WORKING MEMORY PROCESSES IN THE ENCODING OF INTENTIONS

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The primary interest of this investigation concerned working memory functioning and cue/act discrimination during encoding of intentions. The study included manipulations of working memory and intention load to investigate the encoding processes related to prospective memory (PM). Three experiments are presented that involve working memory distraction tasks at the time of encoding the PM intentions, as well as varying numbers of cues and actions. In the first experiment three cues were paired with one action, in the second, one cue with three actions, and in the third, three cues with three actions. Results suggest that the central executive is involved in binding a cue to an action, and that this operation is key to PM success. Furthermore, the phonological loop seems primarily involved with processing of cues and the visuospatial sketchpad with actions. It is further proposed that the processes of the phonological loop and visuospatial sketchpad must be successful before the central executive can bind the cues and acts together, which is possibly the most important part in the encoding of intentions. By directly examining PM at the time of encoding, information was gained that allows for a more complete understanding of the nature of how we form and execute intentions.
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CHAPTER 1

INTRODUCTION

In everyday life people come across the need to remember to perform tasks in the future such as remembering to pick up groceries on the way home, to call a friend later, or to see the dentist next week. These intentions must be performed at a later point from the time that we decide to do them. As can easily be surmised, such intentions play a large role in our lives as we constantly strive to remember to accomplish a variety of acts each day and often express a great deal of frustration when we fail to remember to do something. The type of memory involved in remembering the execution of such actions is typically referred to as prospective memory (PM). Prospective memory encompasses the entirety of processes regarding any sort of goal-oriented action that must be performed in the future. It is this broad sense of the term that is the primary focus of this study.

The focus of much memory research outside of the PM literature has to do with both encoding and retrieval aspects of learning the material and later performance. The vast majority of prospective memory, on the other hand, concentrates primarily on manipulations at the retrieval stage, with subsequent speculation about encoding processes based on the findings at retrieval. While the retrieval-focused research has been fruitful, perhaps more could be gained by concentrating investigative efforts on encoding. Only a handful of studies have specifically approached the questions regarding encoding intentions, and the purpose of the current research is to help expand the
knowledge in that area. It is thought that an inquiry of this sort will aid in providing a more complete picture of prospective memory.

**Prospective Memory Research of the Past**

Prospective memory is distinguished from retrospective memory. While PM is also concerned with the future, retrospective memory includes the semantic and episodic recall of things already learned, and was almost the exclusive focus of research from Ebbinghaus to the 1970s. Loftus (1971) almost seemed to stop the discussion of PM before it began with a study that concluded that there was no real distinction to be made between prospective and retrospective memory. However, others were not so easily persuaded, and a few years later studies were presented that tried to understand, at least to some extent, how we remember to do things in the future.

A common approach in many of the initial studies of prospective memory (e.g., Meacham & Singer, 1977; Wilkins & Baddeley, 1978) was the naturalistic setting inherent in them. Although this provided a means for real-world application, there was too little experimental control to be able to ascertain whether the findings were based on prospective memory performance/failure, or whether other factors (e.g., biological, environmental) contributed to the results. Without more control, little could be said about prospective memory with any certainty. However, in the early part of the last decade a new experimental paradigm was formulated that allowed for much more experimental control and manipulation. Einstein and McDaniel (1990) presented participants with the task of pressing a keystroke in response to some cue in the context of an ongoing task. To help make the task more difficult and more realistic, the PM task
was embedded within a short-term memory task - the performance of which was emphasized in the instructions given to the participant. When participants came upon a particular cue during the short-term memory task (e.g., the word ‘rake’) they were to make a separate key response in addition to the response made for the ongoing task. This elegantly simple design fomented a wave of subsequent research employing the paradigm and has since allowed the accumulation of data on prospective memory regarding cue distinctiveness, age effects, retention interval, divided attention at retrieval and other aspects of PM.

Encoding Intentions

Although the effects of encoding have been studied in great detail in traditional retrospective memory research of already learned things, the encoding of intentions has yet to be studied in great detail. A starting point toward a discussion of encoding intentions might be to consider the intention superiority effect, or ISE (Goschke & Kuhl, 1993), that intentions somehow appear to have a special status in memory compared to memory of actions that are not to be performed. Early on, Koriat, Ben-Zur, and Nussbaum (1990) found that actions to be performed later were better remembered than other actions also learned by means of written verbal instructions but which subjects knew were not to be carried out later. This effect occurred whether or not the intentions themselves were eventually performed or not, implying that encoding processes lead to the memory advantage. The ISE has been replicated in other studies (e.g., Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998) that suggest a heightened activation for intentions compared with other types of memory.
Other PM manipulations relevant to encoding involve the length of the retention interval, the time between encoding of the intention and when the act is eventually performed. Increasing the time period between encoding and retrieval of intentions, and perhaps along with the increase making possible more elaborate encoding or allowing for more maintenance through rehearsal (Meacham & Leiman, 1982), is usually found to have little or no effect (Stone, Dismukes, & Remington, 2001; d’Ydewalle, 1995; Einstein, Holland, McDaniel, & Guynn, 1992; Nigro & Cicogna, 2000). When retention interval effects are found they seem more a result of what is happening during the interval, for example the nature of the tasks being performed (Brandimonte & Passolunghi, 1994; Hicks, Marsh, & Russell, 2000). If it is the case that engagement in certain types of tasks engaged in during encoding are more debilitating in terms of retaining intentions, then perhaps future studies can discern why some tasks will lead to a decrease in PM performance while others have no effect. Until we know more, it is difficult to discern what the retention interval literature tells us about encoding of intentions.

