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PICTURE SUPERIORITY EFFECT IN PROSPECTIVE MEMORY: EXAMINING THE INFLUENCE OF AGE AND ATTENTION LOAD

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PICTURE SUPERIORITY EFFECT IN PROSPECTIVE MEMORY: EXAMINING THE INFLUENCE OF AGE AND ATTENTION LOAD

A Dissertation
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Doctor of Philosophy
Human Factors Psychology

by
Nicole Fink
May 2013

Submitted to:
Dr. Richard Pak, Committee Chair
Dr. Giles Einstein
Dr. Leo Gugerty
Dr. Paul Merritt
ABSTRACT

The picture superiority effect (i.e. better memory for pictures than words) is well established in retrospective memory, but the examination of the picture superiority effect in prospective memory has been underrepresented in the literature. Understanding if pictures lead to better prospective memory than words has the theoretical benefit of increasing our understanding of what particular factors lead to spontaneous retrieval and the practical benefit of informing the design of memory aids. Additionally, I examine if there are differences in ongoing task and prospective memory task performance between age groups (old and young) and under different loads of attention (non-divided and divided). I hypothesized that pictures are more distinct than words, and will therefore promote spontaneous retrieval, which will be exhibited by high and stable performance in the picture (not word) conditions across both divided and non-divided attention tasks and equivalent prospective memory performance by younger and older adults in only the picture, not word conditions. Results demonstrated that a picture superiority effect does exist for prospective memory tasks. Participants viewing all picture stimuli not only remembered to perform the PM task more often than participants who viewed all word stimuli, they also performed the ongoing categorization task faster. Although my hypotheses were not fully supported, there is evidence for picture stimuli leading to spontaneous retrieval more than word stimuli. An applied example of how pictures can help alleviate memory demands is provided through a first-hand account of a newly diagnosed Type 1 diabetic’s daily task of insulin administration.
DEDICATION

I dedicate this manuscript to Bubbie and Zadie, my 83 year old grandmother and 92 year old grandfather with strength and spirit to be admired.
ACKNOWLEDGEMENTS

I would first like to thank my sister and ultimate best friend Kelly for always being there for me when I need to laugh, vent, celebrate, or cry. You truly brought me back to life this past year and I love you so incredibly much. Thank you momma for being such a wonderful nurturer, raising me my whole life and loving me unconditionally through the good times and bad. Also thanks for making school such a top priority in my life; I did it! Thank you daddy for teaching me that there’s no such thing as a bad question, honesty is the best policy, and a positive attitude is crucial. I am grateful for my aunt and cousins, for opening up their home and heart to me this last half year when I was starting a new job, working on a dissertation, and two months after moving in diagnosed with Type 1 Diabetes and chronic heart failure; I am so thankful for how close we have grown. Bubbie and Zadie, without your love and guidance I would not be the person I am today. Thank you for all you have done to support me my entire life.

Thank you Lairla, Alexa, Sarah, Vanessa, and Maria for your never ending love, laughs, and encouragement. I am so grateful for you Margaux, my labmate that I met the first day of graduate school who has turned into a lifelong best friend. Your constant listening ear, feedback, and hope are unparalleled. Thank you Jeremy, my other labmate, for all of you feedback and help with technical issues. I would also like to thank my advisor and committee chair Dr. Richard Pak for always being willing to bounce ideas around, provide feedback, and go rock-climbing. I am grateful for the relationship we have forged these past 6 years and view you as both a mentor and a friend. I am so appreciative for the time and effort that you and the rest of my committee members, Dr. Gil Einstein, Dr. Lee Gugerty, & Dr. Paul Merritt, have put into my dissertation. All of the feedback has helped me to become a better researcher, writer, and critical thinker. Finally, I gratefully acknowledge the assistance of Meghan Goodwin and Natalee Cartee for their help throughout the course of this study.
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CHAPTER ONE

INTRODUCTION

Imagine a typical to-do list that spells out the tasks you need to perform over the next few days. Now imagine that same list, except all of the words about people, places, and objects were replaced with images. Instead of the words, “Meet Kelly at library at 2pm”, you would see pictures of Kelly’s face, the front of the library building, and a clock face set to 2pm. Would you remember to complete more tasks using the picture to-do list or the word to-do list?

The picture superiority effect suggests that you would remember to complete more tasks with the picture to-do list. The picture superiority effect is the well-established experimental finding in retrospective memory research that people exposed to stimuli in picture format perform better on explicit retrospective memory tests than people exposed to the same stimuli in word format. These studies are, however, limited to retrospective memory, where there is an explicit cue to prompt recall. Prospective memory tasks, like those on a to-do list, require self-initiated recall (if no memory aid is used); a person must remember on their own to perform a task when the appropriate cue appears. The question of whether the picture superiority effect exists in prospective memory (i.e., pictures help a person remember to perform a task more often than words), has been severely underrepresented in the literature, and is thus the focus of this paper. Additionally, by manipulating age (i.e. young and old adults) and attention load (i.e.
divided or non-divided), we seek to examine if pictures lead to automatic recall of prospective memory intentions, otherwise known as spontaneous retrieval.

**The Picture Superiority Effect in Retrospective Memory**

Numerous studies have found that when participants are given a list of either pictures or words, and later asked to recall or recognize the stimuli they previously saw, those who saw pictures tend to remember more items than those who saw words (Maistro & Queen, 1992; Pavio, 1971; Shepard, 1967; experiment 1, Winograd, Smith, & Simon 1982). In one picture superiority effect study, Rajaram et al. (1993, experiment 2) displayed both words and pictures to participants on a computer at a rate of 1 every 5 seconds. Following a 15-minute retention interval, participants were given a booklet containing both studied and non-studied items in word form and were asked to indicate whether or not they had seen the item before. If the item was recognized they were asked to indicate if they “remember the word was on the list or [if they] just know on some other basis.” This methodology assumes that remember judgments appear to tap into conscious episodic memory while know judgments do not.

Participants recognized more previously presented pictures (.90) than previously presented words (.69). False positive responses were low (.09) indicating that it was rare for a participant to say they remembered a stimulus and be wrong. When recognition was further broken down into remember or know, pictures were categorized as remember significantly more often (.81) than words (.51), with a very low false positive rate of .01. Words, however, were categorized as know (.18) more often than pictures (.09), with a false positive rate of .08.
The picture superiority effect was also found in a study by Dewhurst & Conway (1994, experiment 1), who presented mixed lists of pictures and words to participants and had them write down the word or the name of the object they saw. The participant controlled the rate of stimuli presentation by pressing spacebar. After an hour long delay period, participants engaged in an electronic recollection test very similar to that of Rajaram et al. (1993) where they were presented with words and asked to indicate if they remember seeing it in either form previously; if yes, they should indicate ‘remember’ or ‘know’. Participants recognized significantly more picture stimuli as remember (.77) than word stimuli (.31), but word stimuli were recognized as know (.28) more often than picture stimuli (.15). False positive responses were low.

Maistro & Queen (1992) presented pure lists of pictures, words, or pictures with word labels to either older or younger adults, forming six between participant conditions. A stimulus was presented once every five seconds on a slide projector. After a delay period, participants were instructed to list as many of the stimuli that they could remember. Despite being a recall instead of recognition task, a picture superiority effect was still apparent. Both young and old participants, when presented with pictures, recalled significantly more items than participants presented with words. Young adults recalled a mean number of 17.3 words and 23.2 pictures, while older adults recalled 15.5 words and 19.5 pictures.

Another picture superiority effect study presented participants with 100 stimuli, 25 displayed in each of 4 conditions, at a rate of 2 sec per slide. There were 3 picture conditions (color photographs, black and white photographs, simple outline drawings).
and 1 word condition (Anglin & Levie, 1985). Twelve unique stimuli, 3 from each format were deemed target stimuli. Eight weeks after initial presentation, a recognition memory test was conducted where participants were shown 12 pairs each consisting of a target stimuli and a distractor stimuli. The only significant difference between groups was a picture superiority effect where black and white photographs were recognized more often than words. The authors suggest that the long length of retention interval (8 weeks) or short presentation rate of pictures (2 sec) may have contributed to the lack of picture superiority effect findings (Anglin & Levie, 1985).

Pictures have also been shown to lead to better memory for advertisements than words (Childers & Houston, 1984; Shepard, 1967). When Childers & Houston instructed participants to focus on appearance-related features of the ads (e.g., shape), recall memory of participants shown all-pictorial ads was better than those shown all-word ads after both a short (30 seconds) and long (2 days) retention interval. However, when participants were instructed to focus on semantic-related features of the ads (e.g. goodness), a picture superiority effect was found only over the long 2 day retention interval.

Additional indirect support for pictures being more memorable than words comes from studies that have found concrete material objects, which easily bring an image to mind, are more likely to be remembered than abstract ideas, qualities, or states (Lutz & Lutz, 1978; Pavio, 1969; Pavio & Csapo, 1973; Roche, Tolan, & Tehan, 2011; Walker & Hulme, 1999). For instance, the concrete words *dog* and *rose* are much more likely to be
remembered that the abstract words *logic* or *consciousness*, which are difficult to visualize.

**Age and the Picture Superiority Effect**

Data regarding the observation of the picture superiority effect in older adults are mixed (Light, 1991). Some studies have found that both younger and older adults experience a picture superiority effect, with pictures being recalled better than words (Park, Puglisis, & Sovacool, 1983; experiment 1 Winograd et al., 1982). There is also neurological support for a picture superiority effect in older adults as measured by high-density event-related potentials (ERP’s) (Ally, Gold, & Budson, 2009). When shown pictures, older and younger adults display an identical early frontal effect, parietal effect, and late frontal effect. However, when shown words, older adults display a diminished early frontal and parietal effect compared to younger adults, suggesting that words do not stimulate as widespread areas of activity as picture do.

In contrast to studies that have found a picture superiority effect in older adults, a host of other studies have not found this to be the case. In these studies, younger adults exhibited a picture superiority effect remembering pictures better than words, but older adults did not exhibit this effect; there were no differences between memory for pictures and words (Rissenberg & Glanzer, 1986; study 2 & 3, Winograd et al., 1982). More picture superiority research with older adults is needed to settle this ongoing debate.

**Theories Explaining the Picture Superiority Effect**
It has been well established (Lutz & Lutz, 1978; Maistro & Queen, 1992; Nelson & Reed, 1976; Pavio, 1971) empirically that pictures are usually remembered better than words, but the explanation behind this picture superiority effect continues to be debated. Several theories have been put forth to explain the effect including: Pavio’s Dual Coding Hypothesis, Nelson’s Sensory Somatic Distinctiveness Model, and Barsalou’s Theory of Perceptual Symbol Systems. Our aim in describing these theories is not to distinguish which, if any, are correct, but rather to provide plausible theoretical explanations for why pictures are more likely to be remembered than words.

