A New Approach to Improving Metamemorial Control in Older Adults

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Abstract

Metamemory is composed of two distinct but interconnected processes: monitoring and control. Monitoring, or the self-awareness of one's own memory, has been known to influence later control processes. Research suggests that older adults frequently exhibit age-related deficits in metamemorial control in spite of their accurate monitoring. In this dissertation, a reduced cognitive resource hypothesis is proposed in order to explain age-related deficits in control efficiency. The hypothesis suggests that cognitively taxing tasks that consume resources prior to control may result in fewer resources at the time of control in older adults. Across the four experiments, I examined the relationship between cognitive burden and effective control in older adults. Experiment 1 tested the hypothesis that metamemorial control following an episodic memory task would be more cognitively demanding as compared to that following a semantic memory task. Experiment 2 tested the hypothesis that explicit monitoring would place a burden on cognitive resources, resulting in deficits in control. In Experiment 3, I hypothesized that cognitive resources would be related to control when study time was limited. In Experiment 4, I hypothesized that presenting specific goals would reduce cognitive burden and result in effective control in older adults. Across the four experiments, older adults spent more time studying information than young adults; however, this extra time did not translate into greater memory improvement in older adults. In Experiment 1, more efficient study time allocation was found in semantic memory tasks as compared to episodic memory tasks in both young and older adults. In Experiment 2, explicit monitoring eliminated age-related differences in study time allocation, contrary to my original hypothesis. When cognitive resources were directly measured using a battery of psychometric tests, cognitive resources did not correlate with control efficiency. In Experiment 3, age-related differences were found in correlations between study time and cognitive resources only when study time was limited. In Experiment 4, age-related differences in study time allocation diminished when specific goals were presented. Additionally, both age groups were able to strategically learn more valuable information. These findings have implications for understanding the impact of cognitive resources on metamemorial control in older adults.

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Dedication

This dissertation is dedicated to the memory of my Dad, Jong-Hyun Lee, Ph.D., who always believed in me and supported me throughout my life.

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A New Approach to Improving Metamemorial Control in Older Adults

Metacognition refers to the self-awareness and self-regulated processes of one's own cognition (Nelson, 1996; Nelson & Narens, 1990). As a subcategory of metacognition, metamemory encompasses monitoring what one does and does not remember, and controlling one's own learning behavior to manage and compensate for monitored discrepancies in learning. Metamemory plays an important role in our daily lives. Effective metamemory can result in successful learning. For example, if an elderly person recognizes that she cannot remember whether she has taken her daily medication (monitoring), she may need to use more effective strategies in order to keep track of her intake, such as noting on a calendar that her daily dose has been ingested (control). In fact, older adults consistently report their forgetfulness in daily life: they reported forgetting recently learned information; they reported the need to reread the sentences that they had read only a few minutes ago; they reported experiencing a "tip-of-the tongue" effect, i.e., they could not articulate a word in spite of their strong feeling of knowing it (Hertzog & Hultsch, 2000; Hertzog, Lineweaver, & McGuire, 1999; Ossher, Flegal, & Lustig, 2013). These age-related reported memory failures suggest that older adults are aware of their relatively impaired memory ability in their daily life (Bender & Raz, 2012; Crumley, Stetler, & Horhota, 2014). Subjective reports of memory difficulties complement experimentally determined accurate metacognitive monitoring in a laboratory setting (Hertzog, Sinclair, & Dunlosky, 2010; Robinson, Hertzog, & Dunlosky, 2006; Thomas, Lee, & Balota, 2013).

Theoretically, metacognition and cognition interact with each other. That is, the meta-processes monitor ongoing cognitive processes and controlling cognition (Nelson, 1996; Van Overschelde, 2008). According to a model proposed by Nelson and Narens (1990), information related to one's own cognition flows from an object-level (cognition including memory) to a meta-level (metacognition) when individuals monitor their cognitive activities. The information relayed via these cognitive processes also flows from the meta-level to the object-level when they control their cognition (see also Dunlosky & Bjork, 2008b; Nelson, 1996; Van Overschelde, 2008). Thus, monitoring of the object-level by the meta-level results in control of the object-level by the meta-level. Additionally, the sub-processes of the meta-level interact. Specifically, research suggests that monitoring influences control (i.e. monitoring-affects-control hypothesis, Nelson & Leonesio, 1988). Thus, both accurate monitoring judgments and effective control are crucial to improve memory retention (Metcalfe & Finn, 2008; Thiede, Anderson, & Therriault, 2003; Tullis & Benjamin, 2011). However, older adults frequently demonstrated deficits in metamemorial control processes in spite of their relatively accurate monitoring (e.g. Dunlosky & Hertzog, 1997).

Reduced Cognitive Resource Hypothesis

This dissertation examines age-related differences in metamemorial control, or processes that are often executed after monitoring, and its influence on the accuracy of memory. In particular, I test the hypothesis that age-related changes in cognitive resources account for these often-found age-related deficits in metamemorial control. Fluid cognitive resources, or processing resources, can be defined as a limited amount of resources that are necessary in order to successfully engage in cognitive tasks (Salthouse, 1990). Cognitive resources include speed of information processing and working memory capacity (Baltes, Lindenberger, & Staudinger, 2006; Rast, 2011; Salthouse, 1996). Cognitive resources have been shown to highly correlate with executive functioning (McCabe, Roediger, McDaniel, Balota, & Hambrick, 2010). Research also suggests that normal aging is associated with diminished cognitive resources (Anderson & Craik, 2000; Bender & Raz, 2012; Craik & Byrd, 1982; Hess, 2014; Salthouse, 1988).

In the present study, I postulate that age-related deficits in metamemorial control are the direct result of a reduction of necessary cognitive resources caused by cognitive processes that occur prior to the implementation of control (i.e. reduced cognitive resource hypothesis). As depicted in Figure 1, cognitive resources are consumed by initially encoding new information, storing and retrieving the information, providing monitoring judgments, and engaging in control. Researchers have demonstrated that cognitive resources affect initial learning and retrieval of material (Bryan, Luszcz & Pointer, 1999; Fastenau, Denburg, & Abeles, 2004; Rabinowitz, Craik, & Ackerman, 1982; Whiting & Smith, 1997; for a review, see Craik & Rose, 2012), recognition of associated items (Bender & Raz, 2012), and motivation to engage in cognitively taxing tasks (Hess, 2014). In a previous study, using an effective but complex encoding strategy was related to cognitive resources (Bryan et al., 1999). Specifically, participants learned a list of words by generating a story using those words, and took a memory test. The results suggest that after this integration encoding, young adults outperformed older adults in a later memory test. That is, young adults used a complex encoding strategy more effectively than older adults. Further, the effectiveness of encoding correlated with executive functioning and working memory capacity.

Another study suggests that monitoring of future memory correlated with executive functioning (Souchay, Isingrini, Clarys, Taconnat, & Eustache, 2004). Previous studies also suggest that cognitive resources influence metamemorial control (Ariel, 2013, Dunlosky & Thiede, 2004; Stine-Morrow, Shake, Miles, & Noh, 2006; Thiede & Dunlosky, 1999). For example, young adults with fewer cognitive processing resources, as measured by the Operation-Span task (Turner & Engle, 1989), demonstrated less efficient study time allocation than those with greater resources (Dunlosky & Thiede, 2004).

In sum, cognitive resources are necessary for elaborative encoding and effective monitoring. Cognitive resources are necessary for difficult control tasks, such as selecting items to restudy when items were presented individually (Dunlosky & Thiede, 2004). Metamemorial control processes are typically measured after individuals learn new information and provide monitoring judgments. Therefore, the reduced cognitive resource hypothesis postulates that less efficient control processes are observed in older adults because fewer cognitive resources are likely available at the time of control. That is, reduced cognitive resources in older adults and cognitively demanding tasks may negatively influence control efficiency and efficacy in older adults. In this dissertation, great control efficiency can be defined as memory improvement after self-paced learning with less study time, and control efficacy can be defined as memory improvement regardless of efficiency. In the following sections of the general introduction, three major topics related to metamemory in older adults are discussed. First, common measurements for metamemorial monitoring processes and age-equivalent monitoring are outlined according to the memory stages. Second, the factors that influence the efficiency and efficacy of metamemorial control are described. Finally, inconsistent findings regarding age-related differences in metamemorial control are reviewed in the context of the reduced cognitive resources hypothesis.

Metamemorial Monitoring Processes

Accurate monitoring processes are known to be necessary in order to improve one's memory retention. In a previous study, a stronger correlation between monitoring and memory accuracy resulted in greater memory improvement (Thiede et al., 2003). Metamemorial monitoring judgments can be measured using various methodologies, including ease-of-learning (EOL) judgments, judgments-of-learning (JOLs), feeling-of-knowing (FOK) judgments and confidence judgments (Nelson, 1996; Nelson & Narens, 1990). According to the framework for metamemory proposed by Nelson and Narens (1990), these metamemorial judgments are associated with specific stages of memory: encoding, storage, and retrieval. Individuals can determine the easiness of to-be-learned information at the time of encoding (EOL), or make a judgment on the accuracy of their future memory performance during encoding but before retrieval (JOL). They can also determine the likelihood that they will be able to later remember a currently inaccessible target (FOK), or provide confidence ratings after retrieval (confidence) (Leonesio & Nelson, 1990; Nelson & Narens, 1990). Previous studies suggest that older adults are able to accurately predict their future memory performance using EOLs and JOLs (Price & Murray, 2012; Hertzog & Dunlosky, 2011), and FOKs (Hertzog, Dunlosky, & Sinclair, 2010; but see also Souchay & Isingirini, 2004a; Souchay, Isingrini, & Espagnet, 2000). However, accurate monitoring judgments in older adults do not always guarantee their efficient control (Dunlosky & Connor, 1997; Tullis & Benjamin, 2012).

Monitoring during Encoding

EOL judgments occur before or during the encoding of information. Participants are typically asked to assess the levels of ease-and-difficulty for to-be-learned items (Leonesio & Nelson, 1990; Underwood, 1966). In a previous study, before both young and older adults studied an entire set of Spanish-English word pairs, they provided subjective judgments on the difficulty for Spanish words alone (Price, Hertzog, & Dunlosky, 2010). The results suggest that subjective EOL judgments in both age groups were highly correlated with the degree of the similarity between Spanish and English words. That is, subjective EOL judgments were in line with the objective difficulty of the materials. Additionally, EOL judgments correlated with participants' later memory performance. This result suggests that individuals remembered less accurately what they considered to be more difficult, and remembered more accurately what they considered to be less difficult.

For JOLs, individuals predict the likelihood of successfully recalling or recognizing items while they learn information. Typically, participants learn a list of items and provide JOLs either immediately after learning each item (immediate JOLs) or after learning the entire set of items (delayed JOLs). Metamemorial judgments are frequently measured by computing the correlation between a monitoring judgment and memory accuracy of the corresponding item. High correlation between JOLs and memory accuracy indicates a strong relationship between prediction and later memory performance. That is, a correlation close to 1 means that individuals provide a correct answer for the item that they predicted to be correct (Nelson & Narens, 1990). For both immediate and delayed JOLs, the JOLs and the actual memory performance are highly correlated in young adults, implying that individuals are aware of the retrievability of each item (Dunlosky & Nelson, 1992; Rhodes & Tauber, 2011). In addition, age-related differences have not been found for either delayed JOLs (Connor, Dunlosky, & Hertzog, 1997; Hertzog & Dunlosky, 2011) or immediate JOLs (Connor et al., 1997; Hertzog et al., 2010; Robinson et al., 2006; Thomas et al., 2013). As one example, Thomas et al. (2013) found that young and older adults demonstrated a strong relationship between immediate JOLs and memory performance for unrelated cue-target word pairs. To summarize, previous studies using EOL and JOLs suggest that older adults are able to accurately judge their future memory of newly learned materials during encoding.

Monitoring during Storage

In a typical FOK experiment, individuals are asked to provide FOK judgments after a failed retrieval attempt. That is, individuals are asked to assess the likelihood that some items that cannot be presently accessed may nevertheless be stored in memory and accessed on a later test. Participants are frequently required to assess the probability (0 – 100 %) of successfully selecting correct answers in a later recognition test after a retrieval failure (Nelson, 1996, Thomas, Bulevich, & Dubois, 2010). Namely, individuals judge how likely they would be able to correctly remember targets even though they currently cannot recall them. In contrast to EOL and JOL judgments, previous research has often demonstrated age-related differences in the accuracy of FOK judgments (Perrotin, Tournelle, & Isingrini, 2008; Souchay et al., 2000; Souchay, Moulin, Clarys, Taconnat, & Isingrini, 2007; Thomas et al., 2010). As an example, in a previous study, young adults demonstrated a stronger correlation between recognition accuracy and FOK judgments for word pairs than older adults (Souchay et al., 2007). However, previous studies suggest that older adults were able to provide accurate FOK judgments in some circumstances, particularly when cognitive support for initial learning was provided (Hertzog et al., 2010; Thomas et al., 2010). For example, unrelated cue-target word pairs were repeatedly presented in order to support initial encoding for older adults (Hertzog et al., 2010). Participants then took a cued recall test, where the cue words were presented alone and the target words were required to be produced. Participants also provided FOK judgments on how likely they could recognize the correct answer in the later memory test. The results suggest that repeatedly presenting stimuli during initial learning led to more accurate FOK judgments in older adults. Further, age-related differences in FOK accuracy were eliminated. Encouraging older adults to use more effective encoding strategies (e.g. using imagery rather than rote learning in order to remember word pairs) also improved the accuracy FOK judgments in older adults (Hertzog et al., 2010).

Additionally, age differences in FOK judgments accuracy were not found in association with semantic memory tasks (Allen-Burge & Storandt, 2000; Butterfield, Nelson, & Peck, 1988; Eakin, Hertzog, & Harris, 2014; Morson, Moulin, Havelka, & Souchay, 2014; Morson, Moulin, & Souchay, 2015; Souchay et al., 2007). Semantic memory refers to general knowledge about the world, whereas episodic memory includes memories for specific personal events, including a specific time, location, and person involved in such events (Tulving, 1972; Tulving, 1985). It is well known that age-related differences are not present in semantic memory, in contrast to episodic memory. One reason why semantic memory may be less susceptible to age-related cognitive changes is because semantic memory does not require the learner to remember contextual elements. Semantic knowledge does not include contextual details or association to the self (e.g. Balota, Dolan, & Duchek, 2000; Mitchell, 1989; for a recent review, see Umanath & Marsh, 2014). Paralleling age-invariance in semantic memory tasks, metamemory researchers consistently demonstrate age-invariance as it relates to metamemorial monitoring accuracy associated with semantic memory (Souchay et al., 2007).

To summarize, previous research suggests that older adults were able to monitor memory as effectively as young adults when they provided their monitoring judgments before retrieval (EOL and JOLs). Improving the quality of initial encoding or using a semantic memory task improved older adults' ability to provide FOK judgments. Additionally, although age-related differences were often found in FOK prediction accuracy associated with recently learned items (episodic memory), older adults were able to provide accurate FOK judgments on general knowledge (semantic memory). Similar to episodic memory, episodic FOK judgments are likely to be influenced by contextual information, whereas semantic FOK judgments are mostly context-free. Further, poorly encoded episodic information can result in poor episodic FOK judgments (Hertzog et al., 2010). Monitoring of semantic knowledge is not dependent on encoding processes (Souchay et al., 2007). Semantic information can be accessed without conscious recollection of detailed contextual information (Balota et al., 2000; Umanath & Marsh, 2014). That is, retrieving general knowledge does not require information connected to when and how that information was stored. These findings are crucial in the context of the reduced cognitive resources. That is, engaging in semantic memory tasks may not be as cognitively demanding as episodic memory tasks because retrieving semantic memory would require neither to encode new information nor to retrieve specific contextual information (Umanath & Marsh, 2014). The reduced cognitive resource hypothesis postulates that semantic memory tasks may free up more cognitive resources in older adults than episodic memory tasks. This will in turn lead to more effective metamemorial control in semantic memory tasks.