The evidence from these studies suggests that what happens at encoding can have considerable effect in determining whether or not the act is eventually performed. Intending to do something results in a heightened activation for the act to be performed, and manipulations of modality and concurrent task demands have been shown to be predictors of PM success (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh, Hancock, & Hicks 2002). It is possible that a great deal of prospective memory failure can be explained simply in terms of difficulties incurred at encoding. If this is the case, the task
now is to find a way to study the encoding of intentions. Namely, the goal is to see how manipulating encoding leads to differences in prospective memory performance, and then make estimations as to why PM is affected by encoding differences. Perhaps comparisons might then be made to the retrospective memory literature that could provide more information about the peculiarities of or similarities to prospective memory.

One method of investigation would examine the possibility of whether divided attention at encoding leads to worse prospective remembering. If particular types of tasks disrupt PM performance more than others, one could then infer which types of processes might be involved in encoding intentions through an understanding of the nature of those tasks. Studies can be found involving divided attention and prospective memory, but they focus on effects at retrieval with some finding little effect (Otani et al., 1997; McGann, Ellis, & Milne, 2002) and others suggesting that divided attention at retrieval will cause a PM detriment under certain conditions (Marsh & Hicks 1998; McDaniel, Einstein, Manzi, Cochran, & Baker, 2000; McGann, Ellis & Milne 2002). Einstein, Smith, McDaniel, and Shaw (1997) looked at ongoing task demands at encoding and retrieval and found that increasing cognitive load by adding to the task performed when the intentions were received resulted in decreased PM performance for young people (see also d'Ydewalle, Boukaert, & Brunfaut 2001; Stone, Dismukes & Remington 2001 and others for effects of ongoing task complexity when the prospective instructions are to be performed). However, what is lacking is a manipulation of factors that can help explain what is occurring in the formation of an intention that is to be performed later. It is one thing to say that certain effects of divided attention can be found (namely negative), but it
is another to be able to suggest how we encode intentions specifically. Specific use of a divided attention paradigm can possibly provide some insight in this area of investigation. By looking at which particular ongoing activities result in worse performance compared to other tasks, one might be able to determine the importance of the particular cognitive functions underlying that ongoing activity and their relationship to prospective memory. An examination of current theory in PM research might provide some idea of which types of tasks would be useful in such an investigation.

Automatic Associative Activation

One theory developed as result of recent research into prospective memory was proffered by Guynn, McDaniel, & Einstein (2001). Their automatic associative activation (AAA) framework has as its basis Moscovitch’s (1994) model for episodic memory retrieval, which postulates a medial-temporal/hippocampal module for encoding, storage and retrieval of associative information. This hippocampal component (not to the exclusion of the hippocampus alone) is involved with consciously apprehended information such that it is responsible for the binding of conscious experience to what amounts to a memory trace (or engram) of some external event. In recall, after initial processing some external or internally generated cue interacts with a memory trace by means of the hippocampal component (the interaction is referred to as ecphory, Semon, 1921) thus allowing for the engram to eventually be delivered to consciousness. The process is automatic and obligatory so long as there is sufficient ecphory to allow for it to occur in the first place.
In terms of PM, Guynn et al. apply the framework with an emphasis toward the association (binding) of the cue (target) and the intended action. It is thought that the act is brought to consciousness by the hippocampal module automatically once the cue is provided, but only if there is enough interaction (ecphory) between the cue and the memory trace of the associated act after the cue has been processed by the hippocampal module. If there is not enough interaction, the intention will not be retrieved in response to the appropriate cue. The associative strength of the cue and act at encoding seems to be key in allowing sufficient ecphory to occur between the cue and the act later at retrieval.

The AAA model is in contrast to those that would propose a more strategic monitoring activity under the service of frontal systems. In these models (Burgess & Shallice, 1997; Bisiacchi, 1996; see also the “Notice Plus Search” model of Einstein & McDaniel, 1996), intentions are retrieved after careful monitoring of the environment for the cue to act by means of a supervisory attentional system (SAS, Norman & Shallice, 1986). The intended action is inhibited in favor of some other ongoing activity, with the SAS in search of the appropriate context with which to switch from a current task to performing the intention at the appropriate time. Although these monitoring theories suggest a different process for PM success, it is possible that monitoring processes of the frontal systems work in concert with the mechanisms of AAA and the hippocampal module (Cohen & O’Reilly, 1996). In this sense, should a lack of ecphory occur it is possible the SAS could aid in retrieval by means of this monitoring role. Guynn et al. initially thought this does not occur in PM as the frontal module would be more involved
in task switching and holding intentions in mind. However, Moscovitch (1994) posits such a system for regular episodic memory recall that would involve more effortful processing and cognitive resources, and would have a neural substrate possibly involving the dorsolateral and ventromedial frontal lobes. McDaniel, Guynn, Einstein, and Breneiser (2004) now think that such a ‘multiprocess’ view of PM would be feasible. The work of Burgess using positron emission tomography (Burgess, Quayle, & Frith, 2001; Burgess, Scott, & Frith, 2003) and West with event-related potential research (West, Herndon, & Crewdson, 2001; West, Herndon, & Ross-Munroe, 2000; West & Ross-Munroe, 2002; West, Wymb, Jakubek, & Herndon, 2003) have also resulted in mounting evidence implicating frontal areas in prospective remembering that suggests this may be worth further consideration.