Pavio’s Dual Coding Hypothesis (Pavio 1969, 1971, 1986, & 1991) suggests that pictures are remembered better than words (i.e. the picture superiority effect) because pictures have both a verbal and spatial code, while words have just a verbal code. That is, while words carry just semantic meaning, pictures have an additional imaginal quality associated with them as well as their semantic meaning. Pavio (1986) also suggests that the imaginal code itself is inherently mnemonically superior to verbal code, although the exact reason why remains unclear.

According to distinctiveness models of the picture superiority effect, semantic processing plays a minor role in the picture over word advantage; it is chiefly perceptual features of pictures that lead to an advantage over words (Mintzer & Snodgrass, 1999; Nicolas & Marchal, 1998). For instance, Nelson’s Sensory Semantic Model (Nelson, Reed, McEvoy, 1977) exerts that pictures have greater visual sensory distinctiveness than words because pictures are substantially more variable and diverse in terms of purely perceptual features. Pictures can take on a diverse range of forms while words are
restrained to a certain set of lines, curves, and letter combinations (Mintzer & Snodgrass, 1999; Nelson, Reed, & Walling, 1976).

Unlike the previous two theories, Barsalou’s Perceptual Symbols Theory (1999) is not meant to directly explain the picture superiority effect, but it does offer a plausible mechanism for why pictures would be expected to be remembered better than words. Barsalou proposes that when a person interacts with the environment or views an image, portions of the sensory-motor cortex are activated, and unconscious, abstract perceptual representations are encoded into long-term memory to function as symbols. These symbols are inherently attached to cognitive (semantic) information associated with the perceived object, and the symbols combine to form concepts and schemas. Barsalou points out, however, that these perceptual representations are not direct, holistic copies of the image, but rather more abstract, schematic representations containing features like color, lines and curve. If one were to only view a word label of an object, primarily the most abstract, semantic information would be encoded, and much of the perceptual information would not be present. On the other hand, if one views a picture of the same object, both abstract semantic and rich perceptual information would be encoded. Consequently, less information would be encoded in long-term memory with words and there would be fewer opportunities to recall. Thus Barsalou’s theory is similar to Paivio’s claim that pictures involve dual coding.

Although all of the above theories provide support for why pictures are more likely to be remembered than words, surprisingly little has been published on whether pictures lead to better prospective memory than words. Only one study with 48
undergraduate participants has examined the picture superiority effect in prospective memory (McDaniel, Robinson-Riegler, & Einstein, 1998). Nevertheless, that one study found a picture superiority effect did exist, with participants in the picture stimuli condition remembering to perform the PM task more often than those in the word condition. If a picture superiority effect does exist in prospective memory, great potential exists for applying it to the design of memory aids. A relatively simple alteration from a text reminder to an image reminder could increase the likelihood of remembering to complete PM tasks.

**Prospective Memory**

Our lives are chockfull of PM tasks. Any time a person forms an intention to complete a task at a future moment they are engaging prospective memory (PM). From vital tasks like remembering to take medication or check bodily statistics (i.e. diabetics must check blood), to professional tasks like remembering to email a document, to social tasks like remembering to return an overdue movie or meet a friend for dinner at 7pm, successful PM is critical to daily human activity. PM intentions differ by the nature of the cue or trigger. An event-based PM task is a task that must be completed when a particular external target cue appears (e.g. get groceries when you drive by grocery store), while a time-based task is one that must be completed at a particular time (e.g. be at doctors at 4:30 pm) or after a certain amount of time has passed (e.g. take heart medicine 30 minutes after dinner) (Einstein & McDaniel, 1990). The current study focuses on event-
based PM tasks because the format (i.e., picture or word) of the target cue is being manipulated.

The typical event-based laboratory paradigm employed in PM studies (Einstein, Holland, McDaniel, & Guynn, 1992; Kidder, Park, Hertzog, and Morrell, 1997) asks participants to engage in an ongoing computer task (e.g., rating the pleasantness of a word or lexical decision task), while also remembering to press a special key when an embedded target (e.g., word, background) appears (first developed by Einstein & McDaniel, 1990). For example, participants may have to perform a short term memory task as the ongoing task while also remembering to press the letter ‘M’ anytime the word ‘flower’ appears. In this paradigm, ongoing task performance is usually measured in terms of correctness and latency. PM performance is determined by the proportion of times the participant remembered to push the designated key when the appropriate target appeared.

**Age and Prospective Memory**

PM task performance is often thought to be worse for older adults than younger adults because it requires self-initiated retrieval (Craik, 1986), a process that is thought to be more difficult with age (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; McDaniel, Einstein, & Rendell, 2008). Indeed, results from several studies have shown that older adults perform worse on event-based PM tasks than younger adults (d’Ydewalle, Luwel, & Brunfaut, 1999; Mäntylä & Nilsson, 1997; Maylor, 1993, 1996; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997).
However, age effects are not always apparent; older adults sometimes demonstrate equivalent event-based performance to that of their younger counterparts (Cherry & LeCompte, 1999; Einstein & McDaniel, 1990; Einstein et al., 1995; Marsh, Hicks, Cook, & Mayhorn, 2007; Reese & Cherry, 2002). A likely explanation for older adults’ equivalent performance is that certain types of tasks do not place heavy demands on self-initiated retrieval, but instead promote spontaneous retrieval, a process thought to be resource-free, automatic, and not impaired with age (Einstein et al., 1995; Henry, MacLeod, Phillips, & Crawford, 2004).

The amount of self-initiated retrieval required by a task versus the amount of environmental support it provides likely plays a key role in older adults’ tendency to remember (Scullen, Bugg, McDaniel, & Einstein, 2011). A meta-analysis by Henry et al. (2004) found that age decrements in PM are lessened when the environment provides cues that promote spontaneous retrieval. The multiprocess theory describes the particular types of tasks and cues that lead to spontaneous retrieval or monitoring (Einstein et al., 2005; McDaniel & Einstein, 2007), and suggest that both are necessary for everyday prospective remembering. Before explaining this reconciling theory of how PM intentions are retrieved (i.e. multiprocess theory), the opposing theories that emphasize either strictly monitoring or strictly spontaneous retrieval will be explained.

**Monitoring vs. Spontaneous Retrieval**

Monitoring and spontaneous retrieval are two opposing accounts of how individuals retrieve a PM intention. Monitoring theorists (e.g., Burgess & Shallice, 1997;
Smith, 2003; Smith, Hunt, McVay, & McConnell, 2007) suggest that successful retrieval of PM intentions requires the use of a capacity consuming executive attentional system that strategically monitors the environment for the target event. When the target event is encountered, the executive attentional system interrupts the ongoing activity and initiates the process for performing the intended task. The key feature of monitoring theories is that PM retrieval requires conscious resources. Support for monitoring comes from studies that have found having a PM intention in mind, versus no PM intention in mind (i.e. control group), causes decrements to ongoing task performance (Guynn, 2003; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Smith, 2003; Einstein et al., 2005; Smith, Hunt, McVay, & McConnell, 2007), seemingly because the act of monitoring the environment consumes resources (e.g., attentional resources) that would be used for the ongoing task. These studies presume that a dual-task tradeoff exists between the effort and attention given to the ongoing and prospective task (i.e., the two tasks draw upon the same hypothetical resource).

Spontaneous retrieval theories oppose the notion that PM retrieval requires attentional resources, and instead suggests that the PM target event involuntarily captures attention, no resources required (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004; McDaniel, Robinson-Riegler, et al., 1998). The underlying rationale for spontaneous retrieval theory is based on Moscovitch’s systems framework (1994). The general idea is that if an incoming cue is strong enough, it will automatically retrieve a previously formed memory trace and a person will remember to perform the task. More specifically, this theory purports that a memory trace is created whenever we
form an intention to perform a PM task. As various cues are encountered, information about each cue is automatically retrieved from memory. If information from the cue currently in working memory interacts with the long-term memory trace containing the intention, then the PM intention will be retrieved. If information from the cue does not interact with the memory trace, the PM intention will likely not be retrieved (unless a directed search is initiated by another aspect of memory). Thus a picture cue, which supposedly has more perceptual information associated with it than a word, has a higher likelihood of interacting with a memory trace than a word cue.

A divided attention paradigm is often used to determine if a specific factor will lead to spontaneous retrieval or monitoring (Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Marsh & Hicks, 1998; McDaniel et al., 2004). In these studies, participants will engage in either a single (non-divided) or concurrent (divided) ongoing task(s) (e.g. lexical decision task and random number generator task), while also having to remember to execute a PM intention when the appropriate target appears. The rationale behind this paradigm is that humans have a limited amount of resources, and dividing attention reduces the amount of resources available. Thus, if monitoring is occurring, performance should decrease between non-divided and divided attention conditions because fewer resources are able to be devoted to monitoring the environment. Conversely, if PM performance remains high and alike between divided and non-divided attention conditions, it likely implies that the task promotes spontaneous retrieval (i.e., it is resource-free). However, another possibility is that the divided attention task is not resource demanding enough.
Multiprocess Theory of Prospective Memory

The multiprocess theory of PM suggests that both monitoring and spontaneous retrieval may be used to retrieve an intention, with the utilized method dependent on characteristics of the specific PM task, ongoing task, and individual (Einstein & McDaniel, 2000; McDaniel et al., 2008; Meier, Zimmermann, & Perrig, 2006). The multiprocess theory delineates particular factors that contribute to whether spontaneous retrieval or monitoring will be used (see Table 1.1) including: 1) whether the ongoing and PM task require the same type of processing (i.e. semantic or perceptual), 2) whether the PM target is focally processed during the ongoing task, 3) how demanding the ongoing task is, 4) how important the PM task is, 5) the length of the retention interval between the time the intention is formed and when it should be recalled, 6) how associated the PM target and intended action are, and 7) how distinctive the PM target is (see McDaniel & Einstein, 2007, Chapter 4 for a thorough review). The table below depicts when each factor is likely to lead to spontaneous retrieval or monitoring. The last factor listed, distinctiveness, has direct relevance to the current study.
Table 1.1
Factors that determine whether spontaneous retrieval or monitoring is likely to be used to retrieve a PM intention

<table>
<thead>
<tr>
<th>Factors that determine how PM intentions are retrieved</th>
<th>Spontaneous Retrieval</th>
<th>Monitoring</th>
</tr>
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<tr>
<td>1. Do the ongoing and PM task require the same type of processing (i.e. semantic or perceptual)?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>2. Will the PM target be focally processed during the ongoing task?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>3. Is the ongoing task demanding?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>4. Is the PM task important?</td>
<td>no</td>
<td>yes</td>
</tr>
<tr>
<td>5. Is there a long retention interval between the time the PM intention is formed and when it must be recalled?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>6. Is there a strong association between the PM target and intended action?</td>
<td>yes</td>
<td>no</td>
</tr>
<tr>
<td>7. Is the PM target distinctive?</td>
<td>yes</td>
<td>no</td>
</tr>
</tbody>
</table>

Distinctiveness in Prospective Memory

Distinctiveness as it relates to picture superiority has already been discussed in this paper. Pictures are considered to be more distinctive than words because they can take on a variety of perceptual features, while words are constrained to certain letters, with a fixed set of lines and curves (Mintzer & Snodgrass, 1999; Nelson, Reed, & Walling, 1976). There is, however, a whole other body of literature on distinctiveness in PM. Generally, distinct target stimuli lead to better PM performance than non-distinct target stimuli.

