Research Council of Canada (NSERC).

Risks or Discomforts: This is a minimal risk study. However, some minor risks may include fatigue and discomfort from answering some questions given their personal nature. Discomfort, if any, is expected to be temporary and should not be greater than what you may experience in a typical day. You may choose to refuse to participate in any aspect of the research (e.g., responding to questionnaire items). You will also be offered to take breaks throughout the testing session. If any aspect of this study makes you feel uncomfortable, you may temporarily or permanently discontinue your participation and still receive your compensation.

Benefits of the Study: There is no direct benefit to participants in this study. However, the information gained from the overall study may improve scientific knowledge in aging and memory. You may also learn about psychological experiments and the effect of aging on memory. When the session is over, we will describe the purpose and hypotheses of the study to you in more detail.

Confidentiality: You will be asked to print and sign your name on this consent form. This consent form and the background questionnaire will be filed separately from your other paper-and-pencil questionnaires. Your name or any other identifiable information will not appear on any other paper-and-pencil questionnaires. Your responses in this study will be confidential. A unique ID will be used on all testing materials and there will be no way of linking your responses with your identity.

Incentives to Participate: As an appreciation for your time and effort, you will receive $18 for your participation in this study.

Voluntary Nature of Participation: Participation in this study is voluntary. Your choice of whether or not to participate will not affect your future relations with Ryerson University or with the investigators, Brenda Wong and Dr. Lixia Yang, involved in the research. If you decide to participate, you are free to withdraw your consent and to stop your participation at any time without penalty or loss of benefits to which you are allowed. Should you withdraw from the study, you will still be fully compensated.

Data Storage and Dissemination of Results: Data on the computer will be transported with an encrypted USB key and will be stored on Ryerson computers that are password protected. Paper-and-pencil questionnaire data will be held in a locked cabinet in a locked laboratory. All data will be stored for up to 10 years. After this period, the data will be destroyed. Results may be shared with others at scholarly meetings or as part of published papers. However, all information will be presented in aggregate form. That is, none of your individual information will be identifiable in any way. Anonymized data may be provided to other researchers for the purpose of study or verification of results; any data that is shared will NOT include the names of ANY participants.

Questions about the Study: If you have any questions about the research now, please ask. If you have questions later about the research, you may contact: Brenda Wong, PhD Student, at brendaiok.wong@psych.ryerson.ca or call (416) 979-5000 ext. 4987. You may also contact the supervisor of this study, Dr. Lixia Yang, at lixiay@psych.ryerson.ca or call (416) 979-5000 ext. 6522.

If you have any questions regarding your rights as a human subject and participant in this study, you may contact the Ryerson University Research Ethics Board: Ryerson Ethics Board, c/o Office of the Vice President, Research and Innovation, Ryerson University 350 Victoria Street Toronto, ON M5B 2K3, 416-979-5042, rebchair@ryerson.ca.

Agreement: Your signature below indicates that you have read the information in this agreement and have had a chance to ask any questions you have about the study. Your signature also indicates that you agree to be in the study and have been told that you can change your mind any time during the study and withdraw from it. You have been given a copy of this agreement.

You have been told that by signing this consent agreement, you are not giving up any of your legal rights.

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Name of Participant (please print)

______________________________ ______________________________
Signature of Participant Date

______________________________ ______________________________
Signature of Investigator Date

Appendix H: Debriefing Form in Study 3

Thank you for your participation! This document explains the issues investigated in this study.

Previous research findings suggest that older adults experience more difficulties remembering associations between pieces of information (i.e., associative memory; for example, putting a face and a name together in memory) than young adults (Old & Naveh-Benjamin, 2008). One possible explanation for this age difference is older adults' declines in attentional resources, which can be defined as a pool of "mental energy" used to complete mental activities at the present moment (Craik & Bryd, 1982). In one study, young participants were asked to learn pairs of words while completing another task at the same time (Kim & Giovanello, 2011). This manipulation divided their attention and drained their attentional resources. As a result, young adults' associative memory performance was comparable to that of older adults. Previous research suggests that older adults are able to compensate for their declines in memory by being strategic in directing their limited attentional resources to information that is important to them, instead of spending their resources on remembering everything. To illustrate, older adults have been found to evaluate the value (i.e., importance) of the to-be-remembered information, and show better memory for words with higher-value than words with lower-value (e.g., Castel, 2007). However, there is still relatively limited research on the role of value in memory for associations between pieces of information, such as pairs of words.

The purpose of this study is to examine whether older adults could also direct their attentional resources to selectively remember high-value word pairs over low-value word pairs, and remember these high-value word pairs as well as young adults. During the study phase, young and older participants were asked to study pairs of words that were each assigned with a point value, with some point values higher than others (e.g., 10 vs. 2 points). Participants would receive the associated points if they could remember the exact word pairs at the recognition tests. The goal of the task was to remember as many word pairs as possible, while maximizing the points received at the recognition tests at the same time.

We are predicting that given older adults' limited availability of attentional resources, they will likely spend more attentional resources to remember higher-value word pairs than lower-value pairs, and show better memory for these high-value word pairs. Moreover, their memory for these pairs is expected to be similar to young adults' performance. The findings of this study will inform whether older adults are able to selectively remember associative information that is important to them, as well as the optimal way to deliver information to elderly. For instance, we may focus on the importance of the information so that older adults will be better able to devote their resources to remember it.

For more information, you can consult the following sources:

Castel, A. D. (2007). The adaptive and strategic use of memory by older adults: Evaluative processing and value-directed remembering. *The Psychology of Learning and Motivation, 48,* 225-270. doi: 10.1016/S0079-7421(07)48006-9

Old, S. R., & Naveh-Benjamin, M. (2008). Differential effects of age on item and associative measures of memory: A meta-analysis. *Psychology and Aging, 23*(1), 104-118. doi: 10.1037/0882-7974.23.1.104

Feel free to contact the investigator, Brenda Wong, at brendaiok.wong@psych.ryerson.ca or (416) 979-5000 ext. 4987 if you have any questions regarding this project.

If you having questions regarding your rights as a human subject in this study, you may contact the Ryerson University Research Ethics Board: Lynn Lavallée, Ph.D., Chair, Research Ethics Board at (416) 979 5000 ext. 4791 or rebchair@ryerson.ca.

References

Anderson, N. D., Craik, F. I. M., & Naveh-Benjamin, M. (1998). The attentional demands of encoding and retrieval in younger and older adults: 1. Evidence from divided attention costs. *Psychology and Aging, 13,* 405-423. doi: 10.1037/0882-7974.13.3.405

Anderson, N. D., Iidaka, T., Cabeza, R., Kapur, S., McIntosh, A. R., & Craik, F. I. M. (2000). The effects of divided attention on encoding- and retrieval-related brain activity: A PET study of younger and older adults. *Journal of Cognitive Neuroscience, 12,* 775-792. doi: 10.1162/089892900562598

Ariel, R., Price, J., & Hertzog, C. (2015). Age-related associative memory deficits in value-based remembering: The contribution of agenda-based regulation and strategy use. *Psychology and Aging, 30,* 795-808. doi: 10.1037/a0039818

Badham, S. P., Estes, Z., & Maylor, E. A. (2012). Integrative and semantic relations equally alleviate age-related associative memory deficits. *Psychology and Aging, 27*, 141-152. doi: 10.1037/a0023924

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