Executive Functioning in Prospective Memory

The ideas of frontal involvement and a SAS-like construct aiding prospective memory brings to mind Baddeley and Hitch’s (1974; Baddeley, 1986) model of working memory and its central executive. The model comprises three components in total- the central executive (CE), phonological loop (PL), and visuospatial sketchpad (VS; though see Baddeley, 2000 & 2002 for a current discussion of the model). The latter two components are thought to be involved in verbal and visual encoding and temporary storage of information respectively, and are presumably slave systems under the influence of the central executive (Baddeley, 1998). The notion of a central executive is less well defined than the other two systems, but is concerned with allocation of attention, integration of information from the other systems, and retrieval of information from long-
term memory. The central executive incorporates the notion of Norman and Shallice’s (1986) Supervisory Attentional System and is intimately, though not exclusively, tied to frontal lobe functioning.

By manipulating the three working memory systems within a prospective memory task, one might discern the type of processing involved with encoding intentions. The phonological loop slave system is involved with the passive rehearsal of items subvocally in order to verbally encode information from the environment for possible transfer to long-term memory. In terms of prospective memory, perhaps one could simply be rehearsing the to-be-performed action utilizing their ‘inner speech’ in hopes of remembering to act at the appropriate time in the future, much like a person might with other simple memory tasks (e.g., remembering a phone number). However, neither Marsh and Hicks (1998) nor Otani et al. (1997) found effects of dividing attention with articulatory suppression at retrieval, but it does not seem that this finding necessarily would hold at encoding, as there are most likely different processes involved. The visuospatial sketchpad is a subsidiary system involved with visual input whether direct or imagined, or spatial input concerning location of stimuli. Its involvement in spatial tasks may play a part in how intentions are encoded in that we in some sense ‘see’ ourselves performing the act in order to better remember to do it when the appropriate circumstance arises or it aids in processing the coordinated movement and manipulations of objects required of an action (Engelkamp, 1998). There are reasons to believe, however, that the central executive is most important of the three systems involved. The central executive seems to be particularly involved with the attentional control of action (e.g., the
Supervisory Attentional System of Norman & Shallice, 1986). For example, the CE switches between the attentional focus on one particular stimulus or activity to another. Attentional processes are thought to be involved in the binding of various information inputs from the environment, including multi-modally, and it is possible the central executive may aid in that process (Baddeley, 1993). This latter notion will be the focus of the current discussion, but the former also has its place in a discussion of prospective memory tasks because there is an ongoing task concurrently performed while the prospective task is to be executed.

Ample evidence can be found with regard to a correlation between PM performance and executive functioning which, though not exclusively, is thought to be a result of more frontal lobe processing (West, Herndon, & Ross-Munroe 2000; Leynes et al. 2003; Burgess, Quayle, & Frith 2001, and others). Marsh and Hicks (1998) conducted several experiments with regard to working memory functioning and its relationship to PM retrieval. The experimenters specifically divided subjects’ attention at PM retrieval, and had participants in either into low and high load conditions with regard to the working memory task. Marsh and Hicks found that a more demanding load produced no real deficit in PM performance for the phonological loop condition, mixed results in the condition in which the visual-spatial sketchpad was manipulated, and a significant decrement in the central executive condition. As will be seen later, the results from this experiment may provoke interesting comparisons to those of this study.

The link between PM and frontal lobe functioning is perhaps not too surprising given the frontal areas’ involvement in coordinating and planning of action. Prospective
memory is essentially remembering to perform some action at an appropriate time or cue. However, what is proposed here is that the central executive function of binding plays a crucial role in our ability to remember to do things in the future. In particular, the binding of the cue to act (context) and the act itself into a unified and meaningful construct is possibly of most concern in PM success.

Guynn, McDaniel, & Einstein (1998) found that if given reminders about the cue only, PM success had no guarantee of improving. Likewise they also found only marginal improvement with reminders about the action only. However, when the participants were reminded of the cues and their corresponding actions, PM performance was enhanced significantly. In situations where there are multiple cues with actions, this binding could also serve to distinguish a cue from prompting the wrong action, and so as the cue is combined with one act it is discriminated towards another.

The Differential Roles of Cues and Acts in Prospective Memory

While dividing attention at encoding with regard to working memory will enable investigators of prospective memory (hopefully) to understand a little more about the encoding of intentions, perhaps more can be done to help understand the nature of the cue-act binding. Although certainly in daily life there is some meaningful connection made between the cue or context for action and the act itself, the basic paradigm used in PM research, which often involves the same or multiple cues requiring the same action upon each presentation, does not allow for much in the way of understanding why we forget to do what we do. An appropriate question would be to inquire if the cue processing is more at fault, or if it is the act that is not recalled when needed. In other
words, is the cue not recognized or is much of PM failure simply the forgetting of what one was supposed to do? The findings of the ISE would suggest that the acts are at the ready, always at the back of our minds and prepared for recall at a moment’s notice. However, there are times with which we are all familiar when we stop in the middle of what we are doing, realize that something else needs to be done at that time, but for one reason or another cannot remember what we are supposed to do. In this situation, we have recognized the cue/context but do not recall the correct action to take.