The majority of distinctiveness studies to date examine a task situation where the target cue is distinctive relative to all of the other stimuli presented. In these studies, all stimuli will be presented in a certain perceptual or semantic format; in the non-distinct condition the target cue will be in that same format, but in the distinct condition the
target cue will be in some distinct format. This type of distinctiveness, where the target
cue stands out from other stimuli, is different than the way the current study
operationalizes distinctiveness—as inherent characteristics about a type of stimuli (i.e.,
pictures) that make it stand out more than another type of stimuli (i.e., words). We are
calling these two types of distinctiveness relative distinctiveness and absolute
distinctiveness, respectively.

Relative distinctiveness studies examine target cues that differ in some salient
semantic or perceptual way from the other cues presented. In most cases distinctive target
cues lead to better PM performance than non-distinctive cues (Cohen, Dixon, Lindsay, &
Masson, 2003; Watkins, 2003). One way distinctiveness has been studied is by examining
a semantically unfamiliar (i.e. distinct) target cue compared to a semantically familiar
(i.e. non-distinct) target cue, when all other stimuli are familiar (Brandimonte &
Passolunghi, 1994). For instance, Einstein & McDaniel (1990, experiment 2) had
participants perform an ongoing short-term memory task with stimuli that were all
semantically familiar words, while also remembering to push a response key when they
saw the unfamiliar PM target ‘MONAD’ or ‘SONE’ (distinct condition), or the familiar
PM target ‘RAKE’ or ‘METHOD’ (non-distinct condition). Results showed substantially
better prospective remembering for both younger and older adults in the distinct,
unfamiliar target word condition (m = .83 and .94 respectively) than the non-distinct,
familiar target condition (m = .28, m = .36). McDaniel & Einstein (1993) corroborated
these findings in a set of two experiments, both demonstrating that unfamiliar (i.e.
distinct) target words lead to better PM performance than familiar words.
While the aforementioned studies examined conceptual (i.e. semantic) distinctiveness of PM targets, a related set of studies has examined perceptual distinctiveness, or distinctness based on the way an item looks. For example, Einstein et al. (2000) found that with all other stimuli displayed in lowercase text, an uppercase (distinct) target word led to better PM performance than a lowercase target word.

Another perceptual distinctiveness experiment (Einstein, Harrison, Mullet, Addington, & Ousterhout, 2011) had participants engage in an ongoing lexical decision task half the time and a lexical decision task plus random number generation task the other half. All stimuli were presented in lowercase letters. The non-distinct target cue was also presented in lowercase letters while the distinct target cue was presented in bold, uppercase letters. Results showed that dividing attention did not affect PM performance of those in the distinct condition (divided = 95.3%, non-divided = 87.5%), but did negatively affect performance of those in the non-distinct, lowercase condition (divided = 39.1%, non-divided = 53.1%)

Studies examining absolute distinctiveness are more rare. Absolute distinctiveness is being defined here as inherent characteristics or qualities of a particular type of stimuli that cause it to stand out more than another type of stimuli. Studies on word valence distinctiveness, which suggest positive and/or negative stimuli are inherently more distinct than neutral stimuli, are the only inherent distinctiveness studies we are aware of (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; Rendell et al., 2011; Schnitzspahn, Horn, Bayen, & Kliegel, 2011). For instance, Altgassen et al. (2010) had participants engage in an ongoing working memory task that presented distinct (positive or negative)
or non-distinct (neutral) pictures to participants and asked them to recall if the picture had been presented one stimulus beforehand. The PM task was to remember to push a key when one of 6 (2 positive, 2 negative, 2 neutral) pictures occurred. Results showed that PM performance was worse for the non-distinct neutral pictures than the distinct positive or negative ones.

Pictures are inherently more distinct than words, yet this type of distinctiveness has yet to be examined in the PM literature. Given that previous PM research suggests that distinctive cues are more likely to be remembered than non-distinct cues, and previous picture superiority effect research has established that pictures are more distinct than words, it is reasonable to assume that pictures should lead to better PM performance than words. Thus, we hypothesize that distinctive cue conditions (i.e., pictures) are more likely to lead to spontaneous retrieval, and thus better PM than non-distinctive cue conditions (i.e., words). Indeed, this was the case in the one study that compared encoding and retrieving either picture stimuli or word stimuli in a PM task; better PM performance was found for picture than word conditions (Experiment 2, McDaniel et al., 1998).

The Picture Superiority Effect in Prospective Memory

The one previous study that examined the picture superiority effect in PM used a factorial design to manipulate encoding format (picture or word), retrieval format (picture or word), and environment where encoding and retrieval occurred (same or different; experiment 2, McDaniel et al., 1998). Participants were introduced to the
ongoing task—a sentence verification task requiring them to indicate if a sentence was
ture or false. The PM target was embedded in the ongoing task practice. During this
practice, participants were always presented with two sentences in word format and two
sentences in picture format; the last sentence always had the PM target (e.g. rose)
embedded as either a word or picture based on encoding condition. After the practice
sentences were removed, participants were told they should knock twice whenever they
saw the PM target (e.g. rose). After a couple of distractor tasks, participants were then,
based on retrieval condition, presented with the ongoing task in all-word or all-picture
verification sentences; the PM target appeared four times.

PM performance was scored as the proportion of times the participant
remembered to knock when the PM target appeared. Results indicated a robust picture
superiority effect, with PM performance significantly higher in the picture encoding
conditions (.91) than the word encoding conditions (.47). Even when the PM target
retrieval format was a word, picture encoding led to equal (in same testing environment)
or better (in different testing environments) PM performance than word encoding.

A host of converging literature from the picture superiority field and PM field
suggest that pictures will lead to better PM performance than words. However, with only
one existing study having examined the topic with only younger adult participants (i.e.,
Experiment 2, McDaniel et al., 1998), additional research is needed to support the
suggestion.
Do Pictures Support Spontaneous Retrieval?

An additional aim of this paper is to examine if picture stimuli promote spontaneous retrieval. A compelling way to demonstrate that a factor promotes spontaneous retrieval is by showing that participants have equivalent levels of PM performance on both a non-divided and divided attention task (Einstein et al., 2011; Marsh, Hicks, & Cook, 2005). This methodology presumes that dividing attention occupies such a large proportion of attentional resources that no additional resources should be left to monitor the environment for the PM target. Consequently, only cues that naturally and automatically capture attention (i.e. those that promote spontaneous retrieval) should be expected to sustain high levels of PM performance under both single and divided attention.

Einstein et al. (2011) used this paradigm to demonstrate that when a PM target is in all capital letters and the rest of the stimuli are in all lowercase letters (i.e. it is distinct), spontaneous retrieval occurs and participants in the distinct condition do not experience decrements in PM performance, even under demanding divided attention situations. When target words were lowercase like the rest of the stimuli, PM performance was significantly worse in the divided attention condition. As it relates to the current study, evidence for spontaneous retrieval of pictures would be provided if we found that participants in the picture condition did not experience a decline in performance between single attention and divided attention tasks.

An additional finding that would demonstrate pictures support spontaneous retrieval would be if older adults had equivalent PM performance to that of younger
adults (Marsh & Hicks, 1998) in the picture condition, but not the word condition. The reasoning behind this is that older adults are suggested to have preserved spontaneous retrieval, but not self-initiated retrieval (Craik, 1986). Therefore, if pictures lead to spontaneous retrieval, older adults should demonstrate high PM performance in picture conditions but not in word conditions.

In order to examine the differing effects of stimuli form, age, and attention load, the current study utilized a dual-task PM paradigm with a category-sorting task as the ongoing task and a random number generator task as the divided attention task. Participants received either all words or all pictures as stimuli and had to remember to push a key when they saw a certain target cue. To be clear, the target cue was the same item, just either in picture or word format.
CHAPTER TWO

METHOD

Participants

Forty-eight younger adults (age 18 – 27) and forty-eight older adults (age 65 – 85) were recruited for this study. Younger adults were either recruited through a student participant pool and received course extra credit for participating, or recruited through flyers and received $7 for participating. Older adults were recruited through an existing database of older adult participants and received $7 compensation.

Participants were tested in sessions of up to 7 participants, always with like ages. All older adult participants were run between 9:30am and 3:30pm in order to provide optimal circadian performance, as time of day is a factor that has been proposed to influence older adults’ memory performance (Hasher, Zacks, & Rahhal, 199; May, Hasher, & Stoltzfus, 1993).

Design

The study was a 2 (age: old, young) x 2 (stimulus form: text, picture) x 2 (attention: divided, non-divided) x 2 (control block, PM block) mixed factor design with age as a quasi-independent grouping variable, stimulus form as a between-subjects factor, and attention and control/PM block as within-subjects factors. Thus, forty-eight participants (24 younger and 24 older) were in the picture condition and 48 were in the word condition; all participants saw pure lists of all pictures or all words. Attention load
was within-subjects, with half of the trials under divided attention and half under full attention.

**Equipment**

The task was programmed in Real Basic for Windows and presented (maximized with no visible user interface) on a computer set at a resolution of 1280 x 1024. Participants sat approximately 18 inches away from the computer screen, and were told to adjust equipment as necessary. Six-foot tall cubicle dividers separated each computer station. A pair of headphones was plugged into the computer on the left side of the participant. Based on pilot testing, a half sheet of paper was placed to the left of the keyboard that reminded participants which keys to push for the ongoing task. A folded sheet of paper that contained the PM instructions was placed at the top left of the computer monitor.

