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# THE ENCODING AND RETRIEVAL OF PROSPECTIVE MEMORY CUES

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## ABSTRACT

The purpose of this study was to investigate the effect of prospective memory (PM) cue type and format on the accuracy and response time of participants, as well as to delineate between the encoding and retrieval of cues based on cue format. To investigate this, a computerized task was designed and administered to forty-four college-aged students. Within-subjects effects for the main variables as well as interactions between variables were significant. Cue type was significant for both accuracy and response time; participants were more accurate and had faster response times with item cues than with category cues. Cue format was significant for retrieval accuracy and encoding response time, but not for encoding accuracy or for retrieval response time. The effect of the cue type on participant accuracy differed for retrieval of word and picture cues; accuracy was high for item type regardless of retrieval format, while retrieval of word categorical cues resulted in notably lower accuracy than retrieval of picture categorical cues. Though participants were more accurate overall with item cue types, the degree of their accuracy depended on the cue format and whether that format was the same for encoding and retrieval (a ‘match’) or not (a ‘mismatch’). Participants were more accurate in match situations across all conditions, with a word-word match demonstrating the highest participant accuracy amongst item cues but a picture-picture match demonstrating the highest accuracy amongst category cues. Encoding format was key amongst the mismatches because regardless of cue type, participants were more accurate encoding words than pictures. Similarly, they were more accurate retrieving pictures than words. In conclusion, these results cumulatively suggest that accuracy in completing a prospective memory task is maximized when the cue itself is an item encoded and retrieved in word format.

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## Introduction

Planning is one of the executive order functions that separates human beings from our evolutionary predecessors. The ability to mentally create an intention, then later remember that intention and execute it, is not only a unique and extremely valuable tool that helps us survive but it also in part defines us as a species. The downside to this, however, comes when our memories fail us. Errors in prospective memory are not only inconvenient in everyday life, for example forgetting to cash a check at the bank before it closes, but they can also prove to be fatal, for example when a pilot forgets to engage his landing sequence or a surgeon forgets to clamp a vital blood vessel before continuing the procedure. These kinds of errors prompt one to ask, what is the most effective way to encode and retrieve information so that we can minimize these errors and fulfill our intentions?

### What is prospective memory?

The term ‘prospective memory’ (PM) describes a situation in which an individual intends to perform an action at a later time. It not only refers to the cognitive process of memory, but it also encompasses planning, attention, and task management. It is also important to distinguish between prospective memory and retrospective memory; for prospective memory, retrieval cues do not specify details regarding the actual intention (Dismukes, 2012). When one mentally forms an intention to later complete a certain task, he or she always runs the risk of forgetting to complete that intention. However, a plethora of research has emerged over the past decade investigating aspects related to prospective memory that could potentially affect prospective memory performance, with the goal of maximizing the number of times any given person actually completes the original intended task. Among these areas of investigation are the difference between event and time based PM, theories to explain retrieval processes of PM cues, types of memory load, event boundaries, interruptions, cue valence and context, and implementations intentions. Cumulatively, this previous research on factors related to PM leads to the development of our hypotheses.

**Event Based vs. Time Based PM**

Dismukes (2012) defines and distinguishes between event-based and time-based PM. Event-based PM refers to one remembering to complete an action or task during a certain event, for example a mother remembering to give a card to her son at his birthday party. In contrast, time-based PM refers to when an individual intends to perform an action at a certain time or after a certain amount of time has passed, for example taking a batch of cookies out of the oven in thirty minutes. In general, people tend to complete time-based tasks less reliably than they complete event-based tasks, and far fewer studies have investigated time-based prospective memory than its counterpart. Yet both event-based and time-based PM are episodic in that they involve intentions that occur once; it is much harder to study habitual tasks as they relate to prospective memory in the laboratory. Their study focuses an event-based PM tasks, such as remembering to tell a friend something at a meeting later that day, though it also recognizes the lack of research on time-based PM tasks, such as taking cookies out of the oven.

**Spontaneous vs. Multiple Process Retrieval**

Rummel and Meiser (2015) argue that spontaneous retrieval processes drive event-based prospective memory, or as they define it, "the ability to remember to execute an intention when an environmental cue occurs" (p. 1). They suggest a spontaneous PM process based on cue-discrepancy, or the concept that people are constantly appraising the stimuli in their environment and will feel a discrepancy if they recognize a cue in the environment that they were previously primed to recognize as more relevant than the rest of their surroundings. This theory suggests that the discrepancy one feels once the prospective cue appears in the environment will prompt him or her to trigger a memory search to determine why that cue is more relevant than the surroundings. This makes the original intention come back into one’s mind and makes it more likely that he or she will complete that particular task or action. In addition to supporting spontaneous process retrieval, their work also found evidence for fluency-based intention execution. In other words, a relevant and recognizable stimulus has the potential to reactivate intentions to complete a prospective memory task even if that particular stimulus is completely unrelated to the task that one consequently remembers.

Einstein and McDaniel (2005) recognize that spontaneous retrieval processes are integral in one’s ability to process and execute prospective memory tasks, but they also suggest that the cognitive system relies on multiple retrieval processes. Data in their earlier research indicated that participants often remembered to complete a task simply because it “popped” back into their mind, prompting the expansion of the previously accepted spontaneous retrieval theory. Additionally, their reflexive-associative theory describes how individuals associate some cue with the target action when they form an intention for an event-based task, then later retrieve the intended action through an automatic associative-memory system once the cue appears. They suggest that this system exists solely for the purpose of “associative encoding and retrieval”, so that whether or not the person is consciously thinking about the prospective intention when the cue appears, its appearance reflexively triggers that individual to retrieve the original intention and perform the task. Their experiment mimicked that of many other laboratory investigations on prospective memory in that participants performed an ongoing, binary decision-making task and were periodically presented with a similar but different PM task. However, instead of randomizing the blocks in their experiment, they rather intentionally had participants alternate between completing blocks of only the ongoing task and of the ongoing task combined with the PM task.

**Types of Memory Load**

Meier and Zimmerman (2015) defined and investigated four different types of load as they relate to prospective memory and task performance. Prospective memory load (PML) refers to the additional demands that result when a prospective memory task is added amidst an ongoing task, and can typically be measured through examining the effects on one's ongoing task performance. Ongoing task load (OTL) refers to the demands of the ongoing task, while prospective load refers to the demands of the prospective memory task. Finally, retrospective load (RL) refers to the number of actions one needs to remember in order to complete the prospective memory task. A plethora of research has been conducted on whether automatic or controlled processes guide prospective memory retrieval, and many researchers have investigated ongoing task load through manipulation and variation of ongoing task number and difficulty. However, fewer studies have examined prospective load, hardly any have examined retrospective load, and none other than Meier and Zimmerman have systematically analyzed all four types of load. Additionally, their study is unique in that it separately analyzes the prospective and retrospective components of memory. Participants were required to continually press a certain key, and were instructed to press a different key with the same finger as soon as the PM cue appeared. By the nature of this design, participants had to first release the ongoing task key before they were able to press the key to complete the prospective memory task; releasing the ongoing key represents the prospective memory component, as one executes that task in the future, whereas pressing the appropriate prospective key indicates the retrospective component, as one must pull that piece of information from past memory. Overall, they found that load affected the retrospective component rather than the prospective component. This is presumed to be because the prospective component could be considered more of an automatic process, requiring minimal processing and able to occur without conscious control, compared to that of the retrospective component, part of a more controlled and resource-demanding process. Their results also demonstrated that prospective load affected categorical targets, but not specific targets. This exemplifies one claim of multiprocess theory that automatic processing is more heavily involved with specific prospective targets, making it more difficult to affect one's performance.