Thinking along these lines, when PM failure occurs it may be due to the fact that one may not recognize the appropriate context for action or may fail to recall the act to perform itself. One perhaps obvious reason for either error may be simply due to interference with other intentions that we have in mind throughout the course of a particular time period. Other cues and acts may be in competition with other intentions and cause confusion at recall. If sufficient binding between the cue and act has not occurred, we may not be able to discriminate on some level which cues go with which acts. The result would then be a lack of ecphory at the time of recall and general PM failure. It is possible that cues and acts are not individually encoded the same way, that different processes are involved in their encoding, which may make the binding process varyingly difficult depending on the circumstances surrounding the type of cues and acts involved. One may ask if prospective memory failure is due more to a failure to recall the cue or the act specifically, or because we are trying to remember too many intentions in general?
A manipulation that might help answer the question would be to vary the number of cues and acts respectively. Although manipulation of the number of items is commonplace in typical retrospective memory research, it is for the most part nonexistent as a focal point of PM research. West (2003) presented results comparing one versus three intentions, but the analysis seemed for the most part an afterthought and with performance near perfect in either case, very little could be gathered from the results. Since the Einstein-McDaniel paradigm was developed, most PM research has simply asked for a key response to a cue, and either the cue is presented multiple times or there might be a variety of cues (e.g., words related to animals). This design does not provide a clear picture of the cue-act binding that possibly is the case in daily activities where there may be many cues associated with a respective action or several actions to one cue (e.g., after work one must remember to pick up groceries, wash the car, and mow the lawn). Plus, it may be the case in the basic Einstein-McDaniel paradigm that the cues become the main focal point of the exercise for those engaged in it, perhaps even the point of simply monitoring for them. As the same key press over and over to any cue that pops up (the act) would most likely not be forgotten, one would only have to worry about monitoring for the cues. It would be interesting to see if a disparity exists in the roles cue and acts play in PM execution, and varying the number of cues and acts within a working memory manipulation might further inform the understanding of PM encoding processes.

The following study is an investigation into the underlying mechanisms of prospective memory. The design calls for a manipulation of the number of cues and acts, as well as an examination of the different components of working memory to see how
intentions are encoded. Each experiment had participants engage in a working memory task at the time they receive the instructions to perform an action later during the course of another task. Experiment 1 had three cues to perform a single act each time. Experiment 2 had one cue that upon successive presentations a different act was to be performed. Finally, three unique cues were paired with three unique actions in Experiment 3. Specifically, the prediction is made that the importance of binding the cues to their actions will play a crucial role. As such, if the CE is made less available by means of a distractor task at the time of encoding, PM performance should be worse in that condition compared to when the other working memory components are engaged at the time of encoding. In addition, it is expected that an increase in the overall number of cues and actions to be encoded will result in worse performance. By exploring the manner of encoding intentions it is thought that a great deal can be learned about what is crucial in remembering to perform an action in the future.
CHAPTER 2

GENERAL METHOD

The participants, methods, and procedure for each experiment are near identical and so are presented here. A description of changes to the general method is given at the introduction to each experiment.

Participants

Participants included 254 volunteers total from the University of North Texas, Department of Psychology research pool. Ages ranged from 18 to 44, with 145 females and 109 males. All participants received credit toward class requirements.

Materials

Experiments were designed and presented using Superlab software version 2.0 (Cedrus, 2001), and run on a Intel Pentium-class PC. Participants heard audio recordings of the prospective instructions via headphones connected to a separate CD player. The rating task consisted of a list of words chosen from Crawford, Leynes, Mayhorn, and Bink (in press). The various objects with which participants executed the intentions were common items such as a book, dice, a bell, chess pieces, etc.

Procedure

For the following, one may refer to Tables 1 and 2 for an outline of the general procedure. After receiving general instructions and practice trials, participants engaged in two successive tasks. The first was a distraction task devised to utilize components of the working memory model proposed by Baddeley (1986). During this distraction task the
intentions to be performed later were given to the participant. The other task was a simple word-rating task. In the rating task, the prospective memory cues to complete the delayed intention were presented.

Three types of distraction tasks were used. Each was associated with one of the three components of working memory - the central executive (CE), the phonological loop (PL), and the visuospatial sketchpad (VS). Random number generation (RNG) was used as the CE task (cf. Marsh & Hicks, 1998). More specifically, in response to a prompt on the monitor (a plus sign: +), participants were told to type in a number 0-9 as quickly as possible. As soon as the participant responded the prompt was removed and followed by a pause that averaged two seconds. This task taxed the central executive by means of both the random generation aspect and the volunteer’s attentional resources involved in anticipation to respond.

Verbal shadowing, reading words from a passage aloud as they appear on the screen in succession, was employed to engage the PL. Participants read aloud an excerpt from *Travels with Charley* by John Steinbeck selected for readability. A single line of text was presented on the screen for 3 seconds to be read aloud, and did not correspond to the natural breaks (commas, periods) found within the passage. Participants were told to read only what was presented, and to begin reading the next line whether they had finished the previous line or not. The goal was to have them engaged verbally without allowing them to get too focused on the content of the story. However, the participants were not conducting the verbal shadowing when the intentions were received as will be discussed later.
A letter rotation task was used to challenge the VS. In this task participants gauged whether a letter (‘F’, ‘L’, or ‘R’) presented on the screen was a correct or mirror-image presentation of the letter (see Figure 1). Letters were rotated anywhere from 0 to 330 degrees in 30 degree increments regardless of whether they were correct or a backwards. The letters were displayed for just under 2 seconds (regardless of response made) followed by a one second pause, and although participants were given a limited amount of time to respond, no emphasis was made on speed of response. The time frame of the trials was chosen in hopes of keeping them actively engaged in the VS task without too long of a pause between trials that would allow for possible interference from other mental activities. Participants in this condition were monitored closely during practice trials and sometimes were given a second run of practice in order to ensure that they were simply performing letter rotation and not some other task, for example, answering whether the letter was rotated or not.