**Tasks**

**Ongoing task.** The ongoing task in this study was a stimuli categorization task where participants had to categorize stimuli as man-made or natural. Stimuli (either word or picture) were presented one at a time on a computer screen and participants were instructed to push F1 for a man-made object or F3 for a natural object. Ongoing task performance was measured in two ways—latency and accuracy. Latency was a mean measure of how long it took the person (in seconds) to respond whether a stimulus was man-made or natural, from the moment the stimulus appeared until the time the
participant pressed F1 or F3. Accuracy represented the proportion of times a participant correctly identified a stimulus to be man-made or natural.

Several factors were taken into consideration when determining the optimal ongoing task for the study. First, the ongoing task had to be possible in both picture and word format. This eliminated tasks like lexical decisions, face naming, or counting the number of vowels. Furthermore, I wanted the ongoing task to have a definitive correct answer for each trial in order to measure ongoing task accuracy and latency. This requirement eliminated ongoing tasks like rating the pleasantness of a stimulus or determining whether a stimulus is “bigger than a breadbox”.

The ongoing task experimental sequence is displayed in Figure 2.1 below. The ongoing task took place across two major blocks, one control block and one PM task embedded block, each consisting of 320 trials (4 quarters of 80 stimuli). Block order (i.e. whether PM or control block came first) was counterbalanced. Each block was divided into four alternating attention quarters; two of the quarters under conditions of non-divided attention where the participant just performed the ongoing task, and two of the quarters under conditions of divided attention where the participant performed both the ongoing and number task. Attention condition presentation order (i.e. whether divided or non-divided comes first) was counterbalanced.

There were two counterbalanced lists of 80 stimuli (50 man-made items and 30 natural item) used for the two blocks. Each list of 80 stimuli was shown in a randomized order four times within the block, once per quarter, for a total of 320 trials per block. During the PM block, a target stimulus appeared towards the end of each quarter.
(represented by red vertical lines in the diagram) on trials 75, 155, 235, and 315. Based on counterbalance condition, the participant received one of two possible target stimuli, ‘candle’ or ‘orange’. All in all, there were a total of 8 counterbalanced conditions based on: block order, stimuli list order, divided attention order, and PM target used.

*Figure 2.1.* Two of the possible eight experimental sequence counterbalance conditions. ‘D’ represents the divided attention conditions. The thick red vertical lines represent where the PM target stimuli occurred.

Stimuli for the ongoing task was chosen from the Bank of Standardized Stimuli (BOSS), a set of 480 high quality stimuli that are normalized on several factors (e.g. familiarity, name-image agreement), and created with the intent to be used in cognitive research (Brodeur, Dionne-Dostie, Montreuil, & LePage, 2010). See *Figure 2.2* for example picture stimuli. The BOSS stimuli were deliberately chosen over the Snodgrass and Vanderwart’s (1980) commonly used standardized list of 260 pictures, because the
BOSS stimuli contain color, texture and 3D cues, similar to photo technology available in reminding devices today, while Snodgrass and Vanderwarts’ stimuli set consists of black and white images.

![Sample Boss Stimuli (picture format) with associated word format.](image)

**Figure 2.2.** Sample Boss Stimuli (picture format) with associated word format.

Several criteria were taken into consideration when determining which stimuli to use in order to ensure as much impartiality as possible between pictures and words:

1. Word must be 8 letters or less.
   a. We did not want any extra-long words acting as a visual cue
2. Name agreement of at least 71%
   a. Name agreement is the proportion of times a stimuli is said to be what the intended title was. For instance, ‘apple’ had a high name agreement of 95% whereas ‘baby seat’ had a low name agreement of 31%.

3. Familiarity of at least 3.5 (out of 5)
   a. Familiarity is a subjective score of how familiar the stimuli is rated to be

4. Object agreement of at least 3.2 (out of 5)
   a. Object agreement is the extent to which the object is similar to the one imagined by the subject.

Given that our ongoing task was to categorize stimuli as man-made or natural, it would have been ideal for each stimuli list to be comprised of 40 man-made and 40 natural items. However, there were not enough natural objects available in the BOSS set of stimuli. Although there are a total of 480 stimuli available in the BOSS set, only 59 of the stimuli were natural objects; 54 of the stimuli were categorized as FOOD while 5 others were categorized as NATURAL (e.g. plant, branch). Of those 59 natural stimuli, only 34 met the four criteria listed above. Surprisingly, no animals were included in this stimuli set.

Thus, it was necessary to gather more natural images with associated text names that met our criteria. A picture/text name agreement study was performed in our lab to determine additional natural stimuli. We examined stimuli that could be categorized as
either FOOD or ANIMALS. The resulting stimuli lists each contained 50 man-made and 30 natural items.

Both word and picture stimuli were presented in a box on the left half of the computer screen and were approximately 400 x 400 pixels in size. Participants controlled the progression of stimuli; each ongoing categorization response made by pressing F1 (manmade) or F3 (natural) triggered a new stimulus to appear.

**Divided Attention Task.** A divided attention task was chosen to increase attentional demands and reduce the resources available for monitoring the PM target. In other words, we aimed to prevent monitoring by maxing out limited resources and forcing spontaneous retrieval. A relatively challenging random number generator task was chosen as the divided attention task because previous research has shown it successfully occupied participants attention enough to interfere with normal (non-salient) prospective remembering (Einstein et al., 2011).

For the random number generator task in our study, participants were instructed to type a random number 1 through 9 any time they hear a beep on their headphones. Beeps were presented every 1 second for younger adults and every 2.5 seconds for older adults. Beep presentation time was determined by three things: 1) previous studies (Einstein et al., 2011), 2) pilot testing with older adults, and 3) the standard adage that older adults perform 1.5 times slower than younger adults (Fisk, Rogers, Charness, Czaja, & Sharit, 2009). Similar to Harrison & Einstein (2010), divided attention task performance was assessed using random number generator software (Towse and Neil,
1998) along three measures of randomness: redundancy, a random number generator score, and turning point index.

The divided attention task was positioned on the right half of the screen with the words “When you hear a beep type a number 1-9” at the top of the box. When a number was entered it appeared briefly on the screen to provide feedback and then disappeared. If the participant did not enter a number when a beep occurred it did not affect the progression of the study, the participant just moved on to the next beep.

**Prospective Memory Task.** The PM task in this study was embedded in the ongoing task, and required participants to push the ‘Q’ key when they saw a predefined target. Half the participants received the target stimuli ‘orange’ and the other half received the target stimuli ‘candle’, based on counterbalance condition. See Figure 2.2 for stimuli images. The PM target was presented towards the end of each of the four quarters of the PM block, on trial numbers 75, 155, 235, and 315 (Einstein et al., 2011). PM targets were matched for number of letters and syllables, naming agreement, familiarity and frequency. PM performance was measured as the proportion of times (out of 4) the participant correctly pushed ‘Q’ when the PM target appeared.

**Procedure**

Participants were first introduced to the ongoing task. They were told the purpose of the study was to complete a stimulus categorization task, and for each stimulus they saw, they should push F1 if it was man-made and F3 if it was natural. The participant
then completed five practice trials of this ongoing categorization task receiving feedback on correctness, though feedback was removed during the actual study.

Participants were then told that sometimes they would have an additional task (i.e., the divided attention task) that they would need to complete at the same time as the categorization task, and they should do both tasks as quickly yet accurately as possible. For the divided attention task, participants were instructed to generate numbers as randomly as possible. Participants were told that random meant each number occurs as frequently as every other and no patterns emerge. Participants wore headphones provided, and were asked to press a number 1 through 9 in as random order as possible anytime they heard a beep. Participants then practiced 10 beeps worth of the divided attention task. After that, participants practiced 10 trials of both the ongoing task and divided attention task together to ensure they understood the task.

From here, instructions diverged based on whether the participant had the control or PM block first. If the control block was first, they were given instructions to start either the single or dual task (based on counterbalance), and then they began the four quarters of 80 trials. If the participant was given the PM block first, or after they had completed 320 trials if they had the control block first, participants were presented with a screen that informed them of an additional secondary concern in this experiment and instructed them to open the folded sheet of paper on the right side of the desk.

The folded sheet of paper presented instructions for the PM task. It said, “We have an additional secondary concern in this experiment. If you happen to see the stimulus in the box below any time during the remainder of the study, press the ‘Q’
button.” A 400 x 400 pixel box with either the target stimulus in picture or word form was presented beneath these instructions. Beneath the stimulus, the participant was informed, “However, remember this is a secondary task and there is only a 5% chance that you will see this stimulus.”

After receiving the PM instructions, participants completed a computerized battery of abilities tests in order to 1) increase the retention interval between presentation and recall of the PM intention and 2) gather abilities information for examining mediators or moderators on observed effects. The following abilities measures were collected: a measure of perceptual speed (the Digit Symbol Substitution Test; Wechsler, 1981), an indicator of crystallized intelligence (the Shipley Vocabulary Test; Shipley, 1940), and a measure of memory span (the Reverse Digit Span; Wechsler, 1997). The abilities tests took approximately 12 minutes to complete, after which the participant received the single or dual task instructions screen and proceeded with the next four quarters of trials. They were not reminded of the PM task again.
CHAPTER THREE

ANALYSIS & RESULTS

The following analyses are designed to answer the questions: Does a picture superiority effect exist in prospective memory on the ongoing or prospective task? Do pictures promote spontaneous retrieval (and conversely do words not lead to spontaneous retrieval), which would be demonstrated by high and stable performance in the picture condition even for older adults and even when under divided attention?

Two younger adults (1 word, 1 picture condition) and two older adults (both word condition) were determined to be outliers and removed from analysis because their ongoing task accuracy or latency score was greater than three standard deviations away from the mean. Participant’s demographics information is reported in Table 3.1.

Table 3.1
Participant’s demographics information

<table>
<thead>
<tr>
<th></th>
<th>Young</th>
<th></th>
<th>Old</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>SD</td>
<td>Mean</td>
<td>SD</td>
</tr>
<tr>
<td>Age</td>
<td>22.80</td>
<td>2.99</td>
<td>72.39</td>
<td>6.16</td>
</tr>
<tr>
<td>Level of education</td>
<td>4.28</td>
<td>1.29</td>
<td>4.76</td>
<td>1.34</td>
</tr>
</tbody>
</table>

*Note. N = 46 per age group. Levels of education: 1 = High school diploma, 2 = Associate’s degree, 3 = Bachelor’s degree, 4 = Master’s Degree, 5 = Doctoral degree, 6 = Other.*
Abilities Test Measures

Three abilities tests were administered: 1) The Digit Symbol Substitution (DSS) test used as a measure of perceptual speed (Wechsler, 1981), 2) The Reverse Digit Span test used as a measure of memory span (Wechsler, 1997), and 3) Shipley’s Vocabulary test used as a measure of crystallized intelligence (Shipley, 1940).