Metamemorial Control

Previous research has used various methodologies to measure the efficiency of metamemorial control, including selectively spending more time studying certain information (Dunlosky & Connor, 1997; Froger, Bouazzaoui, Isingrini, & Taconnat, 2012, Miles & Stine-Morrow, 2004; Nelson & Leonesio, 1988; Son & Kornell, 2008; Tullis & Benjamin, 2011; for a review, see Dunlosky & Ariel, 2011). Previous studies also measured the efficacy of metamemorial control by using different methods, including selecting subsets of items for additional learning (Dunlosky & Hertzog, 1997; Hanczakowski, Zawadzka, & Cockcroft-McKay, 2014; Kornell & Metcalfe, 2006; Tullis & Benjamin, 2012), and choosing effective encoding and/or retrieval strategies to improve memory performance (Van Overschelde, 2008). The efficiency of metamemorial control processes can be determined by considering the time that participants spend on learning and the improvement in their memory accuracy (Tullis &

Benjamin, 2011). As one example of efficient metamemorial control, individuals may devote less time and effort studying to achieve greater gains in memory. The overall efficiency and efficacy of metamemorial control processes appear to be influenced by multiple factors: the level of difficulty of the material to be learned (Metcalfe & Finn, 2008), total available time for study (Kornell & Metcalfe, 2006; Metcalfe, 2009; Son & Metcalfe, 2000), study objectives or goals (Ariel, Dunlosky, & Bailey, 2009; Thiede & Dunlosky, 1999), individual differences in expertise (Metcalfe, 2002), and item display formats (Dunlosky & Thiede, 2004).

Factors that Influence Control

Previous findings suggest that metamemorial control may be driven by item difficulty (Dunlosky & Hertzog, 1998; Metcalfe & Finn, 2008). In metamemorial control tasks, individuals frequently decide to study items according to their subjective judgments of item difficulty (Dunlosky & Hertzog, 1998; Metcalfe, 2009). In certain situations, particularly with unlimited time available, people spend more time studying relatively difficult items and select the most difficult items to study first rather than easier ones (i.e. discrepancy reduction model, Dunlosky & Hertzog, 1998; Thiede & Dunlosky, 1999). That is, when studying information, people attempt to master the most difficult items first in order to reduce the discrepancy between their desire to master this new study material and their current state of mastery, provided there is sufficient time to master items (Dunlosky & Hertzog, 1998; Son & Metcalfe, 2000; Thiede & Dunlosky, 1999). However, given task constraints, including limited time to study or the limited number of items to select for study, individuals cannot master all items. Therefore, individuals need to strategically spend time learning new information. Previous studies suggest that individuals tend to select studying the unknown easier items to master first when given certain time constraints (Metcalfe, 2009), unless they were subject matter experts (e.g. Metcalfe, 2002).

Under time constraints, individuals may want to first learn the items that can be easily mastered, rather than the most difficult items (i.e. the region of proximal learning model, Metcalfe, 2002; Metcalfe & Kornell, 2005). Learning easier unlearned items first may be an efficient strategy to take full advantage of the limited time because the easier items can be mastered with relatively less effort and time, whereas the difficult items may require more effort.

Individuals' internal goals are also known to influence metamemorial control (Ariel et al., 2009; Castel, Murayama, Friedman, McGillivray, & Link, 2013). For example, young adults were asked to maximize point values in a memory test after a self-paced learning (Ariel et al., 2009). With such a goal, individuals often select more valuable items to achieve a task goal regardless of the item difficulty (i.e. the agenda-based regulation model). The agenda-based regulation model suggests that one's internal agenda is developed through the prioritization of items based on criteria to address task constraints (Ariel et al., 2009; Castel et al., 2013; Castel, Balota, & McCabe, 2009). According to this model, individuals develop an agenda, or a specific goal, to select items to study or study longer a certain item in order to successfully and efficiently accomplish task goals. This internal agenda is influenced by task constraints, including a time limit, and does not necessarily follow the subjective or objective item difficulty. For example, in a previous study, young participants studied word pairs with various difficulty levels and different likelihood to be tested (Ariel et al., 2009). Importantly, one group was informed that easy items were more likely to be tested than difficult items, whereas the other group was informed that difficult items were more likely to be tested in a later memory test. The result suggests that both participant groups spent more time studying items with a higher chance of being tested. If participants selected items according to the item difficulty as suggested by the discrepancy reduction model or the region of proximal learning model, participants in both groups would not have demonstrated different metamemorial control processes. Instead, participants attempted to learn as many items as possible in the context of considering the likelihood of what would be tested rather than item difficulty. This result suggests that individuals' specific internal goal to succeed in a cognitive task play a crucial role in metamemorial control.

Finally, previous studies suggest that item display formats influence efficiency of a self-paced learning (Dunlosky & Thiede, 2004; Thiede & Dunlosky, 1999). In studies where study time allocation is used to assess metamemorial control, to-be studied items are often presented sequentially. Sequential presentation may require more cognitive resources than a simultaneous display format. That is, if all items are presented simultaneously, participants may better be able to compare their learning state from one item to another, and effectively spend more time and effort on unknown items, than when items are presented sequentially. On the other hand, if individuals are required to decide which item they would like to study on an item-by-item basis sequentially, they would need to keep track of various factors: task goals, their current learning state, and task constraints, including how many items have been selected and/or how much time remains (Ariel et al., 2009, Experiment 4; Dunlosky & Thiede; 2004; Thiede & Dunlosky, 1999). Therefore, how study materials (e.g. a list of words), are presented also influences the effectiveness of metamemorial control.

Presentation format and agendas have also been shown to interact in older adults. For example, when a list of words was presented simultaneously, older adults were able to strategically select items with higher point values in order to achieve a task goal: accomplishing a maximum total value (Castel et al., 2013). Specifically, even though older adults studied and recalled fewer items in general than younger adults under time constraints, older adults could selectively spend time studying more valuable items. In addition, memory performance of older adults for more valuable information was as accurate as younger adults.

Relationship between Cognitive Resources and Control

Previous research with young adults suggests that individual differences in cognitive resources play a role in the efficiency of the metamemorial control processes, particularly in cognitively demanding tasks (Ariel, 2013; Dunlosky & Thiede, 2004). In a previous study, young participants were required to explicitly provide monitoring judgments and to select a limited number of sequentially presented items for restudying (Dunlosky & Thiede, 2004). The results suggest that young adults with higher working memory capacity engaged in metamemorial control processes more effectively as compared to those with lower working memory capacity. Those young adults with high working memory capacity were able to plan to select a limited number of items to restudy based on their monitoring assessments, execute this plan in order to accomplish a task goal, and improve memory retention even with an item-by-item display format. On the other hand, those with lower working memory capacity were not able to engage in metamemorial control for this complex task as effectively as those with higher working memory capacity (Dunlosky & Thiede, 2004, Experiment 3).

In sum, metamemorial control processes are influenced by individuals' internal agenda to achieve a task goal. Internal agendas are influenced by task constraints, including item difficulty, available time, and item display. As a result, it is crucial for individuals to take into account task constraints, their subjective judgments of difficulty, and memory capacity in order to successfully engage in efficient metamemorial control. Similar to metamemorial monitoring judgments, efficient metamemorial control processes are highly correlated with individuals' cognitive resources, including working memory capacity, speed of processing and executive function (Ariel, 2013; Perrotin, Isingrini, Souchay, Clarys, & Taconnat, 2006; Perrotin et al., 2008; Rhodes & Kelley, 2005; Souchay & Isingrini, 2004a). That is, individuals with more cognitive resources have been shown to engage in more effective metamemorial processes. This also implies that metamemorial processes may require a significant amount of cognitive resources.

Cognitive Resources and Control in Older Adults

Previous research suggests that cognitive resources and metamemorial control are related in young adults (Dunlosky & Thiede, 2004). A relationship between cognitive resource and control in young adults suggest that older adults may demonstrate less effective control than young adults due to reduced cognitive resources. Further, older adults have been shown to rely on similar metamemorial control strategies as young adults. For example, older adults selected difficult items for restudy in an effort to reduce the discrepancy between the learning state and goal state of mastery (Dunlosky & Connor, 1997; Dunlosky & Hertzog, 1997). However, longer study times were less likely to translate into memory gains in older adults as compared to young adults (Dunlosky & Connor, 1997; Tullis & Benjamin, 2012; Souchay & Isingrini, 2004b).

In addition, older adults have been shown to successfully change their metamemorial control strategy when study time is limited, similar to young adults (Price & Murray, 2012). In one study, young, middle-aged, and older participants were asked to learn Chinese-English word pairs, with three different levels of difficulty based on character complexity (Price & Murray, 2012). They first provided EOL judgments on how difficult the Chinese characters appeared to be. During the following study phase, a list of the Chinese-English word pairs with three difficulty levels according to the complexity was simultaneously presented for a limited time (60 s per 6 items). Once participants clicked a Chinese character, they were presented with the entire

Chinese-English word pair. They studied one at a time, and decided when to terminate study. They then took a final memory test. As an index of working memory capacity, participant completed the Listening Span task (Salthouse & Babcock, 1991). Additionally, the Memory Controllability Inventory (Lachman, Bandura, Weaver, & Elliott, 1995) was used to assess memory beliefs on a capability to improve memory. Results showed that participants provided higher EOL judgments for more complex Chinese characters. Results from a listening span task and the Memory Controllability Inventory suggested that individuals with higher working memory capacity and stronger memory beliefs for their memory capacity selected a larger number of complex items to study. Interestingly, older adults spent more time studying objectively and subjectively easier items under time constraints when compared to middle-aged or young adults. Also of interest is the finding that older adults selected fewer items to study than other age groups. Finally, there were no age differences when researchers examined final memory performance only for items selected for restudy. These results suggest that when items were presented simultaneously, older adults were able to effectively learn items under time constraints (Price & Murray, 2012).

This experiment (Price & Murray, 2012) employed different methodologies from other studies that had previously demonstrated less effective metamemorial control in older adults (e.g. Dunlosky & Connor, 1997; Souchay & Isingrini, 2004a; 2004b). First, EOL judgments were used to measure the monitoring process. EOL judgments are made before all items are encoded (e.g. EOL judgments on Chinese characters before learning Chinese-English word pairs). That is, monitoring judgments made in conjunction with encoding may be more cognitively demanding than judgments made prior to encoding of all materials. As a result, EOL may leave resources available for later learning and metamemorial control than any other monitoring judgments.

Second, items were simultaneously presented in an array during the control phase of the experiment. Interestingly, Thiede and Dunlosky (1999) demonstrated that participants selected subjectively difficult items to study when the items were presented sequentially, whereas they selected easier items first when the items were presented simultaneously (see also Dunlosky & Thiede, 2004). Older participants in Price and Murray (2012) may have been able to easily compare item difficulty and select easier items because to-be-learned items were presented simultaneously.

Although older adults are known to accurately predict their future memory performance in typical JOL studies, accurate JOLs do not always guarantee effective metamemorial control (Froger, Sacher, Gaudouen, Isingrini, & Taconnat, 2011; Krueger, 2012; Miles & Stine-Morrow, 2004). In several JOL experiments where participants are given an opportunity to restudy, older adults selected difficult items, but they did not make gains in final memory performance to the same extent as young adults (Dunlosky & Connor, 1997; Dunlosky & Hertzog, 1997; 1998; Froger et al., 2011; Krueger, 2012; Souchay & Isingrini, 2004a; 2004b; Tullis & Benjamin, 2012). These results may indicate less efficient metamemorial control in older adults. However, it also may be premature to make this conclusion. First, possible age-related differences in the quality of initial learning should be considered. If older adults do not encode and store information to the same extent as younger adults, restudying only part of the original items may result in age-related differences in final memory performance. Second, when the task goal is to remember as many items as possible, particularly with task constraints such as limited study time, restudying difficult items rather than easier items may not be an effective strategy. For example, selecting items with lower JOLs would require more time and effort than items with higher JOLs (Dunlosky & Hertzog, 1997). Therefore, when a limited number of items should be selected for restudy or when study time is limited, participants may need to select easier items.

When required to provide FOK judgments, older adults also demonstrated less efficient metamemorial control as compared to young adults (Souchay & Isingrini, 2004b). In Souchay and Isingrini (2004b), participants studied highly related word pairs and took a recall test. Participants also provided FOK judgments by rating the likelihood that the unrecalled items could be recognized. They then restudied the entire set of items in the self-paced learning phase for unlimited time and then took another recall test. The results were similar to previous studies using JOLs (Dunlosky & Hertzog, 1997; Tullis & Benjamin, 2012): both age groups spent more time studying subjectively difficult items with lower FOK judgments relative to those with higher FOK judgments. However, age-related differences were found in the degree of correlation between FOK judgments and study-time allocation. That is, older adults restudied items based on their FOK judgments, but not to the same degree as young adults. Additionally, young adults improved their memory significantly more than older adults.

Research also demonstrated that healthy older adults outperformed older participants with Dementia of the Alzheimer's Type (DAT) in an agenda-based regulation task (Castel et al., 2009). In addition, working memory capacity positively correlated with recall performance of higher valued items for both AD patients and older adults, but not with low valued items. Although research suggests that selectively studying more valuable information is highly correlated with cognitive resources, reduced cognitive resources in older adults may not influence selecting more valuable information. These results suggest that cognitive resources play a crucial role in learning more valuable information strategically; however, older adults may be able to successfully engage in metamemorial control when values of information are varied.

Negative Influence of Monitoring

Although monitoring is crucial for effective control (Nelson, 1997), some research suggests that monitoring may negatively impact metamemorial control (e.g. Krueger, 2012; Stine-Morrow et al., 2006). In a previous study, participants were asked to remember sentences (Stine-Morrow et al., 2006). In an accuracy-emphasized condition, they were asked to remember the content as accurately as possible, whereas in a speed-emphasized condition, they were asked to comprehend the content as quickly as possible. As compared to young adults, older adults spent less time than young adults in the accuracy-focused condition, but spent more time in the speed-emphasized condition. These ineffective allocations of study time led to less memory improvement in older adults. Interestingly, age-related differences in study time allocation disappeared when participants provided judgments-of-interest by indicating how interesting the sentence was, rather than JOLs by indicating how likely they would recall the information (Stine-Morrow et al., 2006). These results imply that providing subjective judgments on memory performance may lead to the consumption of more cognitive resources, and leave fewer cognitive resources available at the time of metamemorial control processes (Figure 1.).

Additionally, confidence judgments also have been shown to reduce the efficacy of restudy (Krueger, 2012). In one study, all participants studied a list of difficult Swahili-English word, and took a cued recall test with the Swahili words as cues. Next, half of participants were presented with the entire set of word pairs, and provided confidence judgments on whether or not they correctly recalled the item on the previous test, whereas the other group did not provide judgments. All participants then restudied items in the self-paced learning trial, and took another cued-recall test. The results showed that older adults recalled fewer items than young adults on the final cued-recall test, and both age groups spent more time restudying items incorrectly recalled on the first cued-recall test. Interestingly, both young and older participants who provided confidence judgments performed worse on the second recall test as compared to those who did not provide monitoring judgments. Although there were no differences in study time allocation, less accurate memory performance after self-paced learning suggests that engaging in the monitoring process disrupted restudy.

Overview of Present Study

In this dissertation, I propose and test a framework for understanding age-related changes in metamemorial control. According to the reduced cognitive resource hypothesis, initial learning, monitoring of learning, remembering specific task goals, and implementation of control processes to support learning, all draw upon the same pool of cognitive resources. Thus, older adults may demonstrate deficits in metamemorial control because these finite resources have been depleted from processes employed during initial learning and monitoring.

Previous studies suggest that small changes to experimental methodology may have large consequences on the kinds of cognitive processes and amount of cognitive resources used. Although the ability to restudy new material is beneficial to long-term retention, older adults may not be able to effectively implement successful restudy strategies, because preceding tasks of new learning, and monitoring of that learning may impact the cognitive resources required for successful subsequent strategy selection. In Experiment 1, I compared metamemorial control processes on episodic tasks and semantic memory tasks in the format of general knowledge questions. A semantic memory task using general knowledge is expected to be cognitively less demanding because semantic memory requires neither remembering contextual information nor making the effort required to encode new information. Older adults should exercise more effective control in the semantic as compared to the episodic task. In Experiment 2, the influence of explicit monitoring processes on metamemorial control was investigated in both young and older adults. A participant group who provided monitoring judgments was compared with a group who did not provide explicit judgments. I tested the hypothesis that cognitively demanding monitoring judgments would result in less effective metamemorial control in older adults. In Experiment 3, both young and older adults were required to study general knowledge of varying difficulty levels. Study time limits were also manipulated. Older adults were expected to use available time less efficiently as compared to young adults when study time was unlimited. I hypothesized that age differences would be found in correlations between cognitive resources and study time allocation when study time was limited. Finally, in Experiment 4, the influence of internal agendas on the efficiency of control was explored. General knowledge topics were presented simultaneously for study. Specific topics were assigned different point values. Thus, Experiment 4 examined the influence of simultaneous display and goal setting on metamemorial control. I hypothesized that presenting specific agenda (i.e. different point values) would lead to efficient metamemorial control in older adults.