**Event Boundaries**

Radvansky (2012) explored the relationship between cognition and event boundaries, or the transitions from one event to another. These transitions can develop in a multitude of ways, ranging from a change in location to the introduction of a new task. His work focuses on how moving from location to location can both hinder or improve PM performance, a phenomenon explained by the Event Horizon model which details how event boundaries can either impair or improve memory based on context and other factors.

One particular condition studied by Radvansky, Krawietz, and Tamplin (2011) was walking through doorways. Similar to the work of Einstein and McDaniel (2005) showing that sometimes an intention spontaneously "pops" into one's mind, Radvansky wanted to determine whether moving from one place to another could trigger a decline in memory of an intended action. Previous research on event-based PM revealed a location-updating effect, meaning that people tend to forget more information when they pass through a doorway than if they remained in the same room as they were in when they formed the initial intention (as cited in Radvansky & Copeland, 2006; Radvansky, Tamplin, & Krawietz, 2010). Their research confirmed that walking through a doorway affects performance because as it serves as an event boundary, causing one to initiate an update of his or her event model. Performance was not only affected by this updating process, as it causes a decrease in the availability of information for objects associated with the task, but also by the presence or absence of an event shift, the presence or absence of retrieval interference, and the priming of relevant information.

**Interruptions**

Finstad, Bink, McDaniel, and Einstein (2006) investigate the effect of breaks and task switches in prospective memory, while Radvansky et al. (2011) explore more in depth how individuals utilize breaks and whether or not they can serve to improve prospective memory performance. Their results indicated that the presence of breaks alone did not produce significant effects because the break alone was not enough to improve prospective memory; rather, the intention of the individual was crucial. Including breaks tended to interfere with task performance except when individuals utilized the break to review the intentions and goals, and when the importance of the PM task was greatly emphasized before the break (as cited in Einstein et al., 2005). Unfortunately, this finding is not of much use in an applied setting because it is not binary in its suggestion to intentionally create breaks in the work setting to maximize prospective memory.

In a more practical analysis of interruptions in the workplace, Kate Walders (2012) conducted a large-scale research study on emergency room doctors and gathered their perceptions of justification, helpfulness, and harmfulness of interruptions in their work. She found that memory events, or reminders to complete a certain task, composed a significant portion of interruptions experienced by physicians. Moreover, both interruptions with and without memory events as well as those that resulted in some kind of physician memory loss were deemed helpful to the interrupter, perceived as justified, and therefore also deemed beneficial to the physician being interrupted. Despite previous research contradictory to these claims in a more generalized setting, this research demonstrates that interruptions are in fact beneficial to physicians because they serve to mediate the generally enormous cognitive load that physicians tend to experience by reminding them not only to complete a certain task but also to complete that task at the time of the reminder. Even those who did not complete the task at the exact time of the reminder were found to be more likely to complete the task in the near future; per spreading activation theory, the reminder itself heightened the activation of the memory of the cue, keeping it towards the forefront of one's memory. Walders acknowledges that interruptions seem to be an effective means of communication between physicians, nurses, and other emergency staff members to exchange information quickly; however, to maximize the benefits and minimize the adverse effects of interruptions, staff must also implement more effective communication protocols between providers to decrease interruptions in the form of potentially distracting, patient-specific questions.

Dismukes' (2012) review focuses on interruptions as they pertain to habitual and episodic task performance and prospective memory. He explains that most everyday and workplace actions are habitual, and also that errors in or forgetting to perform a habitual task tends to have much more detrimental consequences than that of forgetting an episodic task. His review highlights that interruptions, or the absence of cues that normally prompt one to complete a habitual task, habit capture, and multi-tasking can have major negative consequences on a pilot. Previous research has shown that participants complete a given task when interrupted and not subsequently reminded of the task; when the task fell in a normal sequence of habitual tasks or events, but the normal sequence was disrupted; when an individual intentionally replaces a habitual action with an atypical action but does not consciously monitor the execution of that atypical action; and when multitasking or failing to switch attention from one task back to another. He suggests that these four situations apply equally to the field of medicine, amplifying the need for medical professionals to develop tools such as checklists to fight these disruptions to PM performance. Finally, he proposes that implementation intentions, or clearly stating and visualizing when and where one will execute an intention, may be the most effective method to drastically improve PM performance in everyday settings.

**Implementation Intentions**

McDaniel (2008) details how implementation intentions can positively affect prospective memory performance. An implementation intention is a planning technique involving the mental linkage of a situation-specific cue to the intention to perform an action upon the emergence of that cue; McDaniel (2008) found that prospective memory increased significantly in participants who employed implementation intentions. In other words, accuracy increased when the participants formed an intention, or encoded the information, in the same format they would later retrieve it.

**Cue Valence and Context**

Foos, Brewer, Marsh, and Meeks (2009) explore how the context in which event-based PM cues occur affects their detection. Overall, positive cues elicited more responses from participants than did negative cues, and participants missed negatively framed event-based cues much more often than they missed positively framed ones. It can be hypothesized that this is because processing negative cues parallels dividing attention in that the negative thoughts and associations brought to mind when prompted with a negative PM cue more easily displace the original intention than would a positive PM cue. Overall, their results demonstrated that when a cue was presented in any kind of emotional context or valence, participants were less likely to categorize the cue as related to a previously established intention and also less likely to complete the original intention.

**Summary**

Overall, the available research on prospective memory provides a thorough overview of many separate, individual factors that affect how individuals process information and consequently their ability to remember and execute prospective memory tasks. However, the research is sparse in that a plethora of different factors have been studied to see whether or not they affect PM performance yet little research has been done to synthesize these findings. Individually, each study offers distinct and valid results. Yet to truly move forward and progress into the future in this developing field, more research needs to be conducted on a broader level and from a different perspective. For instance, Meier and Zimmerman (2015) suggest that since everyday PM targets are often related to the content of intended actions, which is difficult to manipulate in a laboratory setting, future research should explore how spontaneous retrieval interacts with different 'loads' to affect PM performance. This area synthesizes multiple areas touched on by several articles but synthesized by none. Similarly, Dismukes (2012) suggests that nearly all current theories revolve around cue-based retrieval and the conditions that affect them but hardly any examine the process of encoding and the conditions that affect it.