To determine if participant abilities were randomly distributed between our conditions, a 2 x 2 MANOVA was performed with age (old or young) and stimulus form (word or picture) as the fixed factors and DSS median correct time, DSS median incorrect time, DSS proportion correct, RDS score, and Shipley correct score as the dependent variables (See Tables 3.2 and 3.3). As expected, the multivariate test showed an overall significant main effect of age group, $F(3, 88 \ OR \ 1.91) = 36.20, p = 0.00, \eta^2_p = 0.68$. There was no main effect of stimulus form ($p = .92$) and no interaction between age and stimuli form ($p = .19$).

Table 3.2

<table>
<thead>
<tr>
<th>Ability test performance as a function of age</th>
<th>Young</th>
<th>Old</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$M$</td>
<td>$SD$</td>
</tr>
<tr>
<td>DSS median correct time*</td>
<td>1298.84</td>
<td>359.28</td>
</tr>
<tr>
<td>DSS median incorrect time*</td>
<td>1174.77</td>
<td>229.51</td>
</tr>
<tr>
<td>DSS proportion correct</td>
<td>0.98</td>
<td>0.02</td>
</tr>
<tr>
<td>RDS Score*</td>
<td>8.30</td>
<td>2.47</td>
</tr>
<tr>
<td>Shipley correct*</td>
<td>29.59</td>
<td>4.09</td>
</tr>
</tbody>
</table>

Note: * $p < .01$.  

32
Table 3.3

*Significance test results for each abilities test variable*

<table>
<thead>
<tr>
<th>Variable</th>
<th>F</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>ηp2</th>
</tr>
</thead>
<tbody>
<tr>
<td>DSS median correct time*</td>
<td>68.83</td>
<td>89.90</td>
<td>0.00</td>
<td>0.44</td>
</tr>
<tr>
<td>DSS median incorrect time*</td>
<td>99.42</td>
<td>66.75</td>
<td>0.00</td>
<td>0.53</td>
</tr>
<tr>
<td>DSS proportion correct</td>
<td>1.08</td>
<td>0.01</td>
<td>0.30</td>
<td>0.01</td>
</tr>
<tr>
<td>RDS Score*</td>
<td>19.00</td>
<td>0.47</td>
<td>0.00</td>
<td>0.18</td>
</tr>
<tr>
<td>Shipley correct*</td>
<td>27.69</td>
<td>0.76</td>
<td>0.00</td>
<td>0.24</td>
</tr>
</tbody>
</table>

*Note.* *p* <.01.

**Shipley’s Vocabulary Test.** Analysis of the Shipley’s Vocabulary Test revealed a significant main effect of age with older adults performing better than younger adults.

Older adults had a significantly higher vocabulary score (*M* = 33.59, *SD* = 3.10) than younger adults (*M* = 29.59, *SD* = 4.09), *F*(3, 88) = 29.69, *p* = 0.00, ηp2 = 0.24. See Figure 3.1.

![Shipley Vocabulary score by age group](image.png)

*Figure 3.1. Shipley Vocabulary score by age group*
**Reverse Digit Span Test.** The Reverse Digit Span (RDS) Test revealed a significant main effect of age with younger adults outperforming older adults. Younger adults had a mean RDS score of 8.21 while older adults scored a mean of 6.21, $F(1, 92) = 18.89, p = .00, PES = .17$. See Figure 3.2.

![Figure 3.2](image)

*Figure 3.2. Reverse Digit Span (RDS) score by age group.*

**Digit Symbol Substitution Test.** Three measures were used to analyze the Digit Symbol Substitution Test: proportion correct, median time taken for correct responses, and median time taken for incorrect responses. There were no significant main effects or interactions found for the proportion of test items answered correctly. On average, both younger and older adults performed well on the digit symbol substitution test ($M = .98$ and $.97$ respectively).
However, there was a significant difference between age groups in the median amount of time it took a participant to respond. Median time for correct responses was significantly faster for younger adults ($M = 1306.49$) than for older adults ($M = 2024.39$), $F(1, 92) = 68.83, p = .00, \eta_p^2 = .44$. Median time for incorrect responses was also significantly faster for younger adults ($M = 1182.56$) than older adults ($M = 1827.45$), $F(1, 92) = 98.23, p = .00, \eta_p^2 = .52$. See Figure 3.3. Overall, although older adults were just as accurate as younger adults on the DSS task, it took older adults significantly more time to respond for both correct and incorrect responses.

![Figure 3.3. Digit Symbol Substitution median correct and incorrect time by age group](image)
Dependent Measures

Two separate analyses were performed. First, we conducted a 2 x 2 x 2 x 2 mixed repeated measures multivariate analysis of variance (MANOVA) with age group (young or old) and stimulus form (picture or word) as the between-subjects variables, attention load (non-divided vs. divided) and PM load (control block vs. PM block) as the within-subjects variable, and ongoing accuracy and ongoing latency as the two dependent measures. The means and standard deviations of these dependent measures are presented in Table 3.4.

Table 3.4
Mean ongoing task accuracy and latency scores

<table>
<thead>
<tr>
<th></th>
<th>Ongoing Accuracy</th>
<th>Ongoing Latency (ms)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Picture</td>
<td>Word</td>
</tr>
<tr>
<td>Young</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-divided</td>
<td>Control PM</td>
<td>.95 (.03)</td>
</tr>
<tr>
<td>Divided</td>
<td>Control PM</td>
<td>.93 (.04)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Old</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-divided</td>
<td>Control PM</td>
<td>.97 (.03)</td>
</tr>
<tr>
<td>Divided</td>
<td>Control PM</td>
<td>.95 (.03)</td>
</tr>
</tbody>
</table>

Note. Standard deviations are provided in parentheses next to the means.

The second analysis conducted was a 2 x 2 x 2 mixed repeated measures multivariate analysis of variance (MANOVA) with age group (young or old) and stimuli format (picture or word) as the between-subjects variables, attention load (non-divided vs. divided) as the within-subjects variable, and proportion of correct PM responses as
the dependent measure. Notice that the within subjects condition of PM load was removed from this analysis because it was impossible for a participant to correctly perform a PM task in the control block, as there was no PM task or target stimuli in the control block. The average proportion of times that a PM task was correctly performed is presented in Table 3.5.

The omnibus multivariate test of the 2 x 2 x 2 x 2 repeated measures MANOVA showed overall significant main effects of both between subject’s variables, age and stimuli form, as well as both within subject’s variables, PM load and attention load. The main effect of age revealed that younger adults performance was significantly different from that of older adults, $F(2,87) = 31.48, p = .00, \eta_p^2 = .42$, with younger adults tending to perform better than older adults. The main effect of stimuli form revealed that performance in the picture stimuli condition was significantly worse than those in the word stimuli condition $F(2,87) = 7.30, p = .00, \eta_p^2 = .14$. There was no overall interaction between age and stimulus form ($p = .78$).

Within subjects, there was an overall significant main effect of PM load; participants scores were significantly worse during the time they had no PM intention in mind (i.e. control) compared to the time they had to remember a PM intention, $F(2, 87) = 25.54, p = .00, \eta_p^2 = .37$. There was also a significant PM load x age interaction which showed that having a PM intention in mind differentially affected younger and older adults; older adults performed worse in the PM block than the control block but this was not the case with younger adults.
Additionally, there was an overall significant main effect of attention load \((F(2, 87) = 8.42, \ p = .00, \ \eta^2 = .16)\); participants scores differed significantly between trials under single attention (i.e., only the ongoing categorization task) and trials under divided attention (i.e., both the categorization and random number task), with those under divided attention performing worse. Finally, there was a significant four-way age x stimulus form x PM load x attention load interaction \(F(3, 86) = 73.67, \ p = .03, \ \eta^2 = .08\). All of these omnibus mean differences are explored more thoroughly below, organized by each dependent variable: ongoing task accuracy, ongoing task latency, and PM performance.

**Ongoing Task Accuracy.** Ongoing task accuracy was measured as the proportion of times a participant correctly identified a stimulus to be man-made or natural, (i.e., ‘x’ correct/ 640 total). Ongoing task accuracy performance was high all around and there were no significant differences between older and younger adults \((p = .11)\), or between the word versus picture conditions \((p = .24)\). There was, however, a significant main effect of dividing attention on ongoing task accuracy, \(F(1, 88) = 15.81, \ p = .00, \ \eta^2 = .15\). As displayed in figure 3.4, participants were more accurate on the ongoing task under conditions of non-divided attention than under conditions of divided attention \((M = .95, \ SE = 0.0 \text{ and } M = .93, \ SE = 0.0)\).
Figure 3.4. Proportion of correct man-made/natural categorizations as a function of attention load. *Note.* Standard error was zero for both conditions.

Additionally, there was a significant main effect of PM load on ongoing task accuracy, $F(1, 88) = 49.80, p = .00, \eta^2 = .36$. As shown in Figure 3.5, participants were more accurate on the ongoing task when they did not have to concurrently remember a PM intention (control block; $M = 0.95$, SE= 0.0) than when they did have to a PM intention in memory (PM block; $M = .93$, SE= 0.0).
**Figure 3.5.** Proportion of correct man-made/natural categorizations as a function of PM load. *Note.* Standard error was zero for both conditions.

**Ongoing Task Latency.** Latency was measured as the mean amount of time (in milliseconds) it took a person to respond whether a stimulus was man-made or natural, from the moment the stimulus appeared until the moment F1 or F3 was pressed. Results showed a significant main effect of stimuli form on ongoing task latency, $F(1, 88) = 11.52, p = .00, \eta^2 = 0.12$. Participants in the picture condition categorized stimuli significantly faster ($M = 1068.32\text{ms}, SE= 29.88$) than participants in the word condition ($M = 1213.32\text{ms}, SE= 30.54$). See Figure 3.6.
There was also a main effect of age on ongoing task latency, $F(1, 88) = 63.64$, $p = .00$, $\eta^2_p = .42$. Younger adults performed significantly faster ($M = 970.43\text{ms}$, $SE = 30.19\text{ms}$) than older adults ($M = 1311.21\text{ms}$, $SE = 30.22\text{ms}$). More importantly, there was a significant age x PM load interaction such that having a PM intention in mind differentially affected younger and older adults ongoing latency performance $F(1, 88) = 15.36$, $p = .15$. For older adults, having a PM intention in mind slowed performance relative to having no PM intention in mind (PM block $M = 1391.86$, $SE = 40.54$ and control block $M = 1231.24\text{ms}$, $SE = 36.51$). On the other hand, for younger adults, having a PM intention in mind improved performance relative to having no PM intention in mind (PM block $M = 917.53$, $SE = 40.51$ and control block $M = 1023.32$, $SE = 36.48$). Unlike ongoing task accuracy, there was no main effect of PM load on ongoing task.