Experiment 1

The goal of Experiment 1 was to investigate whether using a semantic memory task would result in more efficient metamemorial control process in older adults as compared to an episodic memory task. Based on the previous findings on relatively accurate semantic memory in both young and older adults (Umanath & Marsh, 2014), the use of general knowledge questions is expected to reduce older adults' cognitive load, thereby freeing up cognitive resources for metamemorial control process. In Experiment 1, participants first answered general knowledge questions and made feeling-of-knowing (FOK) judgments. Following that, participants engaged in a self-paced learning task. Episodic and semantic memory tasks were compared. That is, performance in memory, monitoring, and control were examined for real general knowledge questions (e.g. "In what park is 'Old Faithful' located?"), and fake questions for which participants could not have prior knowledge (e.g. "What is the last name of the singer who popularized a dance known as the 'shake'?").

I hypothesized that a semantic memory task would require fewer cognitive resources than an episodic memory task. Therefore, older adults would have more cognitive resources available when they are asked to study information in the context of an unlimited time study session (i.e. self-paced learning task). I predicted that participants would learn more of the real general knowledge information than fake information, based on the previous findings on accurate semantic memory (Umanath & Marsh, 2014). I also hypothesized that both young and older adults would demonstrate a similar level of the FOK accuracy for real general knowledge (Souchay et al., 2007; Morson et al., 2014). Additionally, I expected that both young and older adults would focus on studying more difficult items (i.e. fake general knowledge, or real general knowledge with lower FOK judgments) in the context of an unlimited time study session (Dunlosky & Hertzog, 1997). Finally, older adults were expected spend more time studying items on average in self-paced learning (Dunlosky & Connor, 1997).

Method

Participants.

Thirty-three older adults (ages between 65 and 87, M= 75.93, SD= 7.28) from the older participant pool in the Cognitive Aging and Memory Lab at Tufts University participated in Experiment 1. They were recruited from local areas near Tufts University in Massachusetts, and given a monetary compensation for their participation ($15 per hour). Older adults were prescreened for medication usage, previous head injuries and dementia. After prescreening, the participants were screened again using the Mini-Mental Status Examination (MMSE; Folstein, Folstein, & McHugh, 1975). The participants who scored at least 27 out of 30 were deemed sufficiently cognitively healthy to participate (*M*= 29.03). Two participants with lower than 27 scores in MMSE were included in the data analysis because their performance on memory and metamemory tasks fell within three standard deviations. Thirty-one young adults (age between 18 and 20, *M*= 18.83) participated in Experiment 1. They were recruited either through introductory courses and received experimental credit or from the Tufts University website and received payment for their participation ($10 per hour). Both young and older adults took a vocabulary test from the Shipley Institute of Living Scale (Shipley, 1940), where older adults outperformed young adults, $t(61) = -2.27$, $p < .05$, $d = .58$. Demographics of participants are listed in Table 1.

Design and Materials.

Experiment 1 used a 2 (Age: Young, Older) x 2 (Item Type: Real, Fake general knowledge questions) mixed factorial design, where Age was a between-group variable and Item Type was a within-group variable. One hundred general knowledge questions from Nelson and Narens (1980) were included in this experiment (e.g. "What is the name of the bird that cannot fly and is the largest bird on earth?"). Nelson and Narens (1980) provided information for the probability to recall and median FOK judgments for each general knowledge question. Among the items, those with a medium level of the probability to recall were included in the present study (M= .59) in order to ensure that participants learn the items at some point but possibly could not recollect the information. Additionally, 24 completely fictitious general knowledge questions (e.g. "What is the last name of the singer who popularized a dance known as the 'shake'?") were selected from Berger and Buhrick (1989). Encoding answers to fake general knowledge questions during a study phase can be considered an episodic memory task because prior learning and existing knowledge of these fake facts would not exist. Comparing metamemorial control in the episodic and semantic memory tasks allowed for the investigation of cognitive resources associated with new encoding in the episodic task with those associated with reactivation of previously learned material in the semantic task.

Procedure.

Young adults were tested in groups ranging from two to four. Older adults were tested individually. A research assistant entered answers for older adults on the computer whereas young adults independently entered answers because older adults found uncomfortable to use a computer. At the beginning of the experiment, participants provided demographic information after giving informed consent. The E-prime software (Version 2.0) was used in order to conduct the general knowledge experiment (Schneider, Eschman, & Zuccolotto, 2002). The experiment was divided into three phases. In the first phase, one hundred real and 24 fake general knowledge questions were presented in a random order. Each of the questions was followed by the question for FOK judgments, i.e., "How likely do you think you can select the correct answer in a later multiple-choice test?" Participants were asked to provide FOK ratings on a scale from zero to 100. FOK responses were required for all questions regardless of whether answers were correct, incorrect, or omitted.

In the second phase, participants were asked to engage in self-paced learning. Questions that participants provided correct answers for and 100% FOK ratings in the first phase were excluded in Phase 2. Out of remaining real general knowledge questions, 24 randomly-selected questions were also excluded in Phase 2 for the purpose of examining FOK accuracy. Specifically, FOK accuracy is determined by comparing FOK judgments with final test performance. FOK predictions would be invalid if restudy followed those predictions. All 24 fake questions were included in Phase 2 for the purpose of study. In Phase 2, participants were given the opportunity to study all questions with their accompanying correct answers. Questions with correct answers were individually presented in a statement (e.g. "Ostrich is the bird that cannot fly and is the largest bird on earth."). At least 48 questions were included in the Phase 2 for study, including 24 real and 24 fake general knowledge questions. If the number of real questions is below 48, randomly selected items from questions with correct answers and 100% FOK were used to make the 48 questions needed for the study. Participants had unlimited time to study each item, but were not allowed to go back to previous studied items. Both age groups read each of the items. Young participants decided when to move to the next questions by pressing the Enter key, and older participants informed the research assistant when they were ready to move on.

After self-paced study, participants were given the MMSE (older adults only) and the Shipley's vocabulary test (both young and older adults). Finally, in Phase 3, participants took a recognition test with four alternatives for the same general knowledge questions from the first phase, with each question followed by a question on confidence judgments for their recognition performance.

Results

Memory Accuracy. All participants provided incorrect answers to all twenty-four fake general knowledge questions. This suggests that these fake questions can be considered entirely new information to all participants, and effectively served as a test of episodic memory.

Older adults performed better than young adults on the initial memory test associated with real general knowledge questions, $t(62) = -2.49$, $p < .01$, $d = .63$, $M_{Young} = .43$, $M_{Older} = .53$.

However, there were no age-related differences for the items that were later included in Phase 2, $t(62) = -1.76$, *n.s., d= .45.* A 2 (Age Group: Young, Older) x 2 (Item Type: Real, Fake) mixed ANOVA was conducted on the mean accuracy of studied items on the final recognition test (Table 5.). A main effect of item type was found, F (1,62)= 48.62, $p < .05$, $\eta_p^2 = .44$. On average, participants performed better on real general knowledge questions (*M*= .95) as compared to fake questions on the final recognition test (*M*= .82). There were no other significant effects. Data regarding memory improvement, or the difference between initial and final memory performance, were not calculated because different formats were used in the initial and final memory tests.

Gamma Correlation between FOK and Final Recognition. Goodman-Kruskal Gamma correlations between the correctness of each item on the final recognition test and the corresponding FOK judgment were used to measure FOK prediction accuracy (Benjamin & Diaz, 2008; Nelson, 1984). Gamma correlations are nonparametric measures that are used to explore a linear relationship between memory performance and subjective judgments. The average of individual gamma correlation was calculated for each participant. Because participants made FOK judgments before Phase 2, in which they studied each of the general knowledge items, correlations between FOKs and final recognition performance will be impacted by the intervening study. Therefore, only real knowledge items that had not been studied were included to examine monitoring accuracy. For a similar reason, the accuracy of FOK judgments for fake general knowledge questions was not measured. The reader will recall that all fake general knowledge questions were presented for study in Phase 2.

An independent t-test comparing average gamma correlations between young and older adults on the subset of general knowledge questions used to examine monitoring accuracy found no difference, *t*(62)= 1.45, *n.s.* This is consistent with the previous findings suggesting older adults are able to predict their future memory of currently inaccessible general knowledge information as accurately as young adults (Morson et al., 2014; Souchay et al., 2007).

Study Time Allocation. In order to investigate the efficiency of study-time allocation for both fake and real general knowledge, a 2 (Age Group: Young, Older) x 2 (Item Type: Real, Fake) mixed ANOVA was conducted on average study time. A main effect of the Item Type was found, $F(1, 62)= 22.51$, $p < .05$, $\eta_p^2= .27$. Also found was a main effect of Age Group, $F(1, 58)= 13.93$, $p< .05$, $\eta_p^2= .19$. The interaction between Age group and Item Type was not significant, $F(1,62)= 1.47$, *n.s.* These results suggest that both young and older adults spent significantly more time studying fake general knowledge (*M*= 6.83 sec) than real general knowledge (*M*= 4.98). Additionally, older adults studied items longer than young adults, regardless of item type ($M_{Young} = 4.43$; M_{Older}== 7.30) (Table 6.).

Gamma Correlation between Memory and Study Time. Goodman-Kruskal Gamma correlations were conducted between the correctness of each item on the initial memory test and average study time (Nelson, 1984). Fake items were not included in this analysis. An independent t-test on average gamma correlations comparing young and older adults was not significant, *t*(62)= -.51. On average, both young and older adults demonstrated that longer study time was correlated with incorrect responses in the initial memory test (M= -.51). Gamma correlations between study time allocation and final recognition accuracy was also measured. A 2(Age Group: Young, Older) x 2 (Item Type: Fake x Real) mixed ANOVA was conducted on the average gamma correlation between the recognition accuracy and study time allocation. A marginally significant effect of Item Type was found, $F(1,40)= 3.83$, $p= .06$, $\eta_p^2= .09$. No further effects were significant.

Gamma Correlation between the FOK judgments and Study Time Allocation. Gamma correlations between study time and the FOK judgments were measured for both age groups and both item type. A 2(Age Group: Young, Older) x 2 (Item Type: Fake x Real) mixed ANOVA was performed on the average gamma correlations. There were not any significant effects. Participants spent longer time studying the items with lower FOK judgments, regardless of the age groups and the item types (M= -.13).

Discussion

In Experiment 1, both young and older adults demonstrated improvements in memory for both real and fake general knowledge after self-paced study. Additionally, both age groups were able to accurately predict their future memory of unrecalled general knowledge items to a similar degree, as demonstrated by significant gamma correlations between FOK judgments and the accuracy of final recognition accuracy. This result is consistent with previous research on age-equivalent semantic FOK judgment prediction accuracy (Morson et al., 2014; Souchay et al., 2007).

As predicted, both young and older adults spent more time studying fake as compared to real general knowledge information. Further, older adults spent on average more time studying both real and general knowledge information as compared to younger adults. This last finding is particularly important in the context of the cognitive resource hypothesis. That is, although older adults spent more time studying, they did not perform better on the final test as compared to young adults. That is, age-differences in study time allocation did not translate to greater improvement on the final memory test for older adults than young adults. This may suggest less effective study time allocation in older adults. However, older adults may not have much room for improvement due to almost perfect accuracy in the final recognition test (M= 95.34) (i.e. a ceiling effect). Therefore, it is premature to conclude that older adults demonstrated less efficient metamemorial control process relative to young adults.

Experiment 2

In Experiment 2, I tested the hypothesis that providing explicit monitoring would lead to less effective metamemorial control. In order to investigate the possibility that explicitly engaging in monitoring would be cognitively taxing for older adults, half of participants were not required to provide monitoring judgments, whereas the other half of participants were. I hypothesized that age-related differences in control efficiency would be reduced when participants were not required to provide monitoring judgments. Specifically, explicit monitoring would negatively influence memory performance (Kruger, 2012) and/or study time allocation (Stine-Morrow et al., 2006). Further, I also hypothesized that explicit monitoring would negatively influence correlations between memory accuracy and study time allocation. In order to directly measure cognitive resources, participants were asked to perform a series of psychometric tests. I expected that older adults would perform worse on these psychometric tests than young adults. I also hypothesized that cognitive resources would be related to efficiency of metamemorial control when study time was unlimited and stimuli were presented sequentially (Dunlosky & Thiede, 2004).

Method.

Participants.

Sixty-five older adults, who did not participated in Experiment 1, were recruited from local areas mostly from a subject pool available in Dr. Thomas' Cognitive Aging and Memory Lab at Tufts University as in Experiment 1. Twelve additional older participants were recruited for a pilot study in order to investigate the difficulty levels of items and to decide the number of items to include. Older adults were paid $15 per hour, and were screened via phone interviews regarding any previous medication, head injuries, and dementia. Additionally, the Mini-Mental Status Examination (MMSE; Folstein et al., 1975) was conducted with a cutoff of 27 out of 30 (M= 29.90), exception of three participants whose MMSE was below 27. Those three participants were included in the data analysis because their memory and metamemory performance were within three standard deviations from the average.

Seventy-five young adults participated in the study for course credit or were recruited from a website of Tufts University ($10 per hour). Fifteen young adults who did not answer any of the questions in the initial test and one young adult who did not answer the final memory test were not included in the data analysis. Finally, the data from two older participants and two young adults were excluded from the data analysis because their average study time data was greater than three standard deviations from the group average. Therefore, in total, the data from sixty-two older adults and fifty-nine young adults are included. Both young and older adults took a vocabulary test from the Shipley Institute of Living Scale (Shipley, 1940). Older adults significantly outperformed young adults in the vocabulary test, $t(118) = -2.454$, $p < .05$, $d = .45$. Additionally, a survey regarding computer experiences and knowledge was collected (Table 2). Young adults provided higher scores in the questions related to the frequency of computer usage, $t(110) = 3.15$, $p < .05$, $d = .60$, comfort level in using a computer, $t(103) = 5.77$, $p < .05$, $d = 1.12$, and the number of electronic devices possessed, $t(100) = 3.134$, $p < .05$, $d = .63$. This survey was included to validate the methodology used for older adult testing (e.g. having an experimenter enter in response for older participants). Demographics and other participant information are included in Table 2.

Design and Materials.

Experiment 2 employed a 2 (Age: Old vs. Young) x 2 (Judgments: Monitoring vs. Memory-irrelevant) between-participant design. In contrast to Experiment 1, only real general knowledge questions were included in order to solely investigate the impact of explicit monitoring judgments on metamemorial control in the context of semantic memory. Sixty difficult general knowledge questions with the lowest probability for recall were selected from Nelson and Narens (1980). Based on data on the probability to recall from Nelson and Narens (1980), relatively more difficult items were included in Experiment 2 (M= .17) than in Experiment 1 (M= .59).

Cognitive resources were measured using four different psychometric tests: Forward Digit Span Task (Wechsler, 1997a), Mental Control (Wechsler, 1997a), Stroop Task (Stroop, 1935), and Wisconsin Card Sorting Task (Nelson, 1976) (Glisky, Polster, & Routhieaux, 1995; Tremont & Alosco, 2011). Digit Span task and Mental Control was adopted from Wechsler Adult Intelligence Scale (Wechsler, 1997a). To conduct the Wisconsin Card Sorting Task and Stroop Task, subsets of the Psychology Experiment Building Language (PEBL) software program were used (Mueller & Piper, 2014; Piper et al., 2012).

Procedure.

Young adults were tested in groups of one or two, and older adults were tested individually. A researcher entered answers for older adults on the computer whereas young adults typed their own answers. The exception to this procedure was the Stroop task. For this task, older adults entered their own responses.

First, participants were asked to complete four psychometric tests. For the Digit Span Task, participants listened to a series of numbers and either typed the answers in order (young adults) or repeated them to a researcher (older adults). The test started with two numbers and stopped when participants provide two consecutive incorrect answers. The Digit Span Task was programed using the E-prime software 2.0. The speed and the accuracy of cognitive processing were measured through Mental Control. Mental Control includes a simple task, such as counting from one to twenty as quickly as possible, and combinations of counting numbers by sixes and saying the days of the week (e.g. 0 - Monday - 6 - Tuesday -12 - Wednesday, etc.). This paper-and-pencil task was individually measured for both young and older adults.

In the Wisconsin Card Sorting Task, participants first saw four different cards, which included different colors, shapes, and numbers of objects. Participants were presented with a series of cards, and asked to decide which card among the four that each belonged to. The rule can be color, shape, or number, and the participants were not explicitly told which rule to follow. However, they received feedback after each trial. Their goal was to figure out the rule as quickly as possible by trial-and-error based on the feedback. Further, when the rule was changed in the middle of the task, participants were asked to figure out the new rule and to employ it to the remainder of the test.