The instructions containing the intentions were received aurally via headphones while the participants were engaged in the working memory distraction task. Intentions were presented at approximately the same time during the first task (~ 2 minutes 30 seconds into the activity) regardless of which of the three working memory tasks the participants were engaged. The following is an excerpt of one of the instructions given: “…In the masculine-feminine rating task…if you see the words ‘child’, ‘forest’, or ‘diet’, stop what you are doing and roll the dice lying on the counter before continuing on the rating task. Again, roll the dice each time you see the words ‘child’, ‘forest’, or ‘diet’.”
For the PL condition, approximately 30 seconds before the instructions were given, participants switched from reading the story to simply repeating a single word (‘the’). This was done to ensure that they were able to hear and understand the instructions clearly while participating in an articulatory suppression task that would continue to challenge the resources of the phonological loop. After two minutes of this repetition the individuals returned to reading the story aloud. To make the task more consistent for the participants, another articulatory suppression block was given later, though no instructions were given during the sequence. The PL and VS conditions were conducted such that the participant could not affect the overall time of the task. However, the RNG task allowed the person to proceed after giving a response to the prompt. As such, enough stimuli were presented to ensure that the task would go a minimum length of time even if the person responded rapidly, and the average time taken was comparable to the other conditions.

After completion of the distraction task, participants then rated words in terms of their masculinity-femininity. Participants were asked to rate the words on a 1 to 5 scale (3 neutral). The entire list presented comprised 170 terms of which three were the cues to perform some action. The presentation was as follows: BLOCK (37 words) - CUE - BLOCK (44) - CUE - BLOCK (44) - CUE - BLOCK (42). Participants saw the same exact words within each block regardless of condition although presentation of the words within a block was random. Thus, each participant came to the cues after the same number of the same words (in random order) were shown.
In order to make the prospective memory task more similar to everyday experience, the decision was made to have participants perform a task that was different from what they were already engaged in. In other words participants were to stop the masculine-feminine rating task in order to execute the intention. Objects were placed on a table in the room, but which was out of view of the participants while they performed the working memory and masculine-feminine rating tasks. The objects that were to be manipulated where placed among many other objects which were not otherwise used in the experiment.
CHAPTER 3

EXPERIMENT 1

This experiment was designed to examine the effects of working memory during the encoding of intentions. If the central executive (CE) is the component most responsible for binding the cue and act, and this process is essential in terms of prospective memory (PM) success, then it is expected that the CE condition should result in the worst performance. Though one might not expect the participants to perform as poorly as in the CE condition, the phonological loop (PL) condition could also prove detrimental to some extent in that it could interfere with typical rehearsal of information. With regard to the visuospatial (VS) group, one would perhaps not expect as much difficulty here because even if participants are in some sense engaging in ‘self-imagery’, the likelihood of the letter rotation task resulting in problems remembering a solitary act seems unlikely. It is possible that just performing the letter rotation task could at least result in less than optimum performance because it is a distraction, though this would be the case for all conditions. In sum, an increase in performance is expected as one goes from the CE group to the PL group to the VS group. This first experiment was formulated with the typical Einstein-McDaniel paradigm in mind but with the hope of pursuing the study within a more practical context. The primary difference with the typical Einstein-McDaniel design and the one presented here is that participants are disengaging from one task to perform another separate and unrelated task, much like what would likely happen in a real-world situation.
Method

Participants and Materials. The participants and materials were in keeping with the general method. Although power analyses were conducted for a range of effect sizes, circumstances and resources did not allow for collection of sizes required for the .80 power level unless a large effect was expected. As such, sample sizes were determined more by what assistance was available for data collection and what could be collected during the course of the academic calendar. Total sample size for Experiment 1 was 108.

Procedure. In this experiment the instructions given were to perform a single task each time a cue word was presented. The cue words were “child”, “forest”, and “diet”, and the subject-performed task (SPT) to be executed at each cue was to roll a pair of die. The volunteers were seated in the laboratory room and given an informal overview of the procedure. Individuals were then given formal instructions displayed on the computer for both the working memory distractor task and masculine-feminine rating task, as well as told they were to receive additional instructions via the headphones. Next, the participants were given practice on both the working memory task and the rating task. After the practice sessions and resolving any questions, the audio was started and the participants were left alone to complete the working memory task. Participants’ performance was monitored by video and audio from another room. Upon completion of the working memory task (approximately ten minutes later), participants began the rating task. The participants were then monitored for execution of the prospective instructions. After the experiment, the participants were debriefed and excused. The data file was then accessed to determine that the actions were performed at the appropriate cue.
Results & Discussion

One-way analysis of variance was utilized as the primary method of analysis for working memory differences within each experiment. Although robust analyses were performed when necessary, as they did not contribute further to the findings only the results of classical methods are presented. Planned comparisons were used to discriminate among the individual groups. Scoring was based on the proportion of actions performed correctly out of three possible. An alpha level of .05 was used unless otherwise indicated, and error rate for multiple comparisons was controlled using the Benjamini-Hochberg (1995) procedure for controlling false discovery rate. Cohen’s (1988) effect size measures are provided to better draw conclusions from the results. However, an informal analysis of some of the more pertinent articles previously cited (e.g., Einstein, Smith, McDaniel & Shaw, 1997; Marsh & Hicks, 1998; Einstein & McDaniel, 1990; Guynn, McDaniel, & Einstein 1998) revealed that large effects according to Cohen’s standard (.10 small, .25 moderate, .40 large for Cohen’s $f$, and .20, .50, .80 for Cohen’s $d$ in comparing two groups; Cohen, 1988) seem to be somewhat rare. Of the 22 significant main effects regarding prospective memory performance examined, 17 fell between .07 and .13 for eta-squared or .27 to .39 for Cohen’s $f$. The effect sizes for significant effects reported here would thus be considered within the range of typical PM research.