Figure 3.6. Mean ongoing latency as a function of stimulus form
latency; performance was not significantly different between the control block and PM block ($p = .43$).

**Figure 3.7.** Mean ongoing latency as a function of PM load and age

In addition, there was a significant four-way interaction between age group, stimulus form, PM load, and attention load $F(1, 88) = 7.10, p = .01, \eta^2 = .08$. The two graphs in Figure 3.8 showcase how the source of this four-way interaction was a significant three-way interaction between attention x stimulus form x PM load in younger adults, but not in older adults. The source of the three-way interaction was a significant two-way interaction between PM load and attention load within the word condition $F(2, 21) = 3.42, p = .05, \eta^2 = .25$, but not the picture condition ($p = .33$).

The source of the two-way interaction was a significant difference in ongoing latency performance between the control block and PM block, but only under divided attention (control $M= 1408.04$ms, $SE= 78.72$ms and $M= 1503.01$ms, $SE= 85.73$ms), not
non-divided attention (control $M = 1312.84\text{ms}$, $SE = 50.18\text{ms}$ and PM $M = 1343.13\text{ms}$, $SE = 61.91\text{ms}$).

It appears that when a situation requires multiple attentional resources either by adding a PM memory demand or dividing attention, older and younger adults demonstrate distinct yet opposite patterns of behavior. Younger adults become more vigilant, and actually perform faster on the ongoing task in the PM block than they do in the control block while older adults get slower in the PM block than the control block. Perhaps younger adults are at a heightened stage of vigilance when they have multiple tasks to complete, but older adults, with limited resources due to natural age-related decrements, don’t have any extra resources to devote to becoming more vigilant about the ongoing task. Only when younger adult’s resources were put under very heavy demands—having word stimuli on the ongoing categorization task while concurrently performing a random number generator task and remembering a PM intention, did ongoing latency times suffer.

Younger adults in the picture condition had significantly equivalent ongoing task latency between the control block and the PM block. Increasing attentional demands by dividing attention or adding a PM task did not differentially affect PM performance in the picture condition. On the other hand, younger adults in the word condition exhibited significantly different performance between the control and PM condition, but only in the divided attention condition. Thus, it appears that increasing attentional demands by using word stimuli, adding a PM task, and dividing attention does limit the amount of resources that can be devoted to the ongoing task and as a result ongoing latency times suffer.
Prospective Memory Task Performance. PM performance was measured as the proportion of times a participant remembered to press ‘Q’ when the target stimuli appeared. There were four possible opportunities for a participant to respond to the PM target stimuli; it appeared once per quarter in the PM block—twice under a non-divided
attention load and twice under divided attention. Mean proportion of correct PM responses organized by age, attention load, and stimulus format are located in Table 3.5 below.

Table 3.5. 
Proportion of correct PM responses as a function of age group, attention load, and stimulus form

<table>
<thead>
<tr>
<th>Age</th>
<th>Attention Load</th>
<th>Stimuli Format</th>
<th>Picture (P)</th>
<th>Word (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>Young</td>
<td>Non-divided</td>
<td></td>
<td>0.39</td>
<td>0.50</td>
</tr>
<tr>
<td></td>
<td>Divided</td>
<td></td>
<td>0.57</td>
<td>0.51</td>
</tr>
<tr>
<td>Old</td>
<td>Non-divided</td>
<td></td>
<td>0.33</td>
<td>0.48</td>
</tr>
<tr>
<td></td>
<td>Divided</td>
<td></td>
<td>0.42</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Note. Each proportion (P) is based out of two possible opportunities to perform the task, twice under conditions of non-divided attention and twice under conditions of divided attention.

Results of the 2 x 2 x 2 MANOVA with PM performance as the dependent variable revealed a significant main effect of age on PM performance, $F(1, 88) = 5.24, p = .03, \eta^2 = .06$. Younger adults had a significantly larger proportion of correct PM responses ($M = 0.37, SE = .06$) than older adults ($M = 0.19, SE = .06$). See Figure 3.9. Additionally, there was a significant main effect of stimulus form on proportion of correct PM responses $F(1, 88) = 13.86, p = .00, \eta^2 = .14$. Participants in the picture condition successfully performed the PM task more often than participants in the word condition (picture $M = .43, SE = .06$ and word $M = .13, SE = .06$). See Figure 3.10.
Figure 3.9. Proportion of correct PM responses as a function of age group

Figure 3.10. Proportion of correct PM responses as a function of stimulus form
CHAPTER FOUR
DISCUSSION

A picture superiority effect, where pictures are remembered better than words, has been demonstrated in retrospective memory research when there is an explicit cue to prompt recall. Prospective memory tasks require self-initiated recall (if no memory aid is used); a person must remember on their own to perform a task when the appropriate cue appears. The question of whether a picture superiority effect exists in prospective memory (i.e., pictures help a person remember to perform a task more often than words) has been severely underrepresented in the literature, and was thus the focus of this paper. Additionally, by manipulating age (i.e. young and old adults) and attention load (i.e. divided or non-divided), we sought to examine if pictures led to automatic recall of prospective memory intentions, otherwise known as spontaneous retrieval.

Given that PM research suggests that distinctive cues are more likely to be remembered than non-distinct cues, and picture superiority effect research has established that pictures are more distinct than words, it is reasonable to assume that pictures should lead to better PM performance than words. Thus, we hypothesized that distinctive cue conditions (i.e., pictures) were more likely to lead to spontaneous retrieval, and thus better PM than non-distinctive cue conditions (i.e., words).
Does a Picture Superiority Effect Exist in Prospective Memory?

The main research question of this study was, “does a picture superiority effect exist in PM?” The results suggest yes, a picture superiority effect exists for prospective memory tasks. Participants viewing all picture stimuli not only remembered to perform the PM task more often than participants who viewed all word stimuli, they also performed the ongoing categorization task faster.

Although we had hypothesized that ongoing task accuracy would also have differential effects based on stimuli format, with word conditions performing worse, ongoing task accuracy was not influenced by what stimuli condition a participant was in. There were no significant differences in ongoing task performance between the word and picture conditions or between older and younger adults.

Ongoing task performance was likely high for a couple of reasons. First, participants were told to complete the ongoing categorization task as quickly yet accurately as possible. Ongoing task latency results showed that older adults performed significantly slower than younger adults, but they managed to have significantly equivalent ongoing task accuracy. Thus, older adults were making a speed accuracy tradeoff sacrificing quickness for accuracy.

Participants were also told that the PM task was a secondary task and there was only a 5% chance that they would see the target stimulus. This underemphasizing of the PM task placed more importance on the ongoing task, and likely led to the low PM performance seen all around (e.g., Kliegel, Martin, McDaniel, & Einstein, 2001, 2004). Although PM performance in the picture condition was better than PM performance in
the word condition, participants in the picture condition only performed the task correctly 21% of the time and those in the word condition only a mere 7% of the time. It appears that a dual-task tradeoff exists between the amount of effort and attention devoted to the ongoing task versus prospective tasks (Marsh & Hicks, 1998; Marsh, Hicks, Cook, 2005). In this case, more emphasis was placed on the ongoing task and consequently PM performance suffered.

**Do Pictures Promote Spontaneous Retrieval?**

The secondary research aim of this study was to determine if pictures (more so than words) promote spontaneous retrieval of a prospective intention. This was the primary hypothesized mechanism for improved PM with picture stimuli. Spontaneous retrieval was to be demonstrated in two ways. First, evidence for spontaneous retrieval of pictures would be provided if we found that participants in the picture condition did not experience a decline in performance between single attention and divided attention tasks, but participants in the word condition did (Einstein et al., 2011; Marsh, Hicks, & Cook, 2005).

This methodology presumes that dividing attention occupies resources and limits monitoring. Consequently, only cues that naturally and automatically capture attention (i.e. those that promote spontaneous retrieval) should be expected to sustain high levels of PM performance under both single and divided attention. Conversely, cues that do not promote spontaneous retrieval should be expected to have low levels of PM performance, regardless of whether participants are under non-divided or divided levels of attention.
Dividing attention appeared to lessen the amount of resources available to perform the ongoing tasks, as demonstrated by significantly lower ongoing task accuracy scores in the divided attention conditions than the non-divided conditions. Contrary to our predictions though, dividing attention did not negatively affect PM task performance. Although we hypothesized an interaction between attention and stimulus format such that PM performance in picture conditions would remain high and alike under both divided and non-divided attention conditions, while word performance would be significantly worse in divided than non-divided attention loads, this was not the case. As seen in Figure 4.1 below, there appeared to be floor effects in PM performance in the word condition, thus it did not matter if the participant was under non-divided or divided attention load.

Figure 4.1. Proportion of correct PM responses as a function of stimulus form and attention load
The second way that spontaneous retrieval was assessed was if older adult participants had equivalent performance to younger adults in the picture conditions, but not the word condition (Marsh & Hicks, 1998). The rational for this is that older adults are suggested to have preserved spontaneous retrieval, which is an automatic process, but not self-initiated retrieval (Craik, 1986). Therefore, if pictures lead to spontaneous retrieval, older adults should demonstrate high PM performance in the picture condition but not in the word condition.

Although there was not an omnibus significant interaction between age and stimulus form, the pattern of results reveals a trend that is consistent with the prediction that age differences would be increased when the target stimuli is non-distinctive (i.e. word format). As seen in Figure 4.2, the difference between older and younger adults is larger for the word condition (26%) than the picture condition (10%). Indeed, pairwise comparisons indicated younger adult performance was not significantly different from that of older adults in the picture conditions ($M = .48$ and $M = .38$; $p = .36$), but there was a significant difference between younger and older adult PM performance in the word condition with older adults performing significantly worse ($M = 0.00$) than younger adults ($M = .26$), $F(1,88) = 11.10$, $p = .00$, $\eta^2 = .11$. 
Support for the Multiprocess Theory

The multiprocess theory suggests that PM cue detection requires resources in some circumstances but not in others. According to this theory, successfully retrieving a PM intention may sometimes be a result of monitoring the environment but other times an intention will be spontaneously retrieved; the utilized method of retrieval is dependent on characteristics of the specific PM task, ongoing task, and individual (Einstein & McDaniel, 2000; McDaniel et al., 2008; Meier et al., 2006). See Table 1.1 for a list of factors in the multiprocess theory that influence how PM intentions are retrieved.