For Stroop task, participants saw each of the colored words (target) and pressed a corresponding number key among four options (e.g. 1=red, 2=green, 3=blue, 4=yellow). There were two sessions for each block: Word naming and Color naming. For the word-naming task, participants were asked to respond according to the meaning of the word, and ignore the color of the word. For the color-naming task, they were asked to respond based on the color of the word, and ignore the actual meaning of the word. For the first block, the four response options on the screen were colored (i.e., the response options were printed in color: 1=Red, 2=Green, 3=Blue, 4=Yellow). For the second block, the four possible response options were written in black. For the third block, four colored squares without word labels were presented as response options.

The metamemorial control experiment began after a short break, which lasted approximately five minutes for older adults in order to avoid fatigue. Young adults started immediately after psychometric tests. In this experiment, there were two participant groups. One group was required to provide explicit monitoring decisions when presented with general knowledge questions in the first phase. The second group did not provide explicit monitoring judgments. Experiment 2 was divided into three phases. In Phase 1, participants were presented with sixty general knowledge questions. For a monitoring group, each general knowledge question was followed by metacognitive judgments, i.e. "How likely do you think you can correctly provide the answer in a later test if you can study them?" For the second group, they were asked to answer a memory-irrelevant question, "How many words were there in the question?" In order to minimize cognitive burden, participants were instructed to simply guess the number of words as quickly as possible. Further, the memory-irrelevant question included four alternative answers: less than 4 words, between 5 and 8, between 9 and 12, and more than 13. Judgments were provided regardless of whether participants answered or failed to answer a given question. After Phase 1, MMSE (older adults only) and the Shipley's vocabulary test (both young and older adults) were administered. In Phase 2, participants studied all general knowledge items. Study time was unlimited. Participants were told that they could spend as much time as they needed to study each of the items, but they could not go back to the previous item. Finally, in Phase 3, all participants took the same recall test as Phase 1 in a new randomized order. Based on the pilot data, the final memory test was modified. Instead of a four alternative recognition test, final memory performance was assessed using a cued recall test in order to prevent a ceiling effect.

Results

Memory Accuracy. The accuracy of initial and final memory performance was measured by calculating the correct proportion (i.e. the number of correct items out of total). Due to low memory accuracy near zero (i.e. floor effect) found in young adults, nine items that could not answer by any young adults in this experiment were excluded from further data analysis. In contrast to Experiment 1, both initial and final tests were cued-recall tests. Therefore, a 2 (Age Group: Young, Older) x 2 (Judgment Group: Monitoring, Memory-irrelevant) ANOVA was conducted on average memory improvement between the initial and the final test. Memory improvement was the difference between initial memory performance and final memory performance. A main effect of Age Group was found, F (1, 177)= 11.75, p < .01, η_p^2= .09. On average, young adults improved their memory (M= .43) to a greater extent than older adults (M= .36). No further effects were significant. The ceiling effect was not found for both young (M= ,64) and older adults (M= .69) in the final memory test. Results from the initial and final memory tests were separately presented in Table 7. No other effects were significant.

Study Time Allocation. A 2 (Age Group: Young, Older) x 2 (Judgment Group: Monitoring, Memory-irrelevant) ANOVA was conducted on average study time allocation, measured in seconds. There was a main effect of Age, F (1, 117)= 27.27, $p< .05$, η_p^2= .19. On average, older adults studied items longer (M= 5.54) than young adults (M= 3.73). No other effects were significant (Table 8.).

Gamma Correlation between Monitoring and Memory. Gamma correlations between initial memory performance and monitoring judgments were calculated for each participant in the Monitoring group. In contrast to Experiment 1 where FOK judgments were measured, participants were asked to predict their future memory after study in Experiment 2. Therefore, all monitoring judgments could be included in this analysis. There were no age-related differences in average gamma correlations, *t* (59)= -.39, *n.s.* On average, both age groups provided higher monitoring judgments for the correct items in the initial memory test. Additionally, gamma correlations between final memory performance and monitoring were measured. There was no age-related differences in average gamma correlations, *t*(57)= .46, *n.s.* On average, both age groups better remembered items that they provided higher monitoring judgments regarding their final memory performance (Table 8.).

Gamma Correlation between Monitoring and Study Time Allocation. For the Monitoring group, gamma correlations between monitoring judgments and average study time were measured. There was a significant age difference in gamma correlations between monitoring judgments and study time allocation, *t*(59)= 2.91, *p< .05, d= .76*. That is, older adults demonstrated a stronger relationship between their monitoring judgments and the study time allocation (*M*= -.34) than young adults (*M*= -.19).

Gamma Correlation between Memory and Study Time. Gamma correlations between study time and memory performance were calculated. A 2 (Age: Young, Older) x 2 (Judgments: Monitoring, Memory-irrelevant) ANOVA was conducted on average gamma correlations between study time and the initial test. An interaction between Age and Judgment Group was found, *F*(1, 117)= 4.05, $p < .05$, η_p^2= .03. Follow-up t-tests revealed that average gamma correlations were significantly different between age groups in the monitoring judgment group, *t* (59)= 3.17, *p< .01*, *d*= .83. That is, older adults demonstrated a stronger correlation between the monitoring judgments and study time (*M*= -.75) than young adults (*M*= -.53). However, gamma correlations did not differ between the two age groups in a memory-irrelevant judgment group, *t* (58)= -.06, *n.s.* A trend toward significance on the main effect of age was found, *F*(1, 117)= 3.68, $p = .06$, η_p^2= .03. There was no main effect of judgments, *F*(1, 117)= .21, *n.s.* When a 2

(Age Group: Young, Older) x 2 (Judgment Group: Monitoring, Memory-irrelevant) ANOVA was conducted on average gamma correlations between study time and the final test, no significant effects were found, F's < 1.5. On average, participants demonstrated negative correlations between study time and final memory performance (*M*= -.24).

Cognitive Resources

Four psychometric tests were conducted in order to measure cognitive resources. First, the accuracy of a Digit Span task was measured. The task stopped after participants made mistakes twice consecutively, and the longest digits that participants could rehearse without errors were included as participants' accuracy score. The Mental Control included 8 sub-items, for a total of 40 points. Each question allocated a maximum of 2 points for accuracy and 3 points for speed. The number of errors reflected in the accuracy such that participants without any errors received 2 points, those with one error received 1 point, and those with more than 2 errors did not receive any points for accuracy. Depending on the response time, participants could receive up to 3 points per question. A proportion of participants' scores out of total scores in Mental Control was included in further data analysis.

The Stroop task included four targets: color-word consistent words, color-word inconsistent words, black words, and colored single features (e.g. XXXXX). It has been found that the classical Stroop effect (i.e. longer RT on color naming than on word naming) was demonstrated only in the second block with black response options (Mueller, 2010c). Thus, the response time (RT) data from the second block for the Stroop Task were only included in further data analysis. The following formula was used in order to calculate response time (RT) data, based on Perrotin et al. (2006): (Conflicting condition RT- Color-naming of single feature RT) / Color-naming of single features RT. For the Card Sorting Task, the number of perseverative errors was included as an index of inhibition failure. The perseverative errors are observed when participants inappropriately follow a previous rule even after they have sufficient trials to figure out a new rule.

Because each of the tasks had different measurements, individual scores were transformed into Z-scores for the purpose of standardization. Z scores were calculated based on the mean and the standard deviation of all participants regardless of participant groups. Finally, one composite score for all four of the psychometric tests was computed. The composite score was calculated by adding the Z-score of the Digit Span task and Mental Control, and then subtracting the Z scores of the Card Soring task and the Stroop task. Ten older participants in the Monitoring group did not complete the psychometric tests.

There was a significant age-related difference in the average composite scores, $t(109)= 5.35$, $p< .05$. Young adults performed better on psychometric tests ($M= 1.14$) than older adults ($M= -1.17$). There were no correlations between performance on psychometric tests and study time (see Table 9.). Performance on psychometric tests correlated to memory improvement in young adults who provided monitoring judgments, $r= .57$, $p< .01$. No further effects were significant.

Discussion

Experiment 2 explored whether explicitly providing monitoring judgments would negatively impact metamemorial control in older adults. In contrast to this hypothesis, monitoring judgments did not play a role in memory improvement for either age group. Regardless of monitoring judgments, young adults improved their memory after studying to a greater degree than older adults. Additionally, providing monitoring judgments did not play a role in the study time allocation for either age group.

As in Experiment 1, older adults studied items longer but improved their memory to a lesser degree than young adults. This implies less efficient metamemorial control in older adults than young adults. Interestingly, older adults demonstrated a stronger correlation between study time and memory accuracy than young adults when they were asked to engage in the explicit monitoring process. However, this pattern disappeared when they did not provide monitoring judgments. These results suggests that in contrast to the hypothesis on negative influence of monitoring judgments for older adults, explicit monitoring may have helped older adults to spend more time studying unknown items.

Finally, older adults performed worse than young adults on psychometric tests. This provided direct evidence that older adults in Experiment 2 had access to fewer cognitive resources than young adults. However, there was no significant correlation between study time allocation and performance on psychometric tests. That is, fewer resources in older adults were not correlated with less effective metamemorial control in this particular study.

Experiment 3

Consistent with results from Experiment 1, in Experiment 2, older participants spent more time studying items, although young adults improved their memory to a greater extent. Age-related differences in gamma correlations between memory accuracy and study time were only found in the monitoring group. Results from Experiment 2 suggest that cognitive resources consumed by explicit monitoring may not influence metamemorial control. Although older adults performed less well on psychometric tests, their reduced cognitive resources did not correlate with memory or metamemory in the context of unlimited study time.

With unlimited study time, participants are typically allowed to spend as much time as they desired. When study time is limited, participants need to strategically spend time studying items that they think they can master within the time allotted. Cognitive resources have been known to influence efficiency of study time allocation when study time is limited (Price & Murray, 2012). Experiment 3 examined the relationship between cognitive resources and control in the context of a limited study time experiment. I hypothesized that limited study time would require more cognitive resources than unlimited study time. In turn, greater age-related differences in correlations between cognitive resource and study time would be found when participants exercised control under limited as compared to unlimited study time constraints. Additionally, general knowledge questions with three different difficulty levels were used as stimuli. To-be-studied items were presented sequentially, as this presentation format has been shown to relate with cognitive resources (Dunlosky & Thiede, 2004). With a limited amount of study time, effective study time allocation would be to focus on unknown easier items rather than difficult items (Metcalfe, 2009). However, this can be challenging in the context of a sequential display format when study time is limited due to their cognitively demanding nature. Therefore, cognitive resources were expected to be required to learn easier items in a sequential display format, particularly when study time was limited.

Method

Participants.

Thirty-one older adults, either who had not participated in the previous two experiments or had participated more than a year ago, were recruited from local areas near Tufts University. They received $15 per hour. They were screened by an initial phone interview for any previous head traumas, medication, usage and dementia. Additionally, they were given the MMSE (Folstein et al., 1975). As in previous experiments the cutoff for participation was 27 (*M*= 29. 47), with the exception of one participant (MMSE= 26). I included one participant with a score of 26, because data from this participant fell within the three standard deviations of group averages. Thirty-four young adults participated in Experiment 3 as a part of experimental requirements for their psychology courses at Tufts University. The data from one older adult and two young adults were not included in experimental data analysis because they could not finish the tasks or because study time was greater than three standard deviations from the group average. Therefore, thirty older adults and thirty-two young adults participated in the study. As in the previous two studies, older adults performed better on the Shipley Institute of Living Scale (Shipley, 1940) as compared to young adults, $t(60) = -4.24$, $p < .05$, $d = 1.09$. Demographic information is included in Table 3.

Design and Materials.

Experiment 3 was a 2 (Age: Old vs. Young) x 3 (Difficulty Level: Easy, Medium, Difficulty) x 2 (Study Time: Unlimited x Limited) mixed design, where Age was a between subject variable, and Difficulty Level and Study Time were within subject variables. A total of ninety-six general knowledge questions were selected from Nelson and Narens (1980). They were categorized according to the difficulty to recall: easy, medium, and difficult ($M_{\text{Easy}} = .85$; $M_{\text{Medium}} = .57$; $M_{\text{Difficult}} = .08$).

Procedure.

The procedure of Experiment 3 was similar to the previous two experiments. First, older adults completed the Mini-Mental State Examination (Folstein et al., 1975). Following, both young and older adults completed four psychometric tests: Forward Digit Span Task (Wechsler, 1997a), Mental Control (Wechsler, 1997a), Stroop Task (Stroop, 1935), and Wisconsin Card Sorting Task (Nelson, 1976).

Older adults took a short break for approximately five minutes before the metamemorial experiment in order to avoid fatigue, whereas young adults immediately began the metamemorial experiment. As in previous experiments, participants were presented with general knowledge questions in the initial test, engaged in a study phase, and took the final memory test. Unlike previous experiments, there were two blocks of experiments, depending on study time in the study phase. For both blocks, in Phase 1, participants were presented with forty-eight general knowledge questions to be answered. Each question was followed by a question regarding monitoring on future memory, that is, “How likely do you think you can correctly provide the answer in a later test if you could study it?” This question was framed such that participants could make monitoring judgments with the consideration of future study. In Phase 2, for Block 1, both age groups were given unlimited time to study 48 question-answer pairings. As in previous experiments, during this unlimited time block, participants decided when to terminate studying each of the items. This was followed by filling out demographic information. For Block 2, both young and older participants were given three minutes to study 48 questions and answers. The total available remaining time for the study phase were presented on the bottom of the screen. Total study time was determined on Experiment 1 data. Three minute was approximately half of the study time that older adults would spend for 48 questions. It is crucial for participants to consider both remaining time and remaining items to study. This was followed by the Shipley vocabulary test (Shipley, 1940). Finally, for both blocks, all participants took a final cued recall test in Phase 3. The order of the two blocks was counterbalanced, such that half of participants completed an unlimited study time block first, followed by a limited study time block, whereas the second half of participants completed a limited study time block first, followed by an unlimited study time block.

Results

Memory Accuracy. Participants were presented with one set of forty-eight general knowledge questions in the context of an unlimited study time block, and the other set of 48 general knowledge questions in the context of a limited study time block. Questions were counterbalanced such that they served in both blocks, resulting in two participant groups. In order to ensure that there was no order effect on item sets, independent t-tests were conducted on memory accuracy. No significant difference was found in initial memory accuracy, $t(60)= .44$, *n.s*., and in final memory accuracy, $t(60)= -.27$, *n.s.*, suggesting no order effect. Therefore, the counterbalance for the item sets was collapsed across the groups.

Additionally, the order of blocks (limited study time first vs. unlimited study time first) was counterbalanced, resulting in two additional participant groups. In order to ensure there was no order effect on blocks, independent samples t-tests were conducted on memory accuracy between the unlimited-time-first group and the limited-time-first group. The results revealed that there were no group differences in initial memory performance, $t(60)= .44$, *n.s*., or in final memory performance, $t(60)= -1.13$, *n.s*. Additionally, no group differences were found in average study time per item in an unlimited study time condition, $t(60)= .70$, *n.s*. These results suggest that the order of the blocks, which depended on whether participants first studied items for unlimited time or limited time, did not influence the memory accuracy. Therefore, the counterbalance for the block order was collapsed across the groups.

A 2 (Age: Young, Older) x 3 (Difficulty: Easy, Medium, Difficult) x 2 (Study Time: Unlimited, Limited) mixed ANOVA was conducted on average memory improvement (Table 11). Memory improvement is the difference between the accuracy of the final memory performance and the initial memory performance. There was a significant main effect of

Difficulty Level, *F*(2, 120)= 780.86, $p< .05$, η_p^2= .57. In order to avoid alpha inflation, a Bonferroni corrected alpha level of .02 (i.e. .05/3) was used for pairwise comparisons. Follow-up t-tests demonstrated that on average, participants improved their memory of easy items to a greater extent than medium items, *t*(61)= -11.82, $p<.001$, *d=3.03,* and medium items than difficult items, *t*(61)= -4.42, $p<.001$, *d=1.32*. A main effect of Study Time was also found, *F*(1, 60)= 9.96, $p< .01$, η_p^2= .14. On average, participants demonstrated greater memory gains when study time was unlimited (*M*= .34) than when study time was limited (*M*=.29). A main effect of Age Group was also found, *F*(1, 60)= 15.88, $p< .05$, η_p^2= .21. On average, young adults improved their memory (*M*=.36) to a greater extent than older adults (*M*=.27). Additionally, a significant interaction between Difficulty Level and Age Group was found, *F*(2, 120)= 3.61, $p< .05$, η_p^2= .07. The follow-up t-test results demonstrated that regardless of study time, both young and older adults improved their memory of the difficult items to the same degree, *t*(60)= .59, *n.s*. However, young adults improved their memory to a greater extent than older adults for both easy, *t*(60)= 3.10, $p< .05$, *d=.80,* and medium items, *t*(60)= 4.71, $p< .001$, *d=1.22*. This suggests that although older adults were able to improve their memory on the difficult items as much as young adults, young adults improved their memory to a greater extent than older adults for medium and easier items. Further, memory improvements were compared according to the difficulty levels in each age group. When Bonferroni corrected alpha level of .02 was used, young adults demonstrated greater memory improvement for medium items than easy items, *t*(31)= -9.68, $p<.001$, *d= 3.48* , but did not demonstrate differences between difficult and medium items, *t*(31)= -1.47, *n.s.* On the other hand, older adults demonstrated greater memory improvement for difficult than medium items, *t*(29)= -7.43, $p<.001$, *d= 2.76*, and for medium items than easy items, *t*(29)= -5.76, $p<.001$, *d=2.14*. There were no other significant effects.