**Present Study**

My research synthesizes many aspects explored in the current literature on this topic and strives to fill the current gap in the research by focusing not only on the retrieval but also on the encoding of cues. It also explores the nature of the cue and the effect that has on accuracy and response time, measures employed to analyze prospective memory performance across many studies. Though previous research has examined certain conditions related to the nature of the cue including categorization and valence, few to none have examined differences between the encoding and retrieval of specific versus categorized cues, nor between words versus pictures.

In the present study, participants were asked to perform a prospective memory task while performing an ongoing judgment task through a computer program. The program, designed specifically for this study, randomized and presented participants with eight different sections each containing twenty screens. On each screen, they saw a colored circle and judged whether it was a primary color (red, yellow, blue) or not (purple, orange, green, brown). Each screen also included a word or a picture, side by side yet irrelevant to the actual color judgment task. All words and pictures were chosen specifically so that no effects would be observed due to cue valence and context. Depending on the program's randomization, the word or picture presented on each display was either neutral (a filler cue) or served as one of the prospective memory cues, which were presented to the participants at the beginning of each section of the experiment. Participants were to complete the color judgment task unless one of the words or pictures matched on of the three prospective memory cues for that portion of the experiment (see Appendix B for complete list of cues). Only three screens in each of the eight sections actually contained a prospective memory cue; all other screens contained filler words and pictures.

Designed to explore the encoding and retrieval of prospective memory cues through accuracy and response time of participants, the study examined the nature (item or category) and format (word or picture) of the cues as participants encoded them prior to beginning the ongoing task and retrieved them during the actual task. Each of the three PM cues per section could be presented prior to beginning the ongoing task (process of encoding) as an item or a category, and as a word or a picture. Similarly, each of the three PM cues per section could be presented during the actual ongoing task (process of retrieval) as an item or a category, and as a word or picture. In other words, the study tested three distinct variables: type (item versus category), encode format (word versus picture), and retrieval format (word versus picture).

**Hypotheses**

I predicted that accuracy will be highest and response time will be quickest when the cue type is an item, rather than as a category, and that accuracy will be highest when the participants encode and retrieve the cue in the same format, either word-word or picture-picture. This hypothesis reflects the principles explored by McDaniel (2008) regarding implementation intentions and their effect on prospective memory performance. I also predicted that main effects, as well as interactive effects, would be observed of the variables.

# Methods

## Participants

Forty-four young adults participated in the study, all of whom are undergraduate students at the Pennsylvania State University (39 women, 5 men; 41 right-handed, 3 left-handed) and received class credit in exchange for their participation. All participants provided consent prior to completion of the study, per the Institutional Review Board.

## Design

The study utilized a 2 (encoding, retrieval) X 2 (cue format: word, picture) X 2 (cue type: item, category) within-participants experimental design. The independent variables studied were type (item vs. category), encode format (word vs. picture), and retrieval format (word vs. picture). The dependent variables studied were accuracy (the number of times they correctly completed the PM task, out of three possible times) and response time (the amount of time elapsed between the appearance of a screen and the participant pressing a key on the keyboard).

## Materials

Participants completed the program through E-Prime individually, in rooms equipped with computers. Preliminary results were exported to Microsoft Excel for preliminary graphing and analysis prior to a more comprehensive statistical analysis completed using IBM SPSS Statistics Software.

## Procedure

The program consisted of three practice tasks that mimicked the tasks asked of the participants throughout the study, followed by a series of eight blocks in a random order. Each block (see Appendix A) consisted of twenty slides, three of which contained the PM cue and seventeen of which contained a filler cue. Each of the 180 slides contained two graphics: a colored circle and either a word or a picture to its right. The ongoing task was determining whether the circle was a primary color (red, blue, or yellow) or not (purple, green, orange, or brown). Participants were instructed to hit the P key if the circle was a primary color, and to hit the O key if the circle was not a primary color. At the beginning of each of the eight blocks, participants read an instructions screen that specified three PM cues for that particular section. The screen explained that the participant was to complete the ongoing task to the best of his or her ability except upon the appearance of one of the PM cues. When a PM cue appeared next to the circle, the participants were to hit the space bar regardless of the color of the circle. The PM cues differed in each of the eight blocks, depending on the nature of the encoding and retrieval cue conditions assigned to each block. See Appendix A, Figure 10 for pictorial representation of the PM cues for each section.

All words and pictures were standardized to the same size so that no visual inconsistencies occurred as to affect the results. Each word and picture could be pronounced in a single syllable when iterated aloud, to ensure simplicity of cues. Filler cues did not overlap with any of the four categories utilized (i.e. since one of the blocks utilized ‘animals’ as its category PM cue, animals were not used as filler cues in any of the blocks). This was done to avoid participant confusion, for depending on the randomization of the experiment and whether or not the participant had already completed the animal category section, a filler cue could have caused confusion or triggered a different control process that we were not interested in measuring. Additionally, typical category PM cues were specifically chosen, rather than utilizing more peripheral category cues (i.e. under the ‘animal’ category, an easily recognizable dog was utilized, rather than a more difficult salamander or anteater).

***Encoding***

At the beginning of each block, participants received specific instructions. Each instructions slide reminded the participant of the ongoing memory task of primary color distinction, then provided three words or pictures to serve as the PM cues for that particular block. Item slides instructed participants to hit the space bar any time one of the items appeared on the screen, whereas category slides instructed participants to hit the space bar any time they saw anything in the category to which the three items belong.

***Retrieval***

Once the participants had read the instructions for the block, twenty screens were presented in random order, and they were expected to remember the ongoing task and PM task instructions given at the beginning of that block. While the instructions presented the three PM cues for encoding in a certain format, it did not provide the participant insight into what format the cues would be presented in later in the block, so the participant did not know ahead of time the format in which he or she would be retrieving the cues. The retrieval format remained consistent for the duration of the block, so regardless of the encoding format on the instructions screen, the retrieval format of the cues remained the same for all twenty slides in each block.

## Results

Results were analyzed through repeated-measures analyses of variance (ANOVAs) using IBM SPSS Statistics Software. A general linear model (GLM) analysis tested for within-subjects effects; main effects, as well as interaction effects between the three variables, were examined.

### Cue Type: Item vs. Category

The analysis of variance for cue type for accuracy and response time demonstrated that an overall significant difference existed between several variable means. Cue type was found to be significant for both accuracy ($F(1,43) = 6.775$, $p < .001$) and response time ($F(1,43) = 11.358$, $p < .005$).