Our study sought mainly to examine the factor of distinctiveness, because pictures have been suggested to be more distinct than words. An examination of the literature on the effects of distinctiveness in PM revealed that the majority of studies to date (besides

**Figure 4.2.** Proportion of correct PM responses as a function of stimuli format and age
word valence distinctiveness studies) have examined *relative distinctiveness*—a task situation where the target cue is distinctive *relative* to all of the other stimuli presented. Relative distinctiveness is fundamentally different than what we are terming *absolute distinctiveness*, or inherent characteristics about a type of stimuli (i.e., pictures) that make it stand out more than another type of stimuli (i.e., words).

One reason why pictures have been suggested to be more distinctive than words is because their perceptual features are more varied. Words are restricted to a certain set of lines, curves, and letter combinations, but pictures can take on a diverse range of forms (Mintzer & Snodgrass, 1999; Nelson et al., 1976; Nicolas & Marchal, 1998). Another reason why pictures may be more distinctive than words is because pictures have both a verbal and spatial code, while words have just a verbal code (Pavio’s Dual Coding Hypothesis; Pavio 1969, 1971, 1986, & 1991). That is, while words carry just semantic meaning, pictures have an additional imaginal quality associated with them as well as their semantic meaning.

Previous relative distinctiveness PM studies have found that distinct PM targets improve PM performance. Results from this study confirm these findings with absolute distinctive stimuli; stimuli that are inherently more distinct will lead to better PM performance.

Although the focus of this paper was on the multiprocess theory factor of distinctiveness, our study actually was the first of its kind to cohesively examine the factors of age, attention load, and PM load in a single study (as well as stimuli format). Indeed, there was a significant main effect of all four main independent variables: age,
attention load, PM load, and stimuli format. These findings suggest, as the multiprocess theory posits, that a variety of factors will influence how a person shifts their attention from performing an ongoing task to executing a PM task at the appropriate moment.

**Practical Relevance of Picture Superiority in PM**

The practical relevance of this study is that our daily lives are inundated with PM tasks, and PM failure can negatively affect our personal health, financial, professional, or social life. Fortunately, there is potential for memory aids to ameliorate memory problems (Fink & Pak, 2010). The question of whether word or picture cues support better PM is important when it comes to the design of memory aids, as the technology readily exists to supplant electronic text with pictures. If pictures do indeed support better PM than words, the relatively simple design change of reminders from text to images may help reduce instances of forgetting both the prospective component (i.e., remembering to perform an intention at the appropriate moment) and the retrospective component (i.e., remembering the contents of the intention) of a PM task.

**Limitations and Future Studies**

The current study was limited to examining the picture superiority effect among pure lists of either all pictures or all words, with a target stimulus in the same format. It would be interesting to see how a condition that had a target stimulus in combined word and picture format would do. Our methodology assumed that pictures were inherently more distinct than words, which we termed absolute distinctiveness. It would be
interesting for a study to research if a picture superiority effect exists with relatively distinct picture and word stimuli. Would a picture target in a pure word list be remembered more frequently than a word target in a pure picture list? Or, does the relative distinctiveness of the target being unique from the rest of the ongoing task stimuli (i.e., word target in all pictures) cause such high PM performance that it outweighs any potential picture superiority effect?

Another interesting experiment would be to actually use pictures or words as PM reminders. Although this study was designed with the practical application of picture reminders in mind, for control purposes it was limited to a non-natural ongoing task, with basic stimuli and a short retention interval, in a confined laboratory setting. Examining naturalistic PM tasks with longer retention intervals and more realistic ongoing and PM tasks would expand our knowledge on the parameters of the picture superiority effect. For instance, a study could use a naturalistic PM task, like calling the research team at a certain time, and have smartphone reminders consisting of either all words or all pictures go out to the participant during the retention interval.

A specific limitation of some of the word stimuli in the ongoing task of this study was that a few were identified by participants as having the ability to be a man-made or natural object. For instance, the word sponge could be interpreted as a sponge from the ocean or sponge you use in your sink. The word ‘straw’ was identified as both a drinking straw or the agriculture material straw. Also, the word ‘iron’ was noted to be an iron for clothes or iron the mineral and the word ‘nail’ as a nail on a finger or a nail that gets hammered. There was no confusion over this in the picture condition as the participant
was able to see an image which explained the verbal letters. Figure 4.3 displays an internet image search of the words ‘iron’ and ‘straw’ and reveals the confusion that participants must have felt. Future studies should do thorough pilot testing to eliminate any words that could potentially be categorized as a manmade or natural objects.

Figure 4.3. A Google search of the words ‘iron’ and ‘straw’

The current study used a random number generator divided attention task similar to the one utilized by Einstein et al., (2011), but with one key difference. Although participants in both studies were expected to generate a random number whenever they heard a beep, Einstein et al., had participants listen to a recording and speak a random number verbally every time they heard a beep, while the current study had participants listen to a recording over headphones and type a random number whenever they heard a beep. The difference in methods of output (verbal versus manual) may have influenced
the difficulty of the divided attention task, thus affecting ongoing or PM task performance (Wickens, 1980, 2002). The divided attention task in the current study may not have been as difficult as the one used by Einstein et al. (2011), which would explain why we did not see a significant effect of dividing attention on PM performance or ongoing task latency. Conversely, as mentioned previously, it is also possible that having word stimuli to remember was so much harder than picture stimuli that it did not matter whether the subject was under divided attention or not, they always had poor PM performance. Future research should replicate this study with varying difficulty levels of a divided attention task. It would also be useful to examine if different types of picture stimuli (e.g., line drawings, scenes instead of objects) have differential effects on PM performance.

My Personal Prospective Memory Journey

I chose to study prospective memory throughout all six years of graduate school, my thesis and dissertation, because I have always been bad at it. I routinely forget to bring my reusable bags in the grocery store and often find myself ‘doubling up’ on my once daily medication because I forgot to take it the day before. Although it has caused annoyance and embarrassment, my poor prospective memory has never been life threatening—until now.

On Thursday October 26th, 2012, I presented two proceedings papers on prospective memory at the 57th Annual Human Factors and Ergonomics Society Conference in Boston, Massachusetts (Fink et al., 2012; Fink, Goodwin, Jewell, Kohn, & Pak,
At 3am the next morning I was taken to the hospital with sharp stomach pains and shortness of breath. I woke up Monday October 29th, after just barely passing the test where one must breath on their own for two hours before the breathing tubes can be removed and the life support machine disconnected. It was that day I learned I had Type 1 diabetes and chronic heart failure. Thankfully, my heart has almost fully recovered; but unfortunately, until a cure is discovered, I will have diabetes forever.

In an instant I went from a person whose only medical PM demands were a few appointments each year and a birth control pill every day, to someone that now needed to remember a plethora of medical-related prospective memory tasks including: always carrying a fast acting source of carbohydrates on person, checking blood sugar before and after eating and exercise, administering insulin before meals and bed, scheduling and showing up for laboratory blood testing and endocrinology appointments every few months, refilling all diabetes supplies before they run out, and dealing with insurance claims for a variety of medical services. Each of these PM tasks involves several steps, requires both prospective and retrospective memory, and has the potential for errors of omission and commission.

Results from the current study and prior research suggest that pictures should lead to both better prospective memory and retrospective memory. The following section provides a task analysis for the diabetic task of ‘administering insulin prior to meals’ in order to 1) showcase the myriad prospective and retrospective memory demands required and 2) explore how pictures and other design solutions can help alleviate memory demands. A brief overview of Type 1 Diabetes is provided first in order for the reader to
have a basic understanding of the relationship between blood sugar, insulin, and food intake.

**Brief Overview on Type 1 Diabetes**

Type 1 Diabetes Mellitus is a disease in which a person has high blood sugar because their pancreas does not produce enough insulin. Consequently, the person must self-inject insulin or wear an insulin pump that injects insulin in order to regulate blood sugar. Figure 4.4 provides an overview of the key points (Mayo Clinic Staff, 2013) necessary to this paper that one should know about diabetic blood sugar control and how various factors affect it.

A Type 1 Diabetic aims to keep his or her blood sugar in a range between 70mg/dl – 180mg/dl (American Diabetes Association, n.d.). It is important to prevent blood sugar from getting too high (hyperglycemia), because over prolonged time it can cause long-term complications like kidney, nerve, and eye damage. However, it is more important, absolutely critical, that a diabetic prevents blood sugar from getting too low (hypoglycemia), because it can cause a person to lose consciousness and even die (National Diabetes Information, 2011). When carbohydrates are ingested it causes blood sugar to rise. Grains, starches, nuts, fruits, and vegetables all contain carbohydrates. Insulin and exercise cause blood sugar to fall; taking too much insulin or exercising more than was accounted for can cause low blood sugar.
Figure 4.4. Illustration of a blood sugar scale for diabetics as well as factors that cause blood sugar to rise or drop. A diabetic patient aims to find the optimal balance between all of these factors and keep blood sugar in the normal (i.e. green) range.

How Can Pictures Aid Memory Demands in Insulin Administration?

For an insulin dependent diabetic, every snack and meal is a complex math problem of trying to determine how many carbohydrates will be consumed and how much insulin should be injected to maintain within their target blood sugar range. The amount of exercise one plans to do must also be considered because exercise naturally drops blood sugar; less insulin is necessary.

All of the mental and physical tasks that come with Type 1 Diabetes are extremely memory demanding. The task analysis found in Appendix A details just one of the new multistep PM tasks I now face as a diabetic—administering insulin before any
snack or meal. The task analysis includes the following 5 sections: 1) step of the insulin administration process, 2) PM memory demands, 3) possible memory failures, 4) retrospective memory demands, and 5) possible picture related human factors design solutions aimed at improving memory performance. A sample screenshot of the first page of the task analysis is provided below in Figure 4.5.

<table>
<thead>
<tr>
<th>Step of the Insulin Administration Process</th>
<th>Prospective Memory Demands (I must remember to do what?)</th>
<th>Potential Memory Failures</th>
<th>Retrospective Memory Demands (I must recall what?)</th>
<th>How can pictures or human factors design solutions improve memory performance?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. a. Have kit on person</td>
<td>- Carry diabetes kit on person at all times to check BS</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Switch the kit from different purses, backpacks, and gym bags</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Return the kit to carrying case after use</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. b. Ensure kit is stocked.</td>
<td>- Stock diabetes kit each morning with necessary equipment</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Several secondary PM demands are also involved here including calling the pharmacy or doctor for refills and picking up prescriptions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Forget a crucial piece of equipment necessary for testing (e.g., blood test strips) and cannot test blood</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 4.5. Screen shot of a task analysis on the diabetic task of administering insulin before a meal. The full task analysis can be found in Appendix A.