Study Time Allocation. A 2 (Age: Young, Older) x 3 (Difficulty: Easy, Medium, Difficult) x 2 (Study Time: Limited vs. Unlimited) mixed ANOVA was conducted on the average study time (Table 12). There was a significant main effect of Difficulty Level, $F(2, 120)= 130.52$, $p< .001$, $\eta_p^2= .69$, and Study Time, $F(1, 60)= 50.54$, $p< .001$, $\eta_p^2= .46$. A significant two-way interaction between Difficulty Level and Study Time was also found, $F(2, 120) = 25.65$, $p< .001$, $\eta_p^2= .30$. A Bonferroni corrected alpha level of .02 was used for paired comparisons. Follow-up t-tests revealed participants studied items longer when study time was unlimited than limited, $t_{\text{Easy}}(61)=5.23$, $p<.001$, $d=1.34$, $t_{\text{Medium}}(61)=5.41$, $p<.001$ $d= 1.39$, $t_{\text{Difficult}}(61)=6.51$, $p<.001$, $d=1.17$. When the differences between the unlimited and limited time conditions were calculated for the average study time, the largest difference in study time between the limited and unlimited time condition was found in difficult items as compared to medium difficulty items, $t(29)=-4.41$, $p<.001$, $d= 1.64$. There was no difference between easy and medium difficulty items, $t(29)= .02$, *n.s.* No other effects were significant.

Gamma Correlation between Memory Accuracy and Study Time. Gamma correlations were calculated between accuracy of the initial test and study time. When a 2 (Age: Young, Older) x 2 (Study Time Limit: Limited, Unlimited) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on average gamma correlations between the initial test and study time, there were no significant effects. A 2 (Age: Young, Older) x 2 (Study Time Limit: Limited, Unlimited) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was also conducted on average gamma correlations between the final memory test accuracy and study time. The results demonstrated a significant interaction between Difficulty Level and Study Time, $F(2, 20)= 6.67$, $p< .05$, $\eta_p^2= .40$. Follow-up t-tests suggest that regardless of age, participants demonstrated a stronger correlation for easy items given unlimited study time than limited time, $t(14)= 3.23$, $p< .05$, $d=1.73$. However, there was no significant difference between the unlimited and limited study time on either medium items, $t(29)= .64$, *n.s.,* or difficult items, t(60)= -.37, *n.s.* A marginally significant main effect of Age group was found, $F(1, 10)= 3.98$, $p= .08$, $\eta_p^2= .28$. There were no other significant effects.

Cognitive Resources. As in Experiment 2, cognitive resources are presented as a single composite score (Table 13.). There was a significant age-related difference, $t\ (60)= 3.87$, $p< .05$, $d= .99$. Young adults significantly outperformed (M= .93) older adults (M= -1.42). There was no correlation between initial memory accuracy and cognitive resources. For final memory performance, young adults demonstrated a positive correlation between cognitive resources and memory accuracy for easy items in the context of unlimited study time ($r= .40$, $p< .05$), and older adults demonstrated positive correlations between cognitive resources and memory accuracy for medium difficulty items in the context of limited study time ($r= .41$, p< .05). For memory improvement, there were no significant correlations. For study time allocation during unlimited study time, both age groups demonstrated negative correlations between cognitive resources and average study time for both easy and medium items (Young: $r_{easy}= -.62$, $p < .05$, $r_{medium}= -.60$, $p< .05$; Older: $r_{easy}= -.43$, $p < .05$, $r_{medium}= -.37$, $p< .05$), but there was no significant correlation in the difficult items. For the limited study time, young adults demonstrated a negative correlation between cognitive resources and average study time for difficult ($r= -.52$, $p < .05$). Older adults demonstrated a negative correlation between cognitive resources and average study time for easy items ($r= -.40$, $p< .05$). Correlations between cognitive resources and study time were also measured regardless of age in order to explore whether or not individual differences in cognitive resources would demonstrate correlations with study time allocation. For the unlimited study time block, easy and medium difficulty items negatively correlated with cognitive resources (r_{Easy}=-.52, p<.001, r_{Medium}=-.43, p<.001). No correlation was found for difficult items, $r_{Difficult}$=-.14, n.s. Similar results were found for a limited study time block, r_{Easy}=0.34, p<.05, r_{Medium}=-.33, p<.05, $r_{Difficult}$=-.17, n.s.) No further correlations were significant.

Discussion

In Experiment 3, the influence of the available study time on metamemorial control was explored in both young and older adults. Study time and item difficulty associated with general knowledge facts were manipulated. When memory improvement from the initial test to the final test after study was explored, both young and older adults demonstrated a great memory improvement. That is, young and older adults demonstrated similar levels of improvement on difficult items. However, young adults demonstrated greater improvement on items of easy and medium difficulty items. These results suggest that older adults may focus on learning difficult items rather than easier items when to-be-studied items were presented sequentially. When study time allocation was measured, participants spent more time studying difficult items than easier items for both unlimited and limited study time blocks. The difference in average study time between unlimited and limited study time blocks was larger for difficult items than easier items. This suggests that when more study time was available, participants tended to use that spare time to learn difficult items rather than easier items. Interestingly, although both age groups spent more time studying difficult items than medium items, only older adults demonstrated greater memory improvement for difficult items than medium items, whereas young adults did not demonstrate any differences.

Correlations between cognitive resources and average study time were also measured. When study time was unlimited, for both age groups, higher cognitive resources were related to less study time on easy and medium items. However, cognitive resources did not correlate with study time for difficult items. This is consistent with previous findings from Experiment 2, where cognitive resources did not correlate with study time when difficult items were used. When study time was limited, for older adults, higher scores on measures of cognitive resources were correlated with less time devoted to easy items. For young adults, higher scores on measures of cognitive resources were correlated with less time devoted to difficult items. The results suggest that older and young adults demonstrated different patterns of correlations between study time and cognitive resources only when study time was limited. Further, cognitive resources may play a role differently depending on age groups when study time was limited.

Experiment 4

The findings from Experiment 3 demonstrate that older adults improved their memory to a similar extent as compared to young adults only for difficult items in a sequential display format. Further, cognitive resources differently correlated with study time allocation depending on age groups when study time was limited. Specifically, higher cognitive resources correlated with less study time for difficult items in young adults in a sequential display format. Interestingly, higher cognitive resources correlated with less study time for easy items in older adults in a sequential display format. With a limited amount of study time, individuals may need to learn unknown easier items first. However, a sequential display format is known to be influenced by cognitive resources. Therefore, spending more time for relatively easier items and/or less time for more difficult items in a sequential format during limited time may require cognitive resources. In order to explore if the display format played a role in age-related differences in study time allocation, to-be-studied items were presented simultaneously in Experiment 4. A simultaneous display format was expected to reduce cognitive burden on older adults. Further, participants were provided with a specific goal to achieve. That is, they were required to gain as many points as possible in the final memory test after self-paced learning. I hypothesized that a simultaneous display format with different point values would result in more efficient metamemorial control in older adults as compared to the situation without specific goals. In order to test this hypothesis, I compared two participant groups: Scaled point group was given questions clustered by different point values during a study phase, whereas Consistent point group was presented with questions with same point values during a study phase. Participants in both Scaled point group and Consistent point group were told that their goal was to achieve as many points as possible. Point value was not manipulated in Consistent point group to look solely at the contribution of format to control processes. I hypothesized that both young and older adults were expected to be able to learn more valuable items than less valuable items. Additionally, I hypothesized that older adults would demonstrate efficient control when point value was manipulated, since different values are often found to lead to successful metamemorial control in older population (Castel et al., 2009; Castel et al., 2013).

Method

Participants.

Forty-eight older adults and fifty-three young adults participated in the study. The same recruitment and screening procedure were used as in previous studies. Ten additional young participants and eleven older adults participated in pilot testing designed to assess item number and limit for study time. Data from four young adults who did not follow the instructions and one young adult whose age was outside of young adult cutoff were not included in the data analysis. Therefore, the data from forty-eight older adults and 48 young adults are included in total. Similar to previous experiments, both age groups took a vocabulary test from Shipley (1940), where older adults outperformed young adults, $t(95)= -3.31$, $p<.01$, $d=.68$. The demographic information is presented in Table 4.

Design and Materials.

Experiment 4 employed a 2 (Age: Young, Old) x 2 (Point Value: Different, Same) x 3 (Difficulty: Easy, Medium, Difficult) mixed design, where Age and Point Value groups were between-group variables, and Difficulty Level was a within-group variable. Eighty-one of the general knowledge questions with three different difficulty levels were chosen from Nelson and Narens (1980). The general knowledge questions were classified according to nine different topics: animals, famous people, geography, health, history, literature, nature, objects, and sports. Each topic included nine questions with 3 different difficulty levels. Each topic was assigned different point values (from 10 to 90 points) for Scaled point group, whereas all topics had the same point value (50 points) for Consistent point group. The total point values were 4,500 points for both Scaled point group and Consistent point group.

Procedure.

First, older adults completed the Mini-Mental State Examination (Folstein et al., 1975) after filling out consent forms. Following that, both young and older adults completed four psychometric tests: Forward Digit Span Task (Wechsler, 1997a), Mental Control (Wechsler, 1997a), Stroop Task (Stroop, 1935), and Wisconsin Card Sorting Task (Nelson, 1976). Both age groups completed Shipley vocabulary test (Shipley, 1940). The metamemorial experiment began after a short break for older adults (approximately 5 minutes) or without a break for young adults. At the beginning of the metamemorial experiments, participants were asked to provide preference ratings on each topic, using a scale from 0 to 100. These ratings were collected in order to investigate the possibility that participants may devote more time studying topics given higher interest ratings.

In Phase 1, participants were presented with a category label, followed by nine questions in that category. The order of category presentation was randomized. Participants were asked to answer each of the questions. They were told that they could skip to the next questions, but they were not allowed to go back to the previous questions. All items from Phase 1 were included in Phase 2. During the study phase (Phase 2), participants were presented with a list of nine categories in a 3 by 3 grid (Figure 2.). Before Phase 2 began, they were encouraged to maximize the scores in the later memory test, and to go back and forth between the category list, the question list, and the answers. For Scaled point group, each topic had different values. Category values were as follows: 10, 20, 30, 40, 50, 60, 70, 80, and 90. The assignment of point values were counterbalanced using a Latin square design so that each category has an equal chance to have each point values. Once participants selected a category to study, a list of questions was presented simultaneously. Participants pressed the number of the questions they wanted to see the answer for. Finally, both young and older adults were given three minutes to study as many questions and answers as they chose, with the remaining time shown on the bottom of the screen (Figure 3). In Phase 3, the same questions were presented during a cued-recall test.

Results

Memory Accuracy. A 2 (Age Group: Young, Older) x 2 (Point Group: Scaled point group, Consistent point group) x 3 (Difficulty Level: Easy, Medium Difficult) ANOVA was conducted on average memory improvement, or the difference between initial test and final test performance (Table 15.). Main effects of Difficulty Level, F (2, 184)= 67. 07, p< .001, η_p^2= .42, and Age Group were found, F(1, 92)= 14.84, p< *.001*, η_p^2= .14. A Bonferroni corrected alpha level of .02 was used for the following pairwise comparisons. Participants improved more for medium items (*M*= .17) than easy items (*M*= .07), $t(95)= -9.16$, $p< .001$, $d=1.88$, but there was no difference between medium and difficult items, t (95)= -1.67, *n.s*. No further effects were significant.

Separate analyses were conducted on Scaled point group in order to explore whether participants strategically remembered a greater number of items with higher point values than items with low point values. For the efficiency of data analysis, categories were grouped into three subgroups. The point values 10, 20, 30 points were grouped as a low point category, 40, 50, 60 points were grouped as a moderate point category, and 70, 80, 90 points were grouped as a high point category. For Scaled point group, a 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) x 3 (Point Level: Low, Moderate, High) mixed ANOVA was conducted on memory improvement (i.e. difference between final memory performance and initial memory performance). There was a main effect of Difficulty Level, $F(2, 90)= 12.23$, $p< .001$, $\eta_p^2= .21$. A Bonferroni corrected alpha level of .02 was used for the following pairwise comparisons. Follow-up t-tests revealed that there was a significant difference between easy and medium difficulty items on memory improvement, $t(46)= -5.56$, $p< .001$, $d=1.64$ $M_{\text{Easy}}=.07$, $M_{\text{Medium}}=.16$, whereas no difference was found between medium and difficult items, $t(46)=1.09$, *n.s.* There was also a main effect of Point Level, $F(2, 90)= 26.60$, $p< .001$, $\eta_p^2= .37$. Follow-up t-tests found a significant difference between higher point items and moderate point items on memory improvement, $t(46)= -3.18$, $p< .01$, $d=.94$. A difference between moderate point items and low point items was not significant when a Bonferroni corrected alpha of .02 was used, $t(46)= -2.08$, *n.s*. On average, participants improved their memory of items with higher points to a greater extent than items with lower points. Finally, a main effect of age group was found, *F*(1, 45)= 7.84, $p< .01$, η_p^2= .148. Young adults demonstrated greater memory improvement (*M*=.17) than older adults (*M*=.11). There were no other significant effects.

Further, separate analyses were conducted on Consistent point group in order to investigate the effect of a simultaneous display format on memory improvement. A 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on memory improvement. There was a significant main effect of Difficulty Level, *F*(2, 94)= 41.85, *p<.05*, η_p^2= .47. A Bonferroni corrected alpha level of .02 was applied for the following comparisons. Follow-up t-tests revealed that there was significant difference between easy (*M*=.06) and medium difficulty items (*M*= .17) on memory improvement, *t*(48)= -7.47, *p<.001*, *d= 2.16*, whereas no difference was found between medium difficulty and difficult items, *t*(48)= -1.27, *n.s.* A significant main effect of Age was also found, *F*(1, 45)= 7.84, p<.01, η_p^2= .15. Young adults demonstrated greater memory improvement (*M*= .17) than older adults (*M*= .11). No further effects were significant.

Point Value Gains. A 2 (Age: Young, Older) x 2 (Point Groups: Scaled point group, Consistent point group) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on the average difference between the points that participants earned on the final test and points earned on the initial test. The results demonstrate main effects of Age, *F* (1, 92)= 16.70, $p< .001$, η_p^2=. 15, and Difficulty Level, *F* (2, 184)= 72. 74, $p< .001$, η_p^2= .442. Follow-up t-tests revealed significant differences between easy and medium difficulty items, *t*(95)= -8.92, *p<.001*, *d=1.83*, and between medium and difficult items, *t*(95)=-2.89, *p<.01*, *d=.59*. On average, participants demonstrated greater point gains for difficult items (M=291.88), followed by medium difficulty (M=237.40), and easy items (M=98.54). On average, young adults gained more points (M=247.15) than older adults (M=164.72). A marginally significant interaction between Difficulty level and Age Group was also found, *F* (2, 184)= 2.78, *p= .07*, η_p^2= .03. There were no further significant effects.