Figures 1 and 2 illustrate the significant differences found in the within-subjects test. Participants were much more accurate, despite whether they were encoding or retrieving, with items ($M = 0.820$, $SD = 0.968$) rather than with categories ($M = 0.543$, $SD = 1.892$). They also had significantly quicker response times when the cues were items ($M = 1.390$ *s*, $SD = 1.951$) versus categories ($M = 1.702$ *s*, $SD = 4.004$). Thus, higher accuracy was associated with lower response time, which makes sense, as retrieval of a category versus an item requires one to retrieve more information.

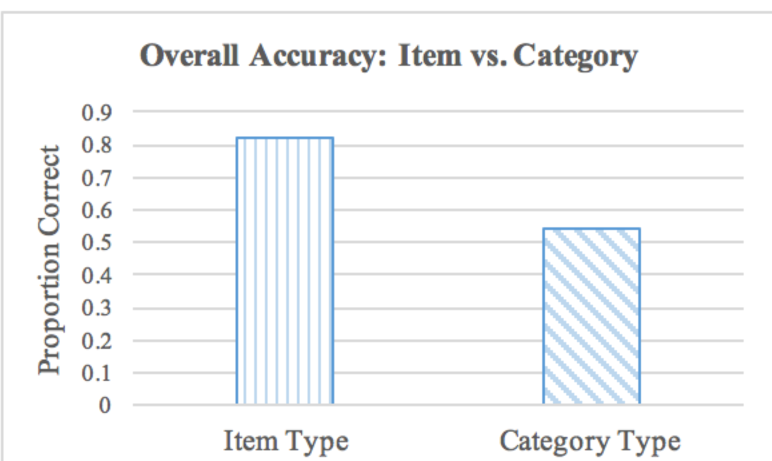



**Figure 1: Overall Accuracy Comparison**

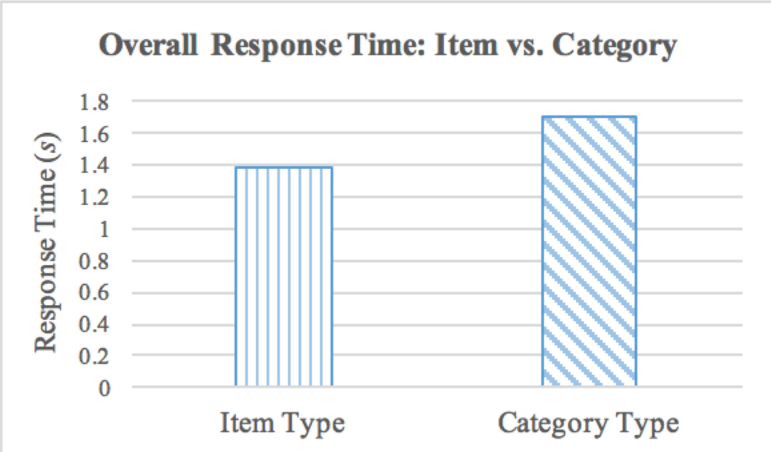



**Figure 2: Overall Response Time Comparison**

**Cue Format: Word vs. Picture**

As illustrated in Figures 3 and 4, retrieval cue format (word versus picture) was significant for accuracy ($F(1,43) = 10.674$, $p < 0.005$), but encoding cue format was not ($F(1,43) = 1.352$, $p = 0.128$). Conversely, encoding cue format was significant for response time ($F(1,43) = 7.454$, $p = 0.009$), but retrieval cue format was not ($F(1,43) = 0.087$, $p = 0.769$).

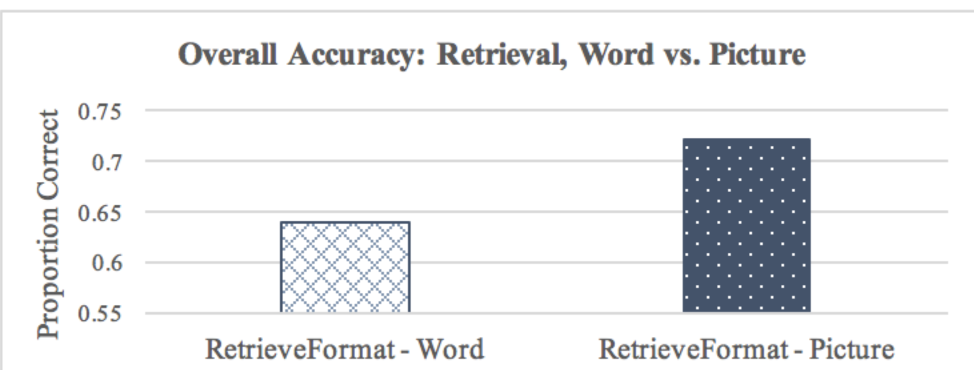



**Figure 3: Retrieval Accuracy as a function of Cue Format**

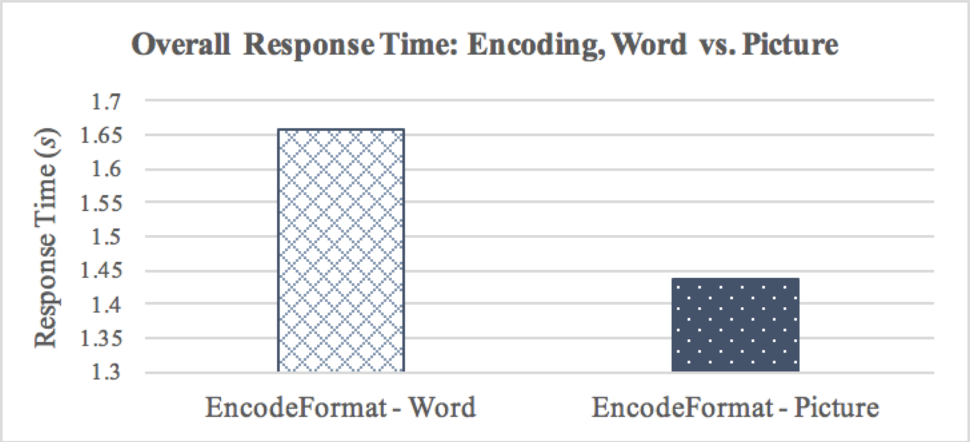



Figure 4: Encoding Response Time as a function of Cue Format

**Simple Interaction Effects**

Figure 5 illustrates the significant interaction between cue type (item or category) and the retrieval format of the cue (word or picture) ($F(1,43) = 7.796$, $p = 0.008$). This interaction suggests that the effect of the cue type on participant accuracy was different for retrieval of word cues than it was for the retrieval of picture cues. Though accuracy was nearly identical for item types regardless of retrieval format, accuracy retrieving categorical cues was lowest when the cue was in word format.