Breaking down the multi-step PM task of insulin administration into its component prospective and retrospective memory demands allows the reader to gain insight into some of the complicated memory challenges a person with Type 1 diabetes must deal with on a daily basis. The task analysis also provides insight to medical device
designers who can utilize knowledge about the picture superiority effect towards improving a user’s experience with insulin administration, while also decreasing errors and preventing injuries. I know from personal experience that memory failure is a problem. I can honestly say that I’ve experienced all but two of the PM failures listed in the third column in Appendix A. If simply changing the format of an item from a word to a picture will make it more distinct, and thus more memorable, it seems reasonable to try and incorporate it into medical device design where lives are at stake.
## Appendix A

Task analysis of the diabetic task of administering insulin before a meal

<table>
<thead>
<tr>
<th>Step of the Insulin Administration Process</th>
<th>Prospective Memory Demands (I must remember to do what?)</th>
<th>Potential Memory Failures</th>
<th>Retrospective Memory Demands (I must recall what?)</th>
<th>How can pictures or human factors design solutions improve memory performance?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. Test blood sugar (BS)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1.a. Have kit on person</strong></td>
<td>Carry diabetes kit on person at all times to check BS</td>
<td>Forget to bring kit with you and cannot test BS</td>
<td>Where is the diabetes kit located/when was the kit last used?</td>
<td>A picture sign of a diabetes kit could be placed in conspicuous locations like a bedroom door or car dashboard to prompt spontaneous retrieval to check and make sure the kit is on person.</td>
</tr>
<tr>
<td></td>
<td>Switch the kit from different purses, backpacks, and gym bags</td>
<td>Forget to return kit to carrying case or lose kit and cannot test BS</td>
<td></td>
<td>Reminders with a diabetes kit image could be sent to a smartphone.</td>
</tr>
<tr>
<td></td>
<td>Return the kit to carrying case after use</td>
<td></td>
<td></td>
<td>To prevent lost kits, a GPS tracking sensor could be attached to the diabetes kit with the ability to be tracked through the internet or navigation program (e.g., Maps).</td>
</tr>
<tr>
<td><strong>1.b. Ensure kit is stocked.</strong></td>
<td>Stock diabetes kit each morning with necessary equipment</td>
<td>Forget a crucial piece of equipment necessary for testing (e.g., blood test strips) and cannot test blood</td>
<td>What does the diabetes kit need to be stocked with? Mine has the following 8 elements (See Appendix B): 1. Meter 2. Blood test strips 3. Insulin pen 4. Lancing Device 5. Lancets 6. Insulin pen needles 7. Alcohol wipes 8. Extra meter battery</td>
<td>In order to easily spot if an item was missing, diabetes kits could be designed so that each item has a unique space designated for it, with a picture of the contents on that section (yet still see-through to see contents).</td>
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<td>Several secondary PM demands are also involved here including calling the pharmacy or doctor for refills and picking up prescriptions</td>
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<td>A laminated picture of the contents of the kit could be placed near where the materials are stored, and easily examined when stocking the kit each day to ensure each item is stocked.</td>
</tr>
<tr>
<td>Step of the Insulin Administration Process</td>
<td>Prospective Memory Demands (I must remember to do what?)</td>
<td>Potential Memory Failures</td>
<td>Retrospective Memory Demands (I must recall what?)</td>
<td>How can pictures or human factors design solutions improve memory performance?</td>
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<tr>
<td>1.c. Test BS</td>
<td>- Test BS before any carbs are ingested</td>
<td>- Forget to test before you eat and don’t know whether to adjust amount of insulin with sliding scale</td>
<td>- What steps are required to test blood (e.g., clean finger, correctly insert strip into meter, squeeze finger, wipe first drop of blood, form drop of blood and hold strip to blood)?</td>
<td>- Training manuals should include pictures to teach steps for checking BS.</td>
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<td>- Rotate finger that gets pricked to avoid scar tissue</td>
<td>- Use the same finger repeatedly and build up scar tissue</td>
<td>- Which finger was pricked last?</td>
<td>- Put a picture of a hand on the lancing device and each time a new lancet is used a different finger would be highlighted in some way.</td>
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<td>2. Determine amount of insulin to administer</td>
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<tr>
<td>2.a. Adjust for current BS level</td>
<td>- Adjust amount of insulin based on current BS level (called a sliding scale)</td>
<td>- Forget to increase insulin when BS is high and BS remains elevated</td>
<td>- How much extra insulin is given if BS is high?</td>
<td>- A picture of a BS range chart similar to the one in Figure 4.4 may be easier to interpret than just reading numbers.</td>
</tr>
<tr>
<td>2.b. Adjust for exercise</td>
<td>- Adjust amount of insulin based on intended exercise for the day</td>
<td>- Forget to decrease insulin to account for exercise and BS drops too low</td>
<td>- If following a planned workout schedule, must remember what activity will be done that day.</td>
<td>- A picture chart of various sports (with duration/intensity) and the amount less of insulin you should take may help decrease mental exertion and potential for errors.</td>
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| 2.c. Adjust for food                     | - Adjust amount of insulin based on the estimated amount of carbohydrates that will be consumed | - Forget to change the units and give too much or too little insulin | - How many grams of carbohydrates are in every single piece of food or beverage?  
- How many servings of carbs are being consumed, following the standard that 15 grams of carbs = 1 serving of carbs, and one is allowed 3-4 servings per meal | - On carb exchange lists (e.g., American Diabetes Association), instead of listing out the amount of food in list format there should be pictures of how much equals one serving (i.e., 15g of carbs).  
- Carb charts should display pictures with 15g portion size, instead of or alongside text like this:  
  2 TBS of raisins  
  17 (3 ounces) small grapes  
  3 ½ glasses (18oz) of merlot.  
- Instead of using specific amounts use familiar standard size objects like 1 ping pong ball equals 1 TBS or a tennis ball size should equal approximately ½ cup. Then, diabetics can associate food with a limited number of items to remember. |
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<td>3. Administer insulin</td>
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</table>
| 3.a Have insulin on person               | - Carry insulin on person at all times in case you will be eating  
- Switch the insulin from different purses and backpacks  
- Return the insulin to the carrying case after use | - Forget to bring insulin with you or lose insulin and insulin cannot be administered. If carbs are consumed, BS can get very high. | - Where is the insulin located/when was the kit last used? | - Design a place in the diabetes BS test kit for the insulin. Since you always have to test BS before eating, it is easy to carry the two together. |
| 3.b Have insulin administration device on person | - If using insulin in a vial, must carry a syringe on person  
- If using an insulin pen, must carry needle caps on person | - Forgets syringe or needle cap and thus cannot administer insulin. If carbs are consumed, BS can get very high. | - Are there needle caps (or syringes) stocked in the diabetes kit? | - Carry extra syringes or pen needles to use as back-up in case you forget to stock kit.  
- Have laminated picture of diabetes kit including pen needles and/syringes to view when stocking.  
- Design a place in kit to store pen needles or syringes. |
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<td>3.c. Protect Insulin from damage</td>
<td>Cannot leave insulin in temperatures below X and above X</td>
<td>Leave insulin in car on very cold or hot day and reduce the medicine’s effectiveness</td>
<td>What are the cut-off temperatures that insulin should not be exposed to?</td>
<td>At a basic level, the temperature extremes should be written on the actual insulin pen or vial…not the box it comes in.</td>
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<td>If using syringe and vial, must keep vial refrigerated (involves several secondary PM demands like making sure cold pack is frozen, remembering to grab from fridge, remembering to re-refrigerate, etc.)</td>
<td>Forget to refrigerate a vial or a box of insulin pens and reduce the insulin’s effectiveness</td>
<td>Where are the cold-pack and cooler located/when were they last used?</td>
<td>A picture of a thermometer that indicates with color and a warning indicator (pilot testing to determine indicator) the extreme temperatures that insulin should not be exposed to.</td>
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<td>Place a picture of the insulin vial on the door before you exit to remind you to grab your insulin</td>
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<td>Program a phone reminder with a picture of insulin and a refrigerator that automatically alerts you around mealtimes</td>
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<td>Design portable, convenient refrigeration like a mini cooler that can be plugged into the wall and car adapter</td>
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| 3.d. Actually administer the insulin     | - Turn dial or fill syringe to appropriate number of units of insulin and inject into skin  
- Check and make sure you are taking the correct insulin, some may look similar | - Forget to inject insulin causing blood sugar to rise  
- Fail to confirm correct insulin and end up injecting basal nighttime insulin when it should have been mealtime bolus insulin or vice versa. BS may drop too high or too low. | - How many units of insulin need to be administered?  
- Which insulin is taken at mealtime and which is taken at nighttime? | - Mandate that different types of insulin must be distinct colors. As seen in Appendix C, some look similar.  
- Make insulin cozies (i.e. holders) in bright identifiable colors |
| 3.e. Not forget that you already administered insulin | - *This is not so much something to ‘remember,’ as something to ‘not forget’. Do not forget that you have already administered insulin.  
- Commission errors of PM are when you forget whether or not you already completed the PM task. | - Unknowingly taking a double dose of insulin could cause blood sugar to drop dangerously low, leading to unconsciousness and even death | - How much insulin was administered?  
- What carbs were accounted for when insulin was administered?  
- What time was insulin administered? | - I think one of the most important things that insulin device makers can do to prevent PM commission errors is integrate a timestamp feature into insulin pens that automatically records the date, time, and amount of insulin that was administered (at a minimum).  
- Until the above technology is readily available, it would be useful for commission error prone diabetics to try and get in a routine of each time they administer insulin. A picture would be particularly for nighttime insulin, when tiredness or alcohol may impair memory. |
Appendix B
Images of the components of my diabetes kit (top) and the kit all packed up (bottom)

1. Meter
2. Blood test strips
3. Insulin pen
4. Lancing device
5. Lancets
6. Insulin pen needles
7. Alcohol wipes
8. Extra meter battery
Appendix C
Insulin pens may look similar but can be very dangerous if accidentally confused

In the above image, the insulin pen on top is for long-lasting nighttime basal insulin. The bottom insulin pen is for rapid-acting mealtime bolus insulin. If a diabetic patient confuses the two pens and accidentally gives themselves the wrong insulin, particularly a nighttime dose of a rapid-acting insulin instead of the appropriate long-lasting insulin, there is potentially fatal consequences as blood sugar can quickly drop too low.
REFERENCES