Study Time Allocation. For study time allocation, the average time that participants spent to study answers were included, presented in milliseconds. Because a list of questions was simultaneously presented in a slide (Figure 3.), study time that participants spent for individual question were not separately measured. A 2 (Age: Young, Older) x 2 (Point Group: Scaled point group, Consistent point group) x 3 (Difficulty levels: Easy, Medium, Difficult) mixed ANOVA was conducted on average study time for answers. Main effects of Age Group, *F*(1, 92)= 35.41, p< .001, η_p^2= .92, and Difficulty Level were found, *F*(2, 184)= 74.28, p< .001, η_p^2= .45. Follow-up t-tests found significant differences between easy and medium difficulty items, *t*(95)= -8.92, *p<.001, d=1.83*, and medium and difficult items, *t*(95)= -4.54, *p< .001*, *d=.93*. On average, participant spent less time studying easy items (*M*= 397 ms), followed by medium (*M*= 686 ms), and difficult items (*M*=885 ms). A significant interaction was found between Difficulty Level and Age group, *F*(2, 184)= 13.60, *p< .001*, η_p^2= .14. A Bonferroni corrected alpha level of .02 was used for the following comparisons. Follow-up t-tests demonstrated significant age-related differences for medium, *t*(94)=-3.63, *p< .001, d=.75* , and difficult items, *t*(94)= -6.36, *p<.001, d=1.31*. There was no significant age-related difference for easy items, *t*(94)=-.52, *n.s.* On average, older adults spent more time studying both medium (M_{Young}=574, M_{Older}=796) and difficult items (M_{Young}=652, M_{Older}=1113). A significant interaction between Age Group and Point Group was also found, *F*(1, 92)= 5.21, *p< .05*, η_p^2= .05. Follow-up t-tests demonstrated that young adults did not differ in average study time between Scaled point group and Consistent point group, *t*(46)= 1.33, *n.s.,* and older adults demonstrated a marginally significant difference in study time between Scaled point group and Consistent point group, t(46)= -1.90, *p=.06*, *d=.56*. Finally, a marginally significant three-way interaction was observed, *F*(2, 184) = 2.53, *p= .08*, η_p^2= .03 (Table 16.).

For Scaled point group, a 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) x 3 (Point Level: Low, Moderate, High) mixed ANOVA was conducted on average study time allocation. There was a main effect of Difficulty Level, *F* (2, 90)= 13.43, *p< .001*, η_p^2= .23. A Bonferroni corrected alpha level of .02 was applied to the following comparisons. Follow-up t-tests revealed significant differences between easy and medium difficulty items, *t*(46)= -6.60, *p< .001*, *d=1.95,* and between medium and difficult items, *t*(46)= -3.52*, p< .01*, *d=1.04*. On average, participant spent more time studying difficult items (*M*=871 ms.) than medium (*M*=672), followed by easy items (*M*=871). A main effect of Point Level was also found, *F*(2, 90)= 35.60, *p< .001*, η_p^2= .44. A Bonferroni corrected alpha level of .02 was applied to the following comparisons. Follow-up t-tests revealed a significant difference in study time between high and moderate point items, *t*(46)= -3.47, *p< .01*, *d=1.02*, whereas no difference between low and moderate point items, *t*(46)= -1.92, *n.s*. On average, participants spent more time studying items with high point values (*M*=1212) than moderate point values (*M*=797). There was a main effect of Age, *F*(1, 45)= 7.30, *p< .05*, η_p^2= .14. Older adults spent more time studying items (*M*=720) than young adults (*M*=575). There was a significant interaction between Difficulty and Point levels, *F*(4, 180)= 4.97, *p< .01*, η_p^2= .10. Bonferroni corrected alpha level of .006 (.05/6) was applied to the following comparisons. Follow-up t-tests suggest that there were no differences in study time between low point items and moderate point items for easy *t*(46)= -1.50, *n.s*., and medium difficulty items, *t*(46)= -2.01, *n.s*. Further, study time between moderate and high point items did not differ for easy *t*(46)= -2.44*, n.s.,* and medium difficulty items *t*(46)= -3.18, *n.s.,* when the alpha level was corrected using Bonferroni. Participants spent significantly more time studying higher point than moderate point difficult items, $t(46) = -3.62$, $p < .001$, $d = 1.07$. Finally, a marginally significant interaction between Point Level and Age Group was found, $F(2, 90) = 2.89$, $p = .06$, $\eta_p^2 = .06$. There were no other significant effects.

For Consistent point group, a 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on study time allocation. There was a significant main effect of Difficulty Level, $F(2, 94) = 46.64$, $p < .001$, $\eta_p^2 = .50$. A Bonferroni corrected alpha level of .02 was used for the following comparisons. Follow-up t-tests demonstrated that there was a difference between easy (M=391) and medium difficulty items (M=697) on average study time, $t(48) = -6.13$, $p < .001$, $d = 1.77$. A significant difference between medium difficulty and difficult items (M=895) was also found, $t(48) = -3.02$, $p < .01$, $d = .87$ A main effect of Age was also found, $F(1, 47) = 6.89$, $p < .05$, $\eta_p^2 = .13$. Young adults spent less time studying items (M=575) than older adults (M=826). No further effects were significant.

Gamma Correlation between Memory Accuracy and Study Time. A 2 (Age: Young, Older) x 2 (Point Group: Scaled point group, Consistent point group) x 3 (Difficulty levels: Easy, Medium, Difficult) mixed ANOVA was conducted on average gamma correlations between study time and initial memory performance. There was a significant main effect of Age, $F(1, 38) = 4.94$, $p < .05$, $\eta_p^2 = .12$. Older adults demonstrated stronger negative correlations (M= -.49) than young adults (M= -.30). No further effects were significant. None of the effects were significant when 2 (Age: Young, Older) x 2 (Point Group: Scaled point group, Consistent point group) x 3 (Difficulty levels: Easy, Medium, Difficult) mixed ANOVA was conducted on average gamma correlations between study time and final memory performance.

Item Selection. When the number of studied items was measured by 2 (Age: young, Older) x 3 (Point Level: Low, Moderate, High) mixed ANOVA for Scaled point group, there were significant main effects of Point Level, $F(2, 90)= 12.16$, $p< .001$, $\eta_p^2= .21$, and Age, $F(1, 45)=$ 40. 24, $p < .001$, $\eta_p^2= .47$. An interaction between Age and Point Level was also significant, $F(1, 90)= 3.29$, $p< .05$, $\eta_p^2= .07$. Bonferroni corrected alpha level of .02 was used in the following comparisons. Follow-up t-tests showed age differences in the number of studied items for moderate point items, $t(45)= 4.83$, $p< .001$, $d=1.44$, and high point items, $t(45)= 3.83$, $p< .001$, $d=1.14$, but not for low point items, $t(45)= 1.20$, *n*.s. On average, young adults selected more items to study for moderate point items ($M= 4.63$) than older adults ($M= 1.71$), and for high point items ($M_{\text{Young}}=5.39$; $M_{\text{Older}}= 2.63$).

Cognitive Resources

The correlation between the composite scores for the psychometric tests and memory performance was calculated for each point group and each age group. There was age-related difference in the composite scores, $t(91)= 5.11$, $p< .001$, $d=1.07$, where young adults outperformed ($M= 1.12$) than older adults ($M= -1.18$) (Table 17*.).* Cognitive resources were not correlated with either memory improvement or study time. There was a significant correlation between cognitive resources and the number of selected categories only for older adults (for Scaled point group, $r= .75$, $p<.001$, for Consistent point group, $r=.50$, $p<.05$). Finally, the composite score marginally correlated with the total points that participants earned only for young adults in Scaled point group, $r= .40$, $p= .06$.

Preference Ratings

Gamma correlations between study choices (whether or not participant select a topic to study) and preference ratings were calculated. When 2 (Age: Young, Older) x 2 (Point Group: Same, Different) ANOVA was conducted on average gamma correlations, there was a trend toward a significant main effect of age, $F(1, 92)= 2.93$, $p= .09$, $\eta_p^2= .03$. There were no other significant effects. Additionally, the Pearson correlation between the preference and the number of selected items were measured for each participant group. Only Consistent point group young adults demonstrated a trend toward the significance, $r = .36$, $p = .08$. No other effects were observed.

Discussion

Experiment 4 was conducted in order to investigate the possible influence of specific agendas on the efficiency of study time allocation in a simultaneous display format. A simultaneous display format with a specific goal was expected to reduce cognitive burden. In particular, I hypothesized that both age groups would be able to achieve a task goal by studying more valuable information rather than less valuable information. The results regarding memory improvement supported this hypothesis. That is, when items were presented with different point values, both young and older adults demonstrated greater memory improvement for the items with higher point values than items with lower point values. Further, both age groups spent more time studying higher point items than lower point items. These results suggest that both age groups were able to strategically learn more valuable information when items were presented simultaneously. Additionally, older adults spent more time studying items with the same point values than items with different point values, whereas young adults did not differ. This suggests that older adults took greater advantage of different point values than young adults. Cognitive resources neither correlated with control efficiency nor yielded age-related differences in this particular study.

General Discussion

Older adults have shown to demonstrate deficits in metamemorial control in spite of their accurate monitoring. Less effective control can be problematic because it negatively influences subsequent learning. Experiments reported in this dissertation were designed to examine whether cognitive resources would account for age-related differences in metamemorial control efficiency. According to the reduced cognitive resource hypothesis proposed in this dissertation, individuals have a finite pool of cognitive resources they use to encode new information, monitor their own memory, remember specific task goals and constraints, and strategically relearn and store the information. Older adults with reduced cognitive resources may have less cognitive resources available at the time of metamemorial control after engaging in cognitively demanding prior tasks. In this dissertation, cognitive resources were investigated in two ways. Across experiments, I manipulated the cognitive demand of specific tasks. Using cognitively less demanding tasks were expected to result in more effective metamemorial control in older adults. Cognitive resources were also investigated in Experiment 2, 3, and 4 by having participants complete psychometric tests and exploring the relationship between performance on those tests and control efficiency. In Experiment 1 and 2, cognitively demanding tasks prior to metamemorial control were explored in order to reduce cognitive burden in older adults. In Experiment 3 and 4, factors that could influence cognitive resources, and in turn, metamemorial control, were investigated.

Cognitively Less Demanding Semantic Memory Task

Across the four experiments, semantic memory tasks, or general knowledge about the world, were used as stimuli in order to reduce cognitive burden. Access to semantic knowledge may require fewer cognitive resources than episodic knowledge (Light, 1991; Umanath & Marsh, 2014); therefore, using general knowledge questions was expected to be cognitively less demanding. In the four experiments, general knowledge questions with various difficulty levels were used as stimuli. Study time allocation and memory accuracy, and relationships between them were measured as an index to gauge the efficiency of metamemorial control processes. Particularly in Experiment 1, metamemorial control was explored in the context of semantic memory as compared to episodic memory. Both young and older adults performed better on a final recognition test when real general knowledge (semantic memory) was used than when fake general knowledge (episodic memory) was used. Additionally, both age groups spent less time studying real general knowledge items than fake general knowledge items. These results suggest that both age groups demonstrated more effective metamemorial control in a semantic memory task relative to an episodic memory task. This also implies that semantic memory tasks were easier to effectively complete and possibly cognitively less demanding for both age groups than episodic memory tasks.

Vital Monitoring for Effective Control

In order to further reduce cognitive burden, participants were asked to provide memory-irrelevant judgments in Experiment 2. I tested the hypothesis that explicitly providing monitoring judgments would be a cognitively demanding task for older adults, leading to their less efficient control processes. Age-related deficits in metamemorial control were expected to be eliminated when older adults did not provide monitoring judgments. In contrast to this hypothesis, age-related differences were found in correlations between initial memory and study time only in the group who provided monitoring judgments. In the monitoring judgment group, older adults demonstrated stronger correlations between study time and initial memory, whereas this age-related difference disappeared when participants provided memory-irrelevant judgments.

These results can be interpreted in different ways. First, engaging in monitoring processes benefited older adults to a greater extent than young adults. This result is in line with the previous findings on the positive impact of accurate monitoring processes on memory improvement (Thiede et al., 2003). Second, older adults may need to explicitly engage in monitoring processes in order to effectively control their learning behavior. On the other hand, young adults may not need to explicitly provide monitoring judgments, probably because they automatically monitor their memory. That is, young adults may spontaneously engage in monitoring processes, whereas older adults may need external instruction in order to monitor their memory processes. This is in line with the environmental support hypothesis, which suggests that older adults may require external supports when encoding new information as they sometimes fail to engage in self-initiated processing, including spontaneously using more effective encoding strategies (for a review, see Craik & Rose, 2012).

Third, although participants were encouraged to guess the number of words in the questions for memory-irrelevant judgments, these judgments may be cognitively more demanding than monitoring judgments. This may have removed the beneficial effect of metamemorial control on memory that older adults could have when providing monitoring judgments. However, when response time was measured for each participant group, there were no significant differences between Monitoring and No monitoring group for both young, $t(57)= 1.00$, *n.s.* and older adults, $t(60) =.41$, *n.s.* Also, although shallow processing judgments (i.e. counting the number of words in questions) were used in order to ensure that the judgments are not cognitively demanding, using interest judgments based on a previous study (Stine-Morrow et al., 2006) may lead to different results. Finally, although either encoding or retrieval strategies were not manipulated in this particular study, using more cognitively demanding strategies, including rehearsal, may consume more cognitive resources, and lead to impaired control in older adults.

The results in Experiment 2 support the monitoring-affects-control hypothesis (Nelson & Leonesio, 1988). That is, individuals engage in control (e.g. study time allocation) based on their monitoring. In turn, this influences later memory performance. According to this hypothesis, it is crucial to accurately monitor memory. In both Experiment 1 and 2, older adults were able to predict their future memory accurately, which is consistent with previous findings on age-equivalent monitoring accuracy (Souchay et al, 2007; Morson et al., 2014; Morson et al., 2015). That is, older adults were also able to predict their future memory after study as accurately as young adults. Further, both age groups spent more time studying items that they answered incorrectly in the initial test and items that they subjectively thought to be more difficult. However, metamemorial control based on accurate monitoring judgments did not yield effective control in older adults. Longer study time, which influenced by monitoring judgments, did not lead to greater memory improvement in older adults as compared to young adults. While monitoring judgments are crucial for metamemorial control, they may not directly influence memory improvement in older adults.

The Effect of Cognitive Resources on Control

Although the reduced cognitive resource hypothesis postulated that providing monitoring judgments would be cognitively demanding, this was not supported by the results from Experiment 2 in two ways. First, older adults in Monitoring group demonstrated more effective metamemorial control than young adults, but not in No Monitoring group. Second, cognitive resources measured by psychometric tests did not correlate with control efficiency in Experiment 2. This may suggest that studying sequentially presented items for an unlimited amount of time would not be related to cognitive resources, particularly when difficult items were used. That is, when study time is unlimited, individuals frequently select difficult items first to master (i.e. the discrepancy reduction model) for both young and older adults (Dunlosky & Connor, 1997). Indeed, this result from Experiment 2 was replicated in Experiment 3 in that correlations between cognitive resources and study time allocation were not significant for difficult items in the unlimited study time condition. However, there are alternative explanations that may account for these results. First, although previous studies suggest that cognitive resources influence metamemorial control in a sequential display format, the majority of studies used study choice, rather than study time allocation to explore metamemorial control (Ariel, 2012; Dunlosky & Thiede, 2004). That is, differences between selecting items to study and study time allocation may lead to the results in Experiment 2. Second, this may also be due to a small sample size, particularly for older adults in the monitoring group (N=21). Indeed, with a relatively large sample size per participant group (N≥30) in Experiment 3, correlations between cognitive resources and control efficiency were found to be significant, whereas no correlations were found in Experiment 4, where sample size was smaller (N≤24). Finally, psychometric tests that were used may not be attuned to measuring cognitive resources. For example, a forward digit span task was used to measure cognitive resources, rather than a backward digit span task. Although a previous study suggests that a magnitude of age-differences between backward and forward digit span tasks did not differ remarkably (Babcock & Salthouse, 1990), a forward digit span task may not directly measure cognitive resources. Further, processing speed measurements were not included in psychometric tests based on previous findings suggesting that monitoring judgments (e.g. FOK) and control (e.g. using effective encoding strategies) were explained by executive functioning rather than speed of processing (Bryan et al., 1999; Perrotin et al., 2006). However, processing speed may play a crucial role in determining the allocation of cognitive resources (Salthouse, 1996).

The Influences of Available Study Time on Control. In both Experiments 1 and 2, metamemorial control was measured in the context of unlimited study time with a sequential item display format. Unlimited study time allows participants to spend as much time as they desire, and individuals typically select difficult items to study (Dunlosky & Hertzog, 1997). Indeed, both young and older adults spent more time studying difficult items in both Experiment 1 and 2. On the other hand, when study time is limited, individuals need to strategically focus on items that can be easily mastered. In Experiment 3, I hypothesized that limited study time may require more cognitive resources than unlimited study time. Further, learning easier items in a sequential display format for a limited amount of time would be cognitively demanding, and thus correlate with cognitive resources.