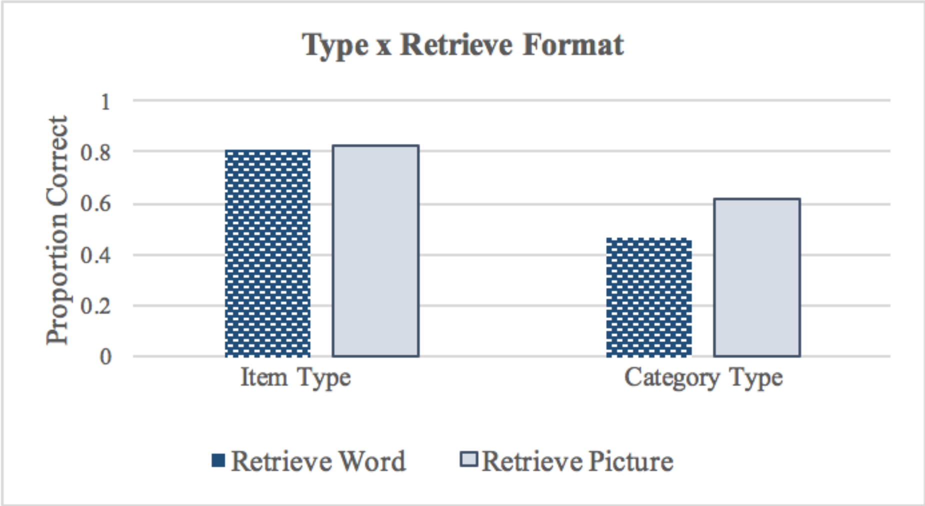



Figure 5: Accuracy Interaction Means for Type x Retrieve Format

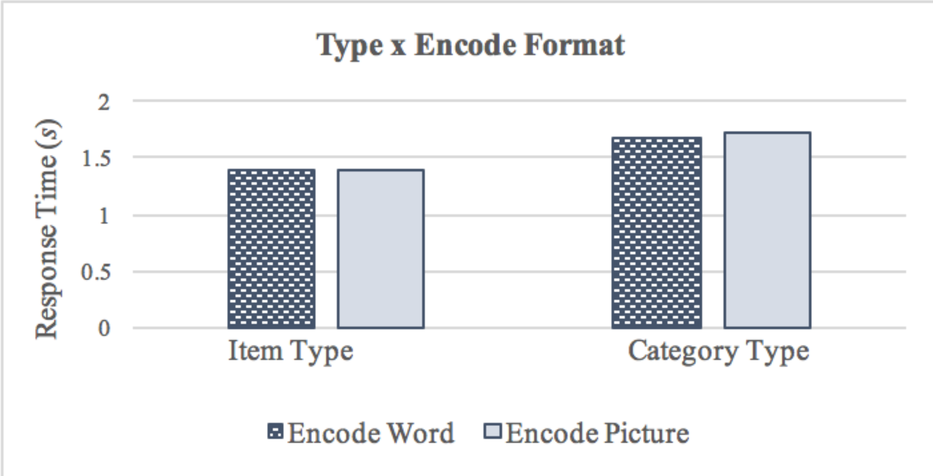



**Figure 6: Response Time Interaction Means for Type x Encode Format**

Figure 6 depicts the significant interaction between the type of cue and the encode format of the cue for response time ($F(1,43) = 7.812$, $p = 0.008$), suggesting that the effect of different cue types on participants' response time was different for cues encoded as words than as cues encoded as pictures. Response times were faster for item cues than for category cues overall, though response times were much closer for words and pictures of the item type than they were for the category type. The interaction likely occurred because though response times were nearly identical for words and pictures of the item type, encoding words was slightly faster than encoding words within the category type.

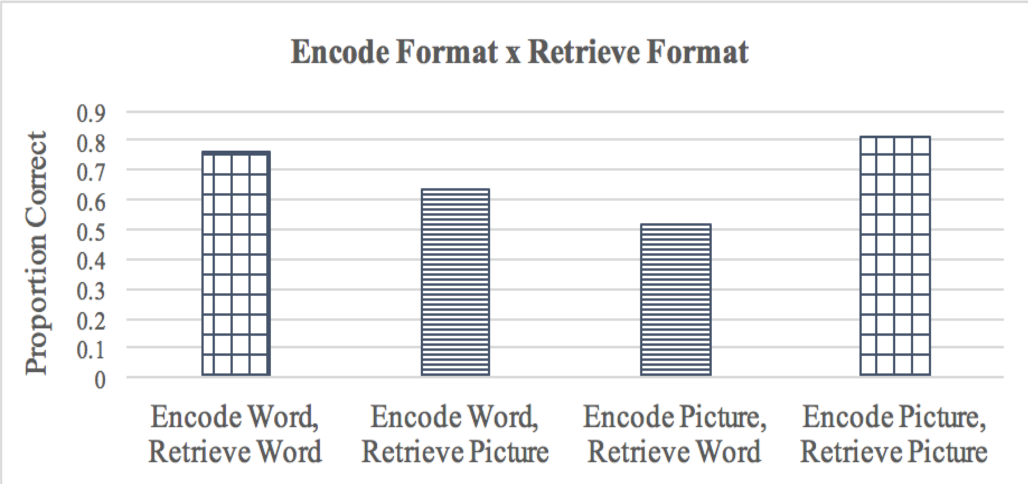



**Figure 7: Accuracy Interaction Means for Encode Format x Retrieve Format**

Figure 7 illustrates the significant interaction between the format of a cue (word or picture) for encoding and for retrieval. An important conclusion to draw from this data is that regardless of the specific condition, participants were more accurate when the format of the cue was the same for both encoding and retrieval, as illustrated by the outer two checkered columns.

**Complex Interaction Effect**

Figures 8 (below) and 9 (see Appendix A) illustrate the estimated marginal means for all conditions for accuracy and response time, respectively. An interaction effect exists between all three variables (type, encode format, and retrieve format) for accuracy ($F(1,43) = 14.331$, $p < .001$), but not for response time ($F(1, 43) = 2.599$, $p = 0.114$). In Figure 8, the x-axis refers to the encoding format; bar shading indicates whether the encoding format is a match or a mismatch with the retrieval format.