Experiment 1 involved participants performing the same subject-performed task (SPT) at each of three cue words. Means and standard errors for all experiments are reported in Table 3. A significant difference among the means was found $F(2, 105) = \ldots$
3.18, $MSE = .10$, $f = .25$, and suggested a moderate effect. Planned comparisons showed that the VS group performed at higher levels than the CE group $t(105) = 2.43$, $MSE = .10$, $f = .24$. However, a post hoc contrast also showed that the VS condition was statistically higher in proportion correct from those in the PL and CE groups together $t(105) = 2.43$, $MSE = .10, f = .24$.

The results presented showed working memory differences in the encoding of intentions. The overall trend hypothesized for Experiment 1 held in that the CE condition performed lowest, VS best, and PL in between though the CE and PL conditions were not statistically different. In post-session interviews the vast majority of participants for this and subsequent experiments claimed to use rote rehearsal as their primary strategy for remembering to perform the intentions. In this situation, rehearsal likely involved the cues alone as the single act was readily recalled. In other words, participants generally repeated the cues to themselves until they felt sufficient encoding had taken place. However, engaging in the articulatory suppression task most likely interfered with that process at the time of encoding for this and the other experiments. As such, it may not be too surprising that the PL condition fared as poorly as the CE condition. In this sense, it is possible that the nature of the PL task perhaps interrupted the participants’ attempts to encode the cues.

An interesting point to note is that the cues in this experiment are here being treated by participants separately from the action to be performed (according to self-report). This finding has interesting implications for PM research that adhere to this typical paradigm with one act performed upon presentation of several cues. It is possible
that the effects seen in such studies may have more to do with the cues than the actions being performed, and in the present experiment it is difficult to tell whether subjects simply forgot what the cues were, or there was a failure to act in terms of insufficient ecphory to trigger act recall. As such retrospective memory for cues and actions will be addressed in the later experiments.
CHAPTER 4

EXPERIMENT 2

Experiment 2 was designed to further explore encoding aspects of working memory. Experiment 1 provided an examination of working memory allocation using the more traditional paradigm, albeit with a more realistic requirement of disengaging from one task to complete another of a different sort, the next step was to further explore the nature of the cue-act association. What remains to be seen is if the results hold in a converse situation where there is one cue for multiple independent actions and also, in what perhaps would be the most realistic situation, an experiment in which there are multiple cues with different actions to be performed for each cue (see Table 2 for a comparison of the three experiments). Again the primary manipulation investigated regarded the working memory components of Baddeley’s model.

With one cue for several actions the possibility of several outcomes is present. With the overall cognitive load being the same as in Experiment 1, there may be little difference in the results of this experiment compared to Experiment 1. On the other hand, now that differentiation of actions is necessary rather than cues, it may be that working memory functioning could be involved in the encoding process in different ways compared to Experiment 1. It is possible, for example, that if participants are on some level engaging in self-imagery to remember the actions they are to perform, then with more actions involved there may be a decrease in PM performance for the VS condition. Where simple verbal encoding could perhaps suffice for one action, visualizing action
might aid in a situation where multiple actions are to take place. In this case, the VS task could interfere whereas before it was possibly not even needed. No difference is expected for the CE condition compared to Experiment 1, as the CE’s involvement in the binding process should be the same for the same load. For the PL condition, better performance might occur compared to Experiment 1 as visual and motor components of remembering actions (Engelkamp, 1998) that were not present before with the multiple cues may aid in the overall remembering of intentions, while the verbal information regarding cues is minimized. In other words, the previous detriment in remembering cues may be counteracted to some extent when it is primarily actions that have to be remembered. In this light, one could also make a case that overall PM success might be enhanced in Experiment 2, as the ISE could result in heightened activation of the three individual actions whereas its effects were not available for the cues in the first experiment. One final possibility is that confusion of actions might result where one forgets if she or he has performed an action or whether they performed it at the appropriate cue, and this could actually lead to lowering overall PM performance compared to Experiment 1. However this final possibility perhaps would be less expected than the other outcomes suggested.

To summarize, the overall load, or number of intentions remains the same for this and Experiment 1, and now one will be able to see if working memory processes are the same for encoding actions as for cues. Put differently, one might be able to determine if the direction of the load (more cue complexity vs. more action complexity) has unique effects on the binding process.
Method

Participants and Materials. The participants and materials were in keeping with the general method. Total sample size for Experiment 2 was 74.