The results demonstrated distinct patterns of correlations between study time and cognitive resources depending on the available study time. When study time was unlimited, both young and older adults demonstrated negative correlations between study time and cognitive resources for easy and medium difficulty items for both age groups. That is, for both age groups, higher cognitive resources related to less study time for easy and medium items, whereas no correlation was found for difficult items when study time was unlimited. This replicates the results from Experiment 2, where no correlations between study time and cognitive resources were found with unlimited study time when general knowledge questions were difficult. This was in line with data regarding memory improvement, where no age-differences were found for difficult items. These results suggest that when study time is unlimited, learning difficult items in a sequential display format may not be cognitively demanding as it has been found regardless of age (Dunlosky & Connor, 1997).

In contrast, when study time was limited, cognitive resources correlated differently with study time depending on the age groups. For older adults, greater cognitive resources were correlated with less study time for easy items and with better memory for medium difficulty items. This suggests that, although older adults remember fewer medium difficulty items than young adults on average, higher cognitive resources may lead older adults to learn more medium difficulty items. This is in line with previous findings that suggest older adults engaged in greater executive functioning than young adults in order to compensate for their age-related declines in episodic memory (Bouazzaoui et al., 2013; Bouazzaoui,et al., 2014). Further, higher cognitive resources in older adults may relate to their awareness that easy items are likely to be already known items. On the other hand, for young adults, cognitive resources negatively correlated with study time for difficult items and positively correlated with memory accuracy of easy items. That is, higher cognitive resources in young adults may relate to more awareness that difficult items are less likely to be mastered with a limited amount of time. This suggests that, with more cognitive resources, both age groups may be able to selectively focus on the unknown easier items within limited study time even with a sequential display format. However, these results need to be interpreted with caution because the psychometric tests that were used in this dissertation may not fully measure cognitive resources.

The influences of Display Formats on Control. In Experiment 1, 2, and 3, to-be-studied items were presented individually. This sequential display format may require more cognitive resources than a simultaneous display format, particularly when study time is limited. In a sequential format, participants need to continuously keep relevant information, including the number of additional items that they need to study, the amount of time left, and whether they would have time to study difficult items or would need to skip to the next item. On the other hand, in a simultaneous format, participants may be more easily able to take into account those factors when studying the items. In order to explore if a simultaneous format would be cognitively less demanding and lead to efficient metamemorial control in older adults, a simultaneous display format was used in Experiment 4. When data from a control group with less specific goals (Consistent point group) were separately analyzed on memory improvement, the differences between medium difficulty and difficult items were not significant, whereas there was significant difference between easy and medium items for both age groups. These results were in line with study time allocation: both age groups spent more time studying difficult items, followed by medium and easy items.

In order to compare control efficiency in a sequential and a simultaneous display format, the limited study time block in Experiment 3 were separately measured. A 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on memory improvement (Table 10.). Main effects of Difficulty Level, $F(2, 120)= 55.56$, $p< .001$, η_p^2=.48, and Age were found, $F(1, 60)= 11.99$, $p< .01$, η_p^2=.17. Further, a significant interaction between Age and Difficulty Level was found, $F(2, 120)= 4.9$, $p<.01$, η_p^2=.08. When a Bonferroni corrected alpha level of .02 was used, a significant age difference was found only for medium difficulty items, $t(60)= 4.33$, $p<.001$, $d=1.12$. These results suggest that when items were presented sequentially, young adults demonstrated greater memory improvement only for medium difficulty items (*M*= .40) than older adults (*M*= .22). These age-related differences on memory improvement for medium difficulty items disappeared when items were presented simultaneously in Experiment 4.

Further, a 2 (Age: Young, Older) x 3 (Difficulty Level: Easy, Medium, Difficult) mixed ANOVA was conducted on average study time in Experiment 3 for the limited study time block

(*Table 11)*. Significant main effects of Difficulty Level, $F(2, 120)= 116.69$, $P<.001$, $\eta_p^2=.66$, was found. When a Bonferroni corrected alpha level of .02 was used, both age groups spent significantly more time studying difficult items ($M=1.82$ sec) than medium difficulty items (M=2.34 sec), $t(61)= -7.09$, $p< .001$, $d=1.82$, followed by easy items (M=3.93 sec), t(61)= 9.52, $p<.001$, $d=.2.44$. No further effects were significant. The results were consistent with the finding from Experiment 4 where both age groups spent more time studying difficult items than easier items.

The results from Experiment 3 and 4 suggest that both age groups used a similar strategy for study time allocation in both simultaneous and sequential display formats under time constraints: spending more time studying difficult items than easier items. This learning strategy yielded different memory improvement depending on display formats. In a sequential format, young adults gained more than older adults only for medium difficulty items, whereas these age-related differences eliminated in a simultaneous display format. This suggests that when study time is limited, learning medium difficulty items may be cognitively taxing in a sequential display format for older adults. However, this comparison between Experiment 3 and 4 should be interpreted with caution since two experiments employed different experimental designs.

Specific Agendas for Effective Control

In Experiment 4, various point values were assigned to each general knowledge topic to explore the influence of specific goals on control. Results suggest that both young and older adults demonstrated greater improvement for easy items than medium or difficult items, yet no difference was observed between medium and difficult items. This differs from Experiment 3, where participants showed a greater improvement for difficult than medium difficulty items. When items were presented simultaneously, participants may be able to strategically learn fewer difficult items under time constraints. In terms of study time allocation, age-related differences were greater when various point values were presented as compared to when the same point values were presented. For the different point group, both young and older adults spent more time studying higher point items than lower point items. This led to greater memory improvement in higher point items than lower point items. These results suggest that although older adults spent more time studying items than young adults on average (i.e. less efficient control), older adults were able to strategically use a limited study time in order to achieve a goal (effective control).

Reduced Cognitive Resource Hypothesis

Previous research suggests that older adults need extra support to utilize more efficient and effective encoding strategies when learning new information due to their fewer cognitive resources (i.e. environmental support hypothesis; Craik, 1986; Froger et al., 2012; Sauzéon, Rodrigues, Corsini, & N'Kaoua, 2013). In a previous study, environmental support was manipulated at the encoding of word pairs. Participants were either presented with none of the encoding strategies, three different strategies (generating a sentence, repeatedly memorizing, and using an imagery technique), or three different strategies and information on their effectiveness. The results suggest that older adults were able to use the most effective encoding strategy, i.e. imagery technique, only when the environmental encoding support was provided. However, young adults were able to spontaneously select the most effective encoding strategy whether or not the encoding supports were provided.

In a similar vein, the reduced cognitive resource hypothesis suggests that older adults may require extra support in order to effectively engage in metamemorial control. Across the four experiments, the reduced cognitive resources hypothesis was partially supported. First, the use of cognitively less demanding tasks, i.e. semantic memory tasks, resulted in more efficient metamemorial control processes when compared to using an episodic memory task in both age groups. Further, older adults demonstrated more accurate semantic memory as compared to young adults in the first place. Using general knowledge that does not require participants to remember the contextual details reduces cognitive burden, which is in a line with the necessary environmental support for older adults when encoding episodic memory. However, more study time that older adults spent did not translate into their greater memory improvement relative to young adults. Although this suggests that older adults may not be as efficient as young adults, both age groups demonstrated effective control to improve their memory. Further, older adults studied longer and learned more difficult items than easy items even when study time was limited. This may suggest that older adults consider themselves experts of genera knowledge. Indeed, previous studies demonstrated that bilingual speakers of Spanish and English selected more difficult Spanish words to learn within limited study time, whereas second language learners of Spanish selected easier words to study under time constraints (Metcalfe, 2002; Metcalfe & Kornell, 2003).

The reduced cognitive resource hypothesis also postulates that monitoring judgments would be cognitively taxing for older adults, resulting in their less effective control. However, in contrast to this hypothesis, monitoring judgments did not result in less efficient control in older adults. Rather, regardless of monitoring, young adults demonstrated greater memory improvement with less study time. Further, providing explicit monitoring resulted in stronger correlations between initial memory test and study time only for older adults as compared to when monitoring was not explicit. These results did not support the reduced cognitive hypothesis, which postulates that explicit monitoring would lead to less efficient control in older adults.

In Experiment 3 and 4, I manipulated the factors that influence metamemorial control, including item difficulty levels, available study time, and display formats. Cognitive resources were related with metamemorial control for relatively easier items, particularly when items were sequentially presented. In particular, greater cognitive resources were related with less study time for relatively easier items when study time was unlimited. When study time was limited, greater cognitive resources were related with less study time for more difficult items in young adults. For older adults, greater cognitive resources were related with less study time for easier items. This indicates that both age groups are likely to demonstrate effective study time allocation with higher cognitive resources. That is, spending less time studying difficult items under time constraints can be effective since difficult items require more time and effort to master. Spending less time studying easy items under time constraints can be also effective since individuals often need to exclude already-known items for study and focus on unknown easier items. Therefore, in a sequential display format, cognitive resources may play a crucial role in order to engage in effective metamemorial control. Further, both young and older adults were able to learn more valuable items when items were presented simultaneously under time constraints. As the reduced cognitive resource hypothesis postulates, presenting specific goals may reduce the cognitive demand in metamemorial control, resulting in successful goal-directed control processes in both young and older adults.

In order to fully understand age-related differences in metamemorial control in the present studies, the reduced cognitive resource hypothesis can be revised to deemphasize the cognitive burden that explicit monitoring judgments may cause. That is, monitoring may be cognitively taxing; however, it is essential for metamemorial control, particularly for older adults. Further, in order to overcome limitations in the present studies, a larger number of participants may be required. This may increase the probability of finding significant correlations between cognitive resources and control. Also, finding causal effect, rather than correlation, would be useful in supplementing the limitations in the present studies. This can be done by recruiting individuals with higher cognitive resources and individuals with lower cognitive resources. Comparing participants in full attention with those with in divided attention can be another way to investigate the causal effect of cognitive resources on control. Finally, in order to ensure the cognitive resources are fully available for both psychometric tests and metamemorial control tests, separately conducting those two sets of tests would be ideal. Collectively, present studies offer insight to ways to overcome potentially less effective control in older adults: reducing cognitive burden on older adults and presenting a specific goal to achieve.

Table 1. Participant Information (Experiment 1)

	Young (N= 31)	Older (N=33)
	M (SD)	M (SD)
Age	18.83 (.99)	75.93 (7.28)
Gender	Male= 9; Female= 22	Male= 14; Female =19
Race	C= 19; B= 1; A= 7; O=4	C= 33
Years of Education	13.6 (.89)	16.07 (2.94)**
Vocabulary Test	32.43 (3.54)	34.55 (3.90)*
MMSE	N/A	29.03 (1.26)

* indicates significant effects from independent t-tests between young and older adults.
* significant at $p < .05$; ** significant at $p < .01$
N/A means analyses could not be conducted.
For racial information, C stands for Caucasians, B stands for African Americans, A refers to Asians, and O stands for others.

Table 2. Participant Information (Experiment 2)

	Young (N=61)	Older Adults (N=65)
	M (SD)	M (SD)
Age	19.13 (1.15)	73.45 (7.57)
Gender	Male=27; Female= 34	Male=17; Female=48
Race	C=41; B=3; A=12; O=5	C=58; B=2; A=1; O=3
Years of Education	14.31 (1.62)	17.00 (3.32)***
Vocabulary Test	32.20 (3.03)	34.23 (5.60)**
MMSE	N/A	29.90 (1.37)
Computer Experiences		
Frequency of usage	7.00 (.00)**	6.40 (1.47)
Comfort to use a computer	3.95 (.22)***	3.39 (.71)
Number of electronic devices	2.30 (.89)**	1.67 (1.14)

* indicates significant effects from independent t-tests between young and older adults.
* significant at $p < .05$; ** significant at $p < .01$
N/A means analyses could not be conducted.
For racial information, C stands for Caucasians, B stands for African Americans, A refers to Asians, and O stands for others.
A question on frequency of computer usage used a scale from 1 to 7 (1=never, 7=Everyday); Comfort to use a computer used a scale from 1 to 4 (1= Feel anxious, 4= very comfortable)

Table 3. Participant Information (Experiment 3)

	Young (N=31)	Older (N=30)
	M (SD)	M (SD)
Age	18.5 (.95)	69.97 (12.35)
Gender	Male= 9; Female= 22	Male=11; Female= 19
Race	C= 21, A=6, O= 4	C=29; A=1
Years of Education	13.72 (1.08)	18.43 (11.56)*
Vocabulary Test	32.34 (3.22)	36.07 (3.23)*
MMSE	N/A	29.36 (.95)
Computer Experiences		
Frequency of Usage	7.00 (0)***	5.9 (2.09)
Comfort to use a computer	3.91 (.26)***	3.33 (.80)
Number of electronic devices	2.81 (1.7)***	1.1 (.99)

* indicates significant effects from independent t-tests between young and older adults.
* p< .05; ** p<.01
N/A means analyses could not be conducted.
For racial information, C stands for Caucasians, B stands for African Americans, A refers to Asians, and O stands for others.
A question on frequency of computer usage used a scale from 1 to 7 (1=never, 7=Everyday); Comfort to use a computer used a scale from 1 to 4 (1= Feel anxious, 4= very comfortable)

Table 4. Participant Information (Experiment 4)

	Young (N=49)	Older (N=48)
	M (SD)	M (SD)
Age	18.86 (.74)	68.81 (7.84)
Gender	Male= 22; Female= 27	Male= 12; Female= 36
Race	C= 34, B= 3, A= 5, O= 7	C= 44, B= 2, O= 2
Years of Education	13.98 (.85)	17.17 (2.71)**
Vocabulary Test	32.80 (2.72)	35.35 (4.67)**
MMSE	N/A	29.35 (.95)
Computer Experiences		
Frequency of Usage	6.98 (.14)***	6.17 (1.67)
Comfort to use a computer	3.94 (.25)***	3.27 (.84)
Number of electronic devices	2.58 (1.09)***	1.60 (.97)

* indicates significant effects from independent t-tests between young and older adults.
* $p < .05$; ** $p < .01$
N/A means analyses could not be conducted.
For racial information, C stands for Caucasians, B stands for African Americans, A refers to Asians, and O stands for others.
A question on frequency of computer usage used a scale from 1 to 7 (1=never, 7=Everyday); Comfort to use a computer used a scale from 1 to 4 (1= Feel anxious, 4= very comfortable)

Table 5. Memory Accuracy (Experiment 1)

	Real General Knowledge		Fake General Knowledge	
	Young M (SD)	Older M (SD)	Young M (SD)	Older M (SD)
Initial Test				
All items	.43 (.16)	.53 (.16)*	N/A	N/A
Later Studied	.30 (.16)	.39 (.23)	N/A	N/A
Final Test				
All Items	.88 (.07)	.92 (.03)*	.83 (.19)	.81 (.17)
Studied Items	.94 (.07)	.97 (.04)	.83 (.19)	.81 (.17)
Memory Improvement	.64 (.16)	.57 (.23)	.83 (.19)	.81 (.17)

* indicates significant effects from independent t-tests between young and older adults.
* p< .05; ** p<.01
N/A means analyses could not be conducted.

Table 6. Metamemory (Experiment 1)

	Real General Knowledge		Fake General Knowledge	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Average Study Time (sec.)	3.74 (1.63)	6.15 (3.91)**	5.11 (3.18)	8.45 (4.12)**
Gamma				
FOK and Final Test	.63 (.25)	.53 (.29)	N/A	N/A
STA and Initial Test	-.52 (.28)	- .49 (.31)	N/A	N/A
STA and Final Test	-.14 (.40)	.03 (.44)	.12 (.44)	.06 (.26)
FOK and STA Test	-.18 (.14)	-.19 (.20)	-.21 (1.3)	.02 (3.11)

* indicates significant effects from independent t-tests between young and older adults
* p< .05; ** p<.01 ; *** p< .001
N/A means analyses could not be conducted.

Table 7. Memory Accuracy (Experiment 2)

	Monitoring group		No monitoring group	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Initial Test	.18 (.11)	.36 (.20)***	.21 (.12)	.31 (.22)*
Final Test	.60 (.17)	.72 (.24)*	.67 (.16)	.66 (.23)
Memory Improvement	.41 (.14)	.37 (.12)	.46 (.12)	.34 (.13)**

* indicates significant effects from independent t-tests between young and older adults
* p< .05; ** p<.01 ; *** p< .001

Table 8. Metamemory (Experiment 2)

	Monitoring group		No monitoring group	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Average Study Time (sec.)	3.85 (2.15)	5.75 (2.08)**	3.62 (1.24)	5.54 (2.02)***
Gamma				
Monitoring and Initial Test	.80 (.22)	.81 (.17)	N/A	N/A
Monitoring and Final Test	.43 (.27)	.38 (.52)	N/A	N/A
STA and Initial Test	-.53 (.33)	-.75 (.23)**	-.62 (.32)	-.61 (.38)
STA and Final Test	-.22 (.23)	-.23 (.34)	-.28 (.21)	-.27 (.27)
Monitoring and STA	-.19 (.21)	-.35 (.20)**	N/A	N/A

* indicates significant effects from independent t-tests between young and older adults, except for correlations, where * indicates a significance of Pearson r.
* p< .05; ** p<.01 ; *** p< .001
N/A means analyses could not be conducted.