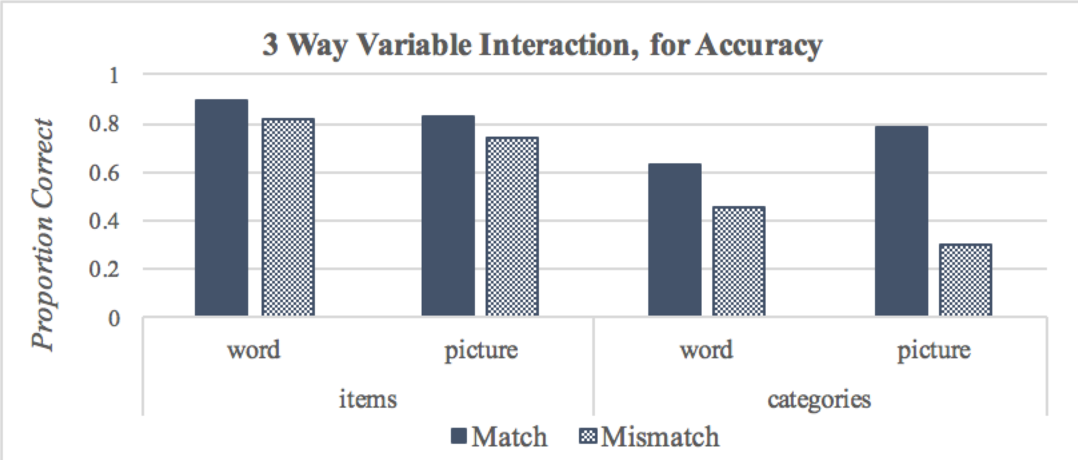



**Figure 8: Type x Encode Format x Retrieve Format Accuracy Interaction Means**

Overall, participants were more accurate with item cue types. However, the degree of their accuracy depended on the cue format (word or picture) and on whether that format was consistent for both encoding and retrieval. A match refers to a condition where the encoding and retrieval format of the cue were the same, either both words or both pictures, while a mismatch refers to a condition where the encoding format was a word and the retrieval format was a picture, or vice versa.

**Match Analysis**

Within each type, participants were more accurate when the format was consistent for both encoding and retrieval. Yet this effect is much larger for the category type, as participant accuracy among matches was very similar for words ($M$ = 0.894) and pictures ($M$ = 0.833), versus a more varied accuracy between category word matches ($M$ = 0.629) and category picture matches ($M$ = 0.788).

A word-word match (both encode and retrieve with a word) demonstrated the highest participant accuracy amongst item cues, yet a picture-picture match (both encode and retrieve with a picture) demonstrated the highest participant accuracy amongst category cues. This differs slightly from the simple interaction effect of cue format (Figure 7), which suggested that regardless of cue type, a picture-picture match (*M* = 0.811) produced slightly more accurate results than a word-word match (*M* = 0.746).

Accuracy also varied amongst matches across cue types. While a large difference (0.265) exists between the accuracy levels of item word matches (*M* = 0.894) and category word matches (*M* = 0.629), participants were similarly accurate with item picture matches (*M* = 0.833) and category picture matches (*M* = 0.788) with a mere 0.045 difference between means.

**Mismatch Analysis**

Across all conditions, participants were less accurate when the encoding and retrieval format of the cues differed. Mismatches also produced more accurate results when the cue type was an item as opposed to a category. This effect was slightly larger for categories than for items, though the effect was not as strong as it was amongst the matches. Mismatch accuracy for item cues encoding with a word (*M* = 0.818) was similar to accuracy for item cues encoding with a picture (*M* = 0.735), as opposed to a larger difference between category cues encoding with a word (*M* = 0.451) and category cues encoding with a picture (*M* = 0.303).

Encoding format was key amongst the mismatches. Regardless of cue type, participants were more accurate when they encoded the cue as a word than when they encoded the cue as a picture. This also means that regardless of cue type, participants were more accurate when they retrieved the cue as a picture than when they retrieved the cue as a word. This interactive effect demonstrates the significance of retrieve format for participant accuracy ($F = 10.674$, $p < 0.005$).

**Conclusions**

The most accurate condition was item type, both encoding and retrieving with a word cue (*M* = 0.894, *SD* = 1.232). The least accurate condition was category type, encoding with a picture cue yet retrieving with a word cue (*M* = 0.303, *SD* = 2.068). The fastest condition was item type, both encoding and retrieving with a picture (*M* = 1.247 *s*, *SD* = 2.677); the slowest condition was category type, encoding with a word yet retrieving with a picture (*M* = 1.921 s, *SD* = 8.138).

## Discussion

The present study examined participant accuracy and response time across conditions, varying cue type (item or category), encode format (word or picture), and retrieve format (word or picture). It was hypothesized that accuracy would be higher in trials where the cue was an item type and where the format of the cue was the same for both encoding and retrieval. Similarly, it was hypothesized that participants would be slower in encoding and retrieving cues that were presented as categories.

Overall, the results were consistent with the hypotheses. Participants were more accurate and exhibited faster response times when the cue type was an item, rather than a category, which is consistent with previous findings concerning the nature of task demands and focal and non-focal cues. Einstein et al. (2005) found that in the context of a category judgment task, a word cue would be more focally processed than a syllable cue, therefore improving prospective memory performance and retrieval through a spontaneous process, as opposed to a non-focal cue. Most research has suggested that for both focal and non-focal cues, increasing the demandingness of the task decreases accuracy and performance, though more of an effect is seen for nonfocal cues (Marsh, Hancock, and Hicks, 2002). Additionally, some studies have found that focal cues tend to produce faster and more accurate results than nonfocal cues (Scullin et al., 2011). When the target cues were items, regardless of whether they were words or pictures, processing those cues would not bring to mind a higher categorization or classification label, thus making those conditions lower in focal processing than their category counterparts. Category-type cues, conversely, require an additional processing step from the participant by mentally categorizing an individual representation into its respective category, then upon retrieval determining whether or not another individual representation fits into the same category. This helps to explain why participants were more accurate and faster in responding to item cues, as opposed to item cues.

As expected, ‘matches’ led to more accurate results than instances in which the encoding and retrieval format of the cue differed. These findings parallel previous conclusions drawn on the link between implementation intentions and increased prospective memory performance: individuals are more likely to remember to do something if they encoded the information originally in the same format they would later retrieve it in, based on the given situation (McDaniel, 2008). However, several unexpected results also emerged independently from that of our hypotheses.

Encoding format, for instance, produced significant, yet different, effects depending on whether the condition was a match or not. For matches, the trend differed between item and category cues, while mismatches produced the same trend across cue types. Among the item cues, word-word matches and picture-picture matches had nearly equal accuracy. Among the category cues, however, picture-picture matches produced notably more accurate results than did the word-word matches. This may have occurred because individuals may be more accustomed to grouping similar items together into a category as pictures or visual representations than doing so when they are in word format. In other words, it may be easier to see pictures of a table, sofa, and drawers and then retrieve pictures of similar aesthetic of other furniture items than it is to see three words and then later retrieve three similar, but distinct words. Additionally, memory research has generally found that people remember pictures better than they remember words (Haber and Myers, 1982; Paivio, 1991; Groome and Levay, 2003). This could be because pictures are naturally more memorable than words, or because they tend to contain more ‘detail’ (i.e. a picture of a dog contains more description than just three letters) (Esgate, Groome, and

Baker, 2005). By contrast, item type cues hypothetically did not require any higher level of processing or categorization in order to group together and recognize, explaining the similarity between the word-word matches and picture-picture matches.

Regardless of cue type, a picture-picture match produced more accurate results than a word-word match. This finding is consistent with the explanation given above, offering support to the notion that pictures are more easily remembered than words. The interaction of all three variables, however, demonstrates an important role for cue type; once cue type is included in the effect, items once again emerge as able to produce more accurate results than could categories. Perhaps pictures are more easily remembered than words and items are easier to encode and retrieve than categories. However, the overall results demonstrate that the latter effect of cue type must be stronger than that of cue format, for items produced more accurate results than their category counterparts in three of the four conditions, and had nearly identical accuracy in the fourth.