Procedure. In the second experiment, the basic design remained as in the first, although in this case there were three SPTs (‘roll the dice’, ‘spin the top’, ‘close the book’) to be executed for one cue. The working memory distractors were kept the same as the initial task. The masculine-feminine rating task was retained for the ongoing task, however it would not make sense to have participants rate a single word three times. In addition, the previous occurrence of the cue could provide priming for later occurrences to that same cue and perhaps heighten recognition for later responses. Therefore, the decision was made then to present the words with various letters of each word capitalized, with the prospective cue being a word presented in all capital letters. This allowed for almost no change in the overall design while permitting a way to have a single cue present itself more than once. However, the change did impose an ordering of PM response, such that the participants were told to perform a specific action upon the first presentation of a word in all capital letters, a second act upon the second presentation, and a third for the third. As such, half the participants received a different ordering of the actions. The details of this slight change in design for Experiment 2 will be elaborated in the general discussion, but suffice it to say at this point that this change was made in order to minimize any change from the overall design. Another task might have allowed for multiple presentations of the same cue in a more natural manner perhaps, but changing the task at the time the intention is carried out was thought to carry
far more serious consequences in terms of generalization and comparison to the other experiments (see Marsh, Hancock, & Hicks, 2002; d’Ydewalle, Bouckaert, & Brunfaut, 2001; Martin & Schumann-Hengsteler, 2001; Meier & Graf, 2000; and Marsh & Hicks, 1998 for examples of how characteristics of the ongoing task may influence PM performance).

For the first experiment, debriefings were held with participants in which they were informed of the purpose of the experiment and asked questions about the particulars of their performance (e.g., did they understand the instructions, how did they help themselves remember, etc.). The process was formalized with a questionnaire for Experiments 2 and 3, which contained questions regarding their understanding of instructions, perceived difficulty of the working memory and masculine-feminine rating tasks, what memory strategy they used, explicit recall of cues and acts, and recognition of the cues/acts from a list of words they had seen in the rating task or a list of actions that included several of the objects in the room. As mentioned earlier, the questionnaire was administered so as to help resolve some of the issues raised by Experiment 1, and perhaps provide more information about what processes might be occurring in the encoding of intentions.

Results & Discussion

No effect of working memory condition was found $F(2,71) < 1$, $MSE = .08$ (see column 2 of Table 3) and performance was quite high. However, this condition may have had errors that were due to ‘misrecognition’ of the cue. For example, some participants did not respond to the first cue, and then performed the first two actions at
the second and third presentation of the cue. This could possibly be seen as a perceptual error, as participants did not report having seen the cue (rather than reporting they simply forgot to do it initially). Still others may have remembered to perform all SPTs but did them in the inappropriate order. With this in mind, results were also analyzed using a lenient scoring in which all appropriate SPTs performed were counted as successful execution of the intention. With lenient scoring again no significant difference was found among CE ($M = .94, SE = .03$), PL ($M = .89, SE = .04$), or VS ($M = .91, SE = .06$) groups, $F(2,71) = 1.03, MSE = .07$.

**Difficulty Ratings of Working Memory Tasks.** As mentioned previously, the questionnaire asked participants to rate the working memory task in terms of difficulty on a scale of 1 to 9. It might have been possible, for example, that some of the effects seen were due to difficulty of the task at the time of encoding. Results show a strong difference between working memory tasks in terms of difficulty $F(2,71) = 10.32, MSE = 3.31, f = .54$ (see Table 4). Comparisons among the groups showed the VS group to be significantly lower than the CE ($t(71) = 4.20, MSE = 58.46, d = 1.13$) and PL groups ($t(71) = 3.58, MSE = 42.32, d = 1.06$), which were not significantly different from one another. Although the VS condition was seen as more difficult, the difficulty of the task apparently had little bearing on the PM results for this experiment as the VS group performed best overall ($r = .21$ was not significant for the relationship between task difficulty and PM performance).

**Recall and Recognition of Actions.** In Experiment 2 there was no specific cue to recall nor would participants have any reason to attend to the identity of the cue for later
recall. Because recall for actions was near perfect and recognition for action perfect, the data were analyzable.

Despite the trend predicted of PM performance increasing from CE to PL to VS conditions being present there were no statistically significant working memory effects. Perhaps this result can be explained in terms of the ISE, which suggests heightened activation for actions compared to memorized lists of other information, such that the actions are more easily recalled than cues. Interestingly, the PL condition showed very similar results to the VS condition. Participants again generally reported rehearsal as a memory aid, though this time for the actions as the single cue (a word in all capital letters) was seemingly encoded easily. Perhaps the PL is now also involved in rehearsal of the actions. In general, given what amounts to the same situation as Experiment 1 but having to remember actions rather than cues, participants performed at higher levels. Again this suggests a possible differential processing of cues and actions in PM situations, something that is not specifically addressed in the literature as something that could affect PM performance.
The final experiment of this study should allow for further elucidation of encoding effects in prospective memory. Upon first glance one might think that this experiment would result in the worst PM performance in general as it contains the most PM elements (cues and acts) or load. However, if the intention superiority effect is strong enough there might not be a significant decrease in actions performed compared with the first experiment, as the heightened activation associated with actions would reduce the effects of adding two more actions to perform. With regard to the CE condition one might think that, with more elements to bind together, the process might not be as efficient and possibly lead to discrimination problems (i.e., performing incorrect acts to cues). On the other hand, the situation could also be similar to the other experiments in that there are three binding pairs of some cue to some act in all experiments. In that case it might be that as far as the CE is concerned the circumstances are the same. The PL condition should fare similarly as in Experiment 1, though might have a slight decrease in performance due to the increase of actions (i.e., increase in overall load). Based on previous reasoning, the VS condition would be expected to result in similar performance to Experiment 2, as the function of the VS is more associated with actions.