Table 9. Cognitive Resources (Experiment 2)

	Monitoring group		No monitoring group	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Cognitive Resources				
Psychometric tests				
Digit Span	7.38 (1.59)**	6.29 (1.21)	8.14 (1.04)***	6.33 (.92)
Mental Control	30.78 (4.93)**	25.62 (5.49)	29.03 (6.57) *	23.97 (3.93)
Stroop Task	.04 (.02)	.04 (.02)	.03 (.02)	.02 (.08)
Wisconsin Card Sorting	15.76 (4.79)*	20.13 (4.26)	13.46 (10.66)**	19.71 (11.19)
Composite Scores	1.52 (1.96)**	.75 (2.24)	-.58 (2.19)***	-1.57 (2.52)
Correlation with Study Time	$r = .19$	$r = -.05$	$r = .19$	$r = .04$
Correlation with Memory	$r = .57$**	$r = -.16$	$r = .14$	$r = .25$

* indicates significant effects from independent t-tests between young and older adults, except for correlations, where * indicates a significance of Pearson r.
* p< .05; ** p<.01 ; *** p< .001
N/A means analyses could not be conducted.

Table 10. Correlations between Psychometric Tests (Experiment 2)

	Mental Control	Digit Span	Card Sorting	Stroop	Age
Mental Control	-				
Digit Span	.43**	-			
Card Sorting	-.22*	-.19*	-		
Stroop	*n.s.*	*n.s.*	*n.s.*	-	
Age	-.43**	-.40**	.22*	*n.s.*	-

* p< .05; ** p<.01

Table 11. Memory Accuracy (Experiment 3)

	Unlimited Study Time		Limited Study Time	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Easy				
Initial Test	.72 (.23)	.86 (.09)	.77 (.18)	.94 (.14)
Final Test	.95 (.07)	.96 (.06)	.95 (.07)	.95 (.08)
Memory Improvement	.22 (.19)	.11 (.08)	.17 (.13)	.11 (.13)
Medium				
Initial test	.51 (.21)	.64 (.16)	.53 (.21)	.63 (.19)
Final Test	.92 (.10)	.92 (.11)	.93 (.08)	.86 (.16)
Memory Improvement	.41 (.18)	.28 (.11)	.40 (.18)	.22 (.15)
Difficult				
Initial test	.03 (.04)	.14 (.14)	.03 (.04)	.16 (.14)
Final Test	.54 (.22)	.62 (.24)	.46 (.19)	.57 (.21)
Memory Improvement	.51 (.21)	.48 (.22)	.40 (.18)	.51 (.17)

Table 12. Metamemory (Experiment 3)

	Unlimited Study Time		Limited Study Time	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Easy				
Average Study Time (sec.)	2.15 (.95)	2.44 (1.16)	1.83 (.77)	1.81 (.64)
Gamma				
STA and Initial Test	-.86 (.12)	-.73 (.33)	-.87 (.16)	-.67 (.41)
STA and Final Test	.05 (.70)	-.40 (.44)	-.32 (.53)	-.67 (.25)
Medium				
Average Study Time (sec.)	3.29 (1.80)	3.10 (1.11)	2.21 (.69)	2.48 (1.03)
Gamma				
STA and Initial Test	-.88 (.21)	-.74 (.23)	-.96 (.06)	-.70 (.27)
STA and Final Test	-.19 (.23)	-.50 (.21)	-.23 (.54)	-.20 (.29)
Difficult				
Average Study Time (sec.)	6.24 (3.56)	6.24 (3.08)	4.08 (1.59)	3.86 (1.30)
Gamma				
STA and Initial Test	-.72 (.49)	-.74 (.43)	-.90 (.08)	-.83 (.22)
STA and Final Test	-.50 (.22)	.11 (.39)	.11 (.39)	-.34 (.14)

Table 13. Cognitive Resources (Experiment 3)

	Young M (SD)	Older M (SD)
Cognitive Resources		
Digit Span	8.88 (1.48)	7.41 (1.35)
Mental Control	29.73 (4.02)	27.07 (5.36)
Stroop Task	.03 (.06)	.04 (.03)
Wisconsin Card Sorting	13.90 (5.06)	20.76 (11.65)
Composite Score	.92 (2.55)	-1.42 (2.20)
Correlation with Study Time		
Unlimited		
Easy	*r*= -.62*	*r*= -.43*
Medium	*r*= -.60*	*r*= -.37*
Difficult	*n.s.*	*n.s.*
Limited		
Easy	*n.s*	*r*= -.40*
Medium	*n.s.*	*n.s*
Difficult	*r*= -.52*	*n.s*
Correlation with Memory		
Unlimited		
Easy	*n.s*	*r=.40**
Medium	*r*= .41*	*n.s*
Difficult	*n.s*	*n.s*

Table 14. Correlations between Psychometric Tests (Experiment 3)

	Mental Control	Digit Span	Card Sorting	Stroop	Age
Mental Control	-				
Digit Span	*n.s.*	-			
Card Sorting	*n.s.*	*n.s.*	-		
Stoop	*n.s.*	*n.s.*	*n.s.*	-	
Age	*n.s.*	-.47**	.32*	*n.s.*	-

* p< .05; ** p<.01

Table 15. Memory Accuracy (Experiment 4)

	Scaled point group		Consistent point group	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Easy				
Initial Test	.77 (.09)	.77 (.19)	.74 (.13)	.86 (.12)
Final Test	.86 (.07)	.83 (.17)	.89 (.10)	.94 (.14)
Memory Improvement	.09 (.08)	.05 (.07)	.09 (.08)	.04 (.07)
Medium				
Initial test	.40 (.17)	.52 (.26)	.37 (.14)	.54 (.19)
Final Test	.60 (.16)	.64 (.25)	.58 (.21)	.68 (.19)
Memory Improvement	.21 (.11)	.13 (.10)	.21 (.13)	.14 (.08)
Difficult				
Initial test	.15 (.14)	.30 (.21)	.13 (.08)	.33 (.18)
Final Test	.36 (.17)	.46(.26)	.33 (.15)	.51 (.23)
Memory Improvement	.21 (.09)	.16 (.10)	.20 (.10)	.18 (.09)

Table 16. Metamemory (Experiment 4)

	Scaled point group		Consistent point group	
	Young	Older	Young	Older
	M (SD)	M (SD)	M (SD)	M (SD)
Easy				
Average Study Time (ms.)	386.41 (181)	421.32 (273)	383.68 (182)	398.76 (294)
Gamma				
STA and Initial Test	-.54 (.35)	-.53 (.78)	-.28 (.45)	-.59 (.39)
STA and Final Test	.08 (.71)	.55(.42)	-.40 (.69)	-.18 (.89)
Medium				
Average Study Time (ms.)	618.28 (252)	724.86 (289)	534.50 (253)	867.15 (274)
Gamma				
STA and Initial Test	-.20 (.40)	-.52 (.83)	-.14 (.49)	-.36 (.73)
STA and Final Test	.11 (.68)	.15 (.49)	-.04 (.59)	-.25 (.69)
Difficult				
Average Study Time (ms.)	721.79 (265)	1014.12 (400)	588.51 (240)	1213.46 (446)
Gamma				
STA and Initial Test	-.41 (.57)	-.70 (.48)	-.29 (.55)	-.58 (.58)
STA and Final Test	-.36(.25)	-.27 (.22)	-.12 (.42)	.07 (.52)

Table 17. Cognitive Resources (Experiment 4)

	Young M (SD)	Older M (SD)
Cognitive Resources		
Digit Span	8.67 (1.24)	7.67 (1.24)
Mental Control	30.17 (4.43)	27.88 (5.78)
Stroop Task	.004 (.14)	.04 (.03)
Wisconsin Card Sorting	.14.58 (4.63)	19.98 (9.96)
Composite Score	.17 (1.17)	-.19 (1.95)

Table 18. Correlations between Psychometric Tests (Experiment 4)

	Mental Control	Digit Span	Card Sorting	Stroop	Age
Mental Control	-				
Digit Span	.25*	-			
Card Sorting	-.30**	-.29**	-		
Stroop	*n.s.*	*n.s.*	*n.s.*	-	
Age	-.24*	-.45**	.37**	*n.s.*	-

* p< .05; ** p<.01

Figure 1. Usages of Cognitive Resources

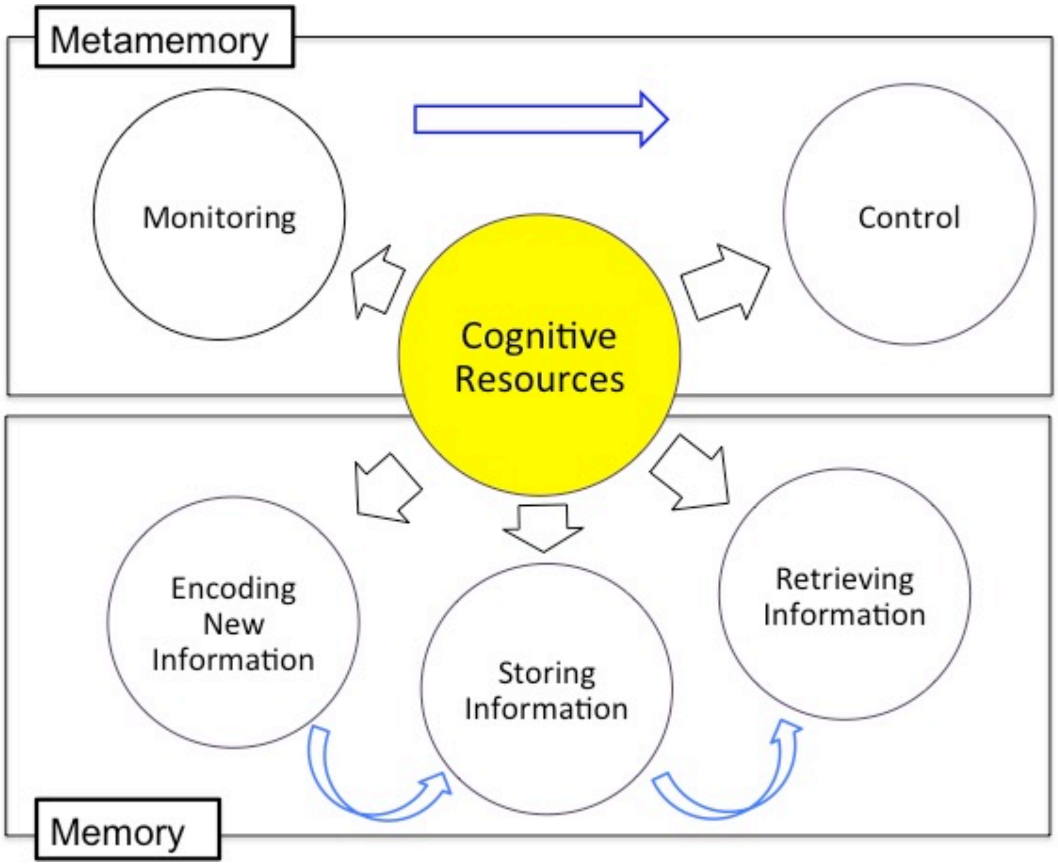

Figure 2. Examples of Category Choice in Study Phase in Experiment 4.

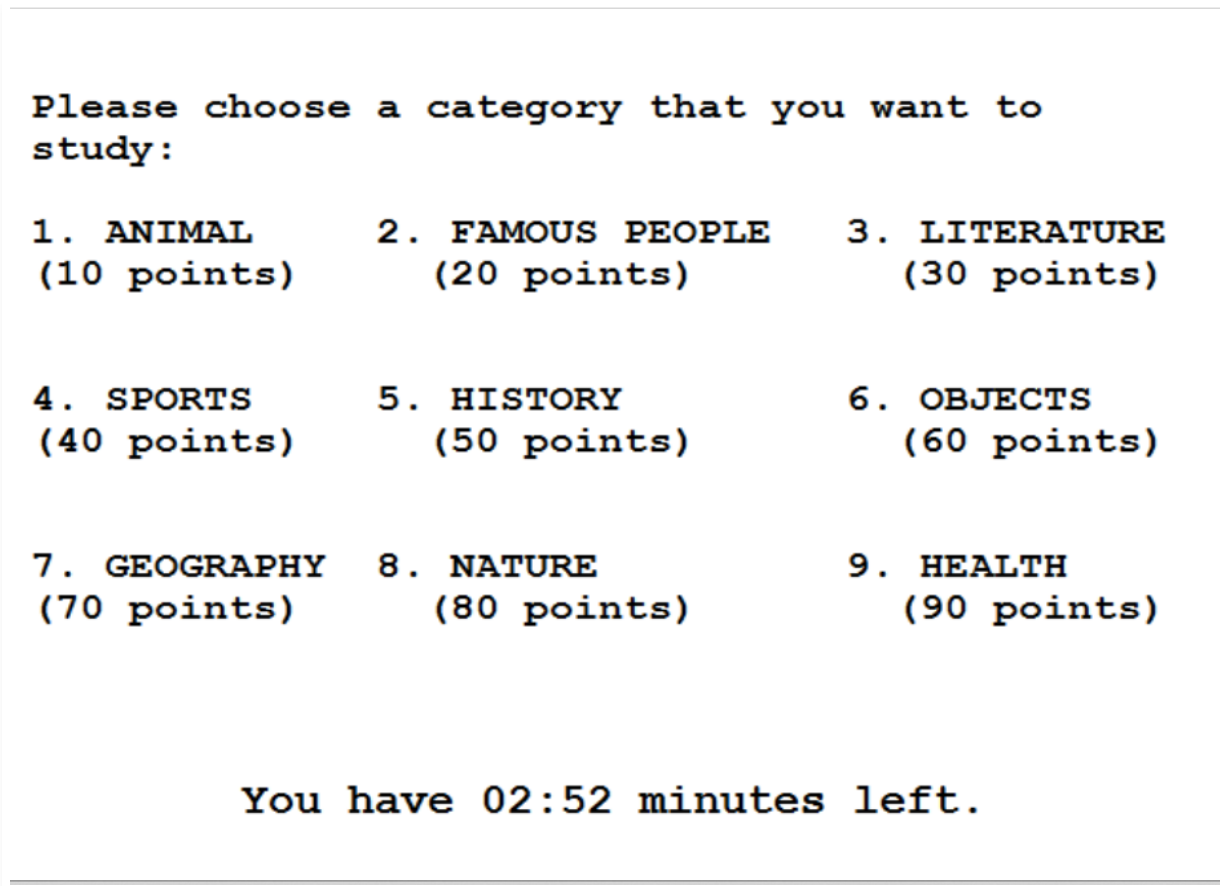

Figure 3. Examples of Question List in Study Phase in Experiment 4

1. What is the last name of the boy in the book "Treasure Island"?
2. What is the last name of the man who wrote the "Star Spangled Banner"?
3. What is the last name of the author who wrote "Romeo and Juliet"?
4. What is the name of Dorothy's dog in "The Wizard of Oz"?
5. What is the name of Tarzan's girlfriend?
6. What is the only word that raven says in Edgar Allen Poe's poem "The Raven?"
7. What is the last name of the author of "The Agony and the Ecstasy"?
8. What is the last name of the author who wrote "Oliver Twist"?
9. What is the last name of the author who wrote "The Old Man and the Sea"?

Please press the number to see the answer of the question.
Also, press "b" to go back to the category list.

You have 02:46 minutes left.

Appendix

Glossary

Control efficacy: memory improvement regardless of efficiency

Control efficiency: memory improvement after self-paced learning with a limited study time

Cognitive resources: a limited amount of resources that are necessary in order to successfully engage in cognitive tasks, such as working memory capacity and processing speed

Discrepancy reduction model: one of the models to explain metamemorial control; suggesting that individuals attempt to master the most difficult items first in order to reduce the discrepancy between their desire to master this new study material and their current state of mastery

Ease of learning (EOL) judgment: monitoring assessment of the levels of ease-and-difficulty for to-be-learned items

Feeling of knowing (FOK) judgment: monitoring assessment of the likelihood of successfully recognizing items that are currently not recalled

Judgment of learning (JOL): monitoring assessment of the likelihood of successfully recalling or recognizing items during learning

Region of proximal learning model: one of the models to explain metamemorial control; individuals attempt to study the unknown easier items to master first when given certain time constraints unless they were subject matter experts

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