For the mismatch cases, encoding in word format produced more accurate results for both item and category types. One could also view this result as retrieving in picture format produced more accurate results for both item and category types in the case of a mismatch. Interestingly, retrieval format produced a significant main effect for accuracy, though encoding format did not. Perhaps since people can remember pictures more easily than words, it was easier for them to encode with a word then later recognize that word in picture form than it would be to do the opposite, starting with an easy-to-remember picture then later having to retrieve that picture in word form. Though the mechanisms underlying specific encoding and retrieval strategies are very similar, research shows that memory for pictures may be mediated by bilateral vision and medial temporal cortices, more effective and automatic areas of processing than the ones that might mediate memory for words (Grady, McIntosh, Rajah, and Craik, 1998). In other words, the mind might be more accurate at retrieving a picture than a word in a mismatch situation simply because of the complex processes in place to effectively do so.

**Practical Implications**

In order to maximize accuracy, the current study suggests that one should employ item cues and encode and retrieve them as words. However, it is important to keep in mind that while the results offer items as more accurate than categories, it is also better to have a cue format 'match' than to either encode or retrieve an item. These principles can be applied to everyday life to better understand the relationship between planning and action, and the effectiveness of reminders in prospective memory performance.

In one case, the results can be applied to everyday reminders. For example, you need to remember to pick up your prescription at the pharmacy later in the day. Our study suggests that to have the best chance at completing that task, you would mentally make a note to yourself of 'prescription', then write a note stating 'prescription'. Essentially, you are encoding and retrieving the reminder in the same format, and in word form. Based on the conclusions of this study, you would have a better chance at remembering to pick up your prescription than if you wrote a note of 'drugstore', a more categorical term, or if the encoding and retrieval formats were not a match.

The current investigation has broader implications for everyday life and for the medical field. For instance, surgeons need to remember series of steps in a procedure, and their ability to execute those steps in the exact order that they originally learned them can be the difference between a life or death situation in the operating room. For a complex procedure, a 'reminder' check sheet would be most useful to a surgeon if it contained a simple list of words in order, those words each representing a unique step of the procedure as the surgeon originally learned and encoded the steps.

At the Cincinnati Children's Hospital Medical Center, each surgical division developed reminder procedures similar to that described above in order to reduce the occurrence of surgical site infections (SSIs) following surgery. The reminder list they created was implemented on every computer (for encoding) and printed on every surgical schedule (for retrieval) so that nurses, surgeons, and anesthesiologists all followed the same procedure. By doing this, the hospital reduced its average length of patient stay to 10 days per case, saving the hospital an average of $6.3 million and preventing approximately 233 SSIs across a span of six years (Committee on the Learning Health Care System in America, 2013).

**Limitations**

The directions for each block were seemingly neutral and did not explicitly suggest participants should form implementation intentions. However, some participants still may have formed stronger, more associative linkages than others were able to (Kliegel et al, 2007), improving their performance and affecting the results. In addition, participant priming could have affected their prospective memory performance, for if a participant had been primed somehow to certain words or pictures is unknown. To ensure this phenomenon did not interfere with the phenomenon in question and to set an equal stage for all participants, we could have added a section in the beginning of the experiment where the individuals would have 30 seconds to write down as many items as possible that fall under each of the four utilized categories (vehicles, animals, food, and furniture).

PM cues were presented in each block fifteen percent of the time; though significant results were produced, if the study were to be replicated, one might consider testing a group with a lower percentage of PM cue appearance. Other studies have used as many as 80 filler cues and only two PM cues, meaning the PM cue was presented approximately three percent of the time as opposed to the current study's fifteen percent (McDaniel, Howard, and Butler, 2008). Hypothetically, making the distinction between the ongoing task and the PM cue appearance more difficult may amplify the results found in this study and provide further insight into this phenomenon.

Despite cue format, both words and pictures were encoded by participants visually. However, many PM cues are encoded through audition on a day to day basis, rather than through visual representations. Though Einstein et al. (2003) did not find significant differences between the encoding of visual and auditory cues, the difference remains a valid variation to be considered.

**Future Directions**

Moving forward, it will be important for future studies to further explore the function of cue nature and format in prospective memory based on encoding and retrieval, continue to expand and strengthen the external validity of studies, and broaden potential results to account for situations of both practical and professional nature.

Appendix A: **Additional Figures**

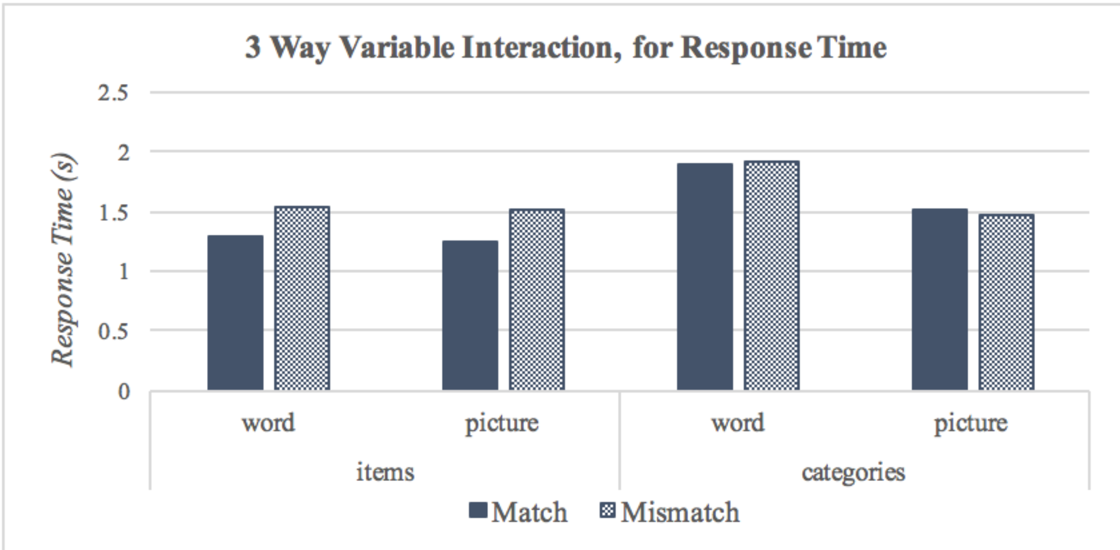



**Figure 9: Type x Encode Format x Retrieve Format Response Time Interaction Means**

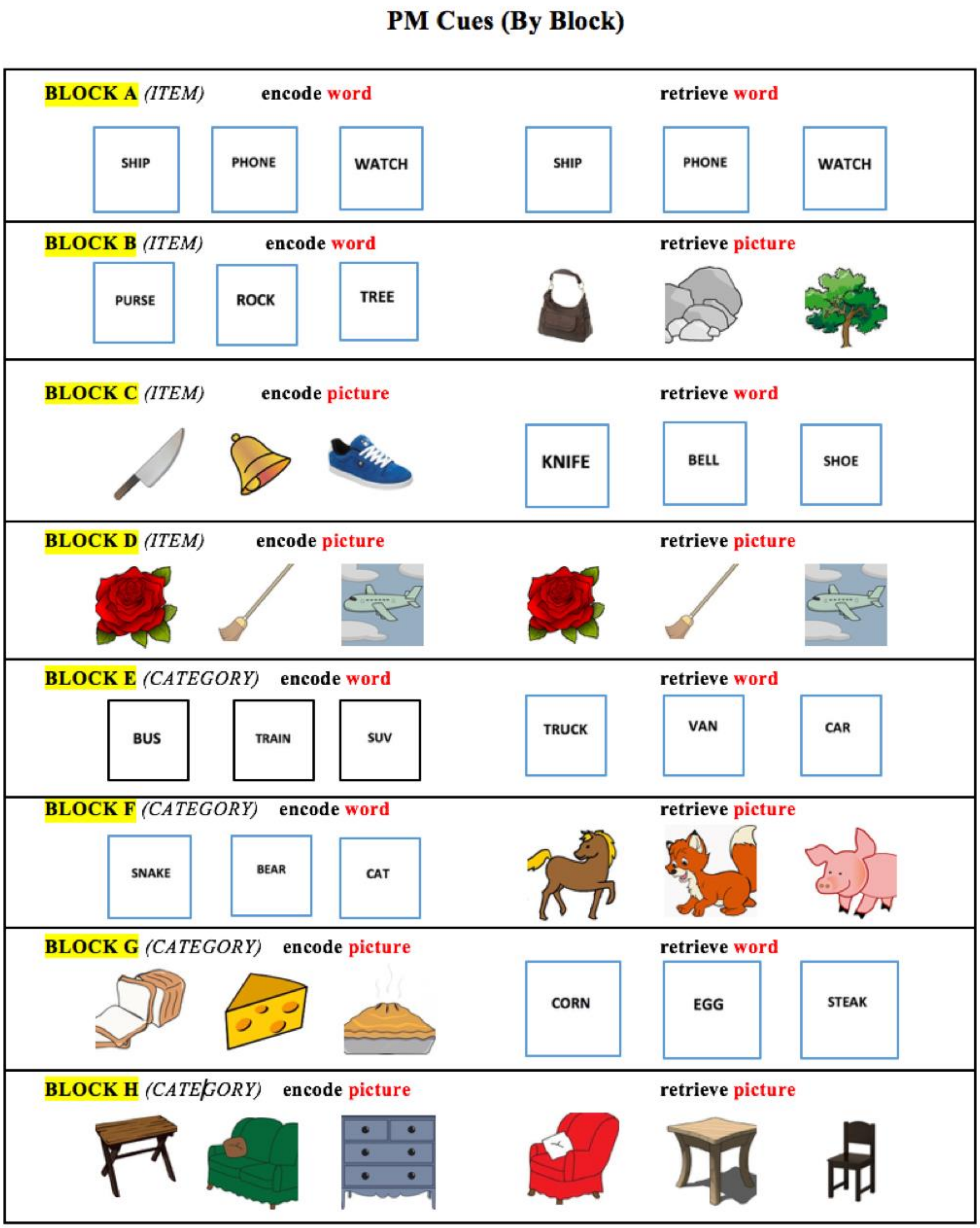
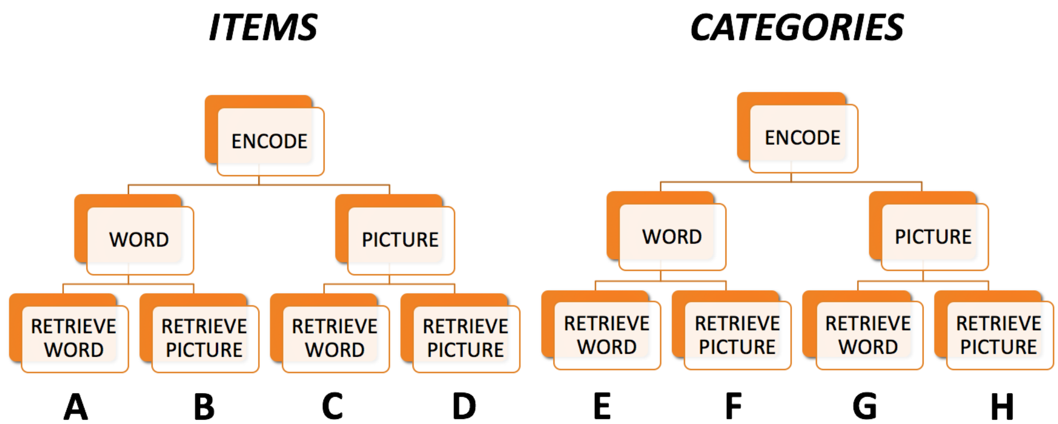



Figure 10: PM Cues By Block

Appendix B: **Debriefing Handout**

# Prospective Memory Experiment
## *Debriefing*

The purpose of the experiment in which you just participated is to examine how the nature and the format of a perspective memory cue affects how effectively one can encode and retrieve cue information amidst completing another unrelated task. You completed eight different tasks throughout the experiment, which were presented in a random order; see below.




We hypothesize that accuracy will be significantly higher in trials where the participant encodes the cue as a picture item and ones where the nature of the retrieval cue matches that of the encoded cue. For instance, a participant would demonstrate higher accuracy in trials where they encode with a picture and retrieve with a picture as opposed to encoding with a picture and retrieving with a word. Additionally, we expect that speed of response will parallel this same trend.

In this experiment, the cue type (item or category) and cue format (word or picture) are the independent variables. The dependent variables are accuracy, measured as a fraction of the number of correct to total responses, and response speed, measured in seconds.

We are interested in these variables because they reflect the use of prospective memory as it pertains to the nature and format of the cue, amidst completion of an unrelated and ongoing working memory task. This research has a plethora of real-world applications, ranging from remembering to complete basic tasks on an everyday basis to the complex and critical nature of remembering information and executing multiple tasks as an Emergency Room physician.

If you have any further questions about this experiment, please contact either the student or the professor working on the project:

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Homecoming Queen 2015

Stan Latta Dedication Scholarship Recipient 2015

The President's Sparks Award Recipient 2014

The President's Freshman Award Recipient 2013

*The Pennsylvania State University Ambulance Service*

Alumni Scholarship Recipient 2015

Volunteer of the Year Award 2014

*Delta Zeta Sorority*

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National Charline Chilson Scholarship Recipient 2015

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