This design provided what was perhaps the most real-world scenario compared with the other experiments and most PM research in general with unique cues associated
with unique acts. Furthermore, combined with the other experiments this design speaks
to working memory influences during the encoding of intentions, intention load, and
possible differential processing of cues and actions.

Method

Participants and Materials. The participants and materials will be in keeping
with the general method. Total sample size for Experiment 3 was 72.

Procedure. The third experiment was exactly as the first, with the exception that
instead of the same act performed at each cue, each cue would have a specific act
corresponding to it (the same actions as those in Experiment 2).

Results & Discussion

Experiment 3 involved the performance of three different actions each paired with
a specific cue word. One-way analysis of variance showed significant differences among
the means and the strongest effect of the three experiments, $F(2, 69) = 3.86, p = .026, f$
= .32. However, in this experiment the VS condition showed a marked decline in PM
performance compared to the two previous experiments. The differences described by
planned comparisons showed that those in the VS condition performed significantly
lower compared to those of the CE group $t(69) = 2.59, MSE = .13, f = .31$. The VS
condition also had lower performance than the PL group, $t(69) = 2.18, MSE = .13, f = .26$.
The CE and PL groups were not significantly different from one another $t(69) = .41, MSE$
= .13.

Difficulty Ratings of Working Memory Tasks. As in Experiment 2, results showed
a significant and large effect of differences in working memory task with regard to their
perceived difficulty $F(2,69) = 9.50$, $MSE = 2.74$, $f = .52$ (see Table 4). Comparisons among the groups revealed significant differences for all comparisons of each group to one another. The VS task proved to be more difficult than both the CE ($t(69) = 4.36$, $MSE = 52.08$, $d = 1.25$) and PL tasks ($t(69) = 2.09$, $MSE = 52.08$, $d = .55$). The CE task was seen as easier than the PL task ($t(69) = 2.26$, $MSE = 14.08$, $d = .54$). These results are for the most part consistent with Experiment 2 and perhaps not too surprising given the nature of the tasks. One may be tempted to suggest that difficulty alone could explain the performance seen in Experiment 3 as the VS condition was rated as more difficult than others, but one should first remember that this apparent difficulty seemingly had little to no effect in Experiment 2 and the VS condition showed the highest performance in Experiment 2.

Perhaps then the difficulty of working memory task only has an effect in this experiment because of the increased in PM load (in terms of total number of cues and actions). However, if difficulty were the explanation of performance, such a result would suggest that PM performance in this condition more to do with the allocation of cognitive resources, and as such the CE would be involved as well, rather than the VS mechanism alone. In other words, the results might also implicate CE functioning if difficulty were the primary explanatory factor. However, the correlation between task difficulty and performance, though perhaps somewhat attenuated due to the lack of range in PM performance responses, was low and not statistically significant ($r(70) = .15$). Furthermore, for both Experiment 2 and 3 combined the correlations between PM performance and ratings on the working memory task ($r(144) = .17$) and on the and
masculine feminine rating task \( r(144) = .14 \) were both low and not significantly different from one another (95% CI for the difference between correlations: -0.21 to 0.26). The ratings for the working memory and masculine-feminine rating task were significantly positively correlated with one another \( r(144) = .37 \). These findings seem mostly to reflect that participants rated both tasks in a similar manner though how difficult they found each task had little relation to their performance.

**Recall and Recognition of Cues and Acts.** Paired t-tests, were used to examine the recall/recognition differences in Experiment 3 (see Table 5), with the Benjamini-Yekutieli correction for multiple dependent analyses employed to help control Type I error rate (Benjamini & Yekutieli, 2001). The analyses show that, as would be expected, recognition was better than recall. Moreover, the results show that overall remembrance of actions was enhanced compared to overall remembrance of cues. Specifically, recall for cues was significantly lower than that of acts, \( t(71) = 3.77, MSE = .03, d = .45 \). Recognition of cues was also lower than recognition of acts, \( t(71) = 4.14, MSE = .01, d = .49 \), which participants performed almost perfectly.

Further investigation of the mean correct recall for cues and acts by working memory condition revealed some interesting patterns (Table 5). For the CE condition, recall and recognition for cues and acts were both affected equally and resulted in exact recall scores. In fact, the correlation between the number of acts and cues recalled in this condition was very high \( r(22) = .84 \), implying that whenever a cue was not recalled, some act was also lost (though not necessarily of the correct pairing, i.e., a discrimination difficulty). These results seem to suggest that interference with the CE contributes to
cue-act confusion later. Again, recall was high in general for cues and acts, but at the
time of performance participants were unsure of which act to perform when the cue was
presented, or the cue, when presented, did was not sufficiently bound to the act and so did
not provide the ecphory needed for recall of the action. This may be taken as evidence
that the CE is involved primarily in the cue-act binding process.

The PL condition affected cue recall but does not seem to have affected recall of
actions at all. There was no correlation between the recall of cues and acts \((r(22) = 0.08)\),
primarily because although many had trouble remembering the cues, only one participant
did not recall all the actions to be performed. In line with previous ideas, these findings
suggest that the PL was involved primarily in processing of the purely verbal information
of the cues. Participants were aware of what act was to be performed, but were not
remembering the cue. The results for the PL group may be evidence that the cues and
acts were in some respect processed separately, and the PL distraction affects cue
encoding specifically.

The VS condition affected both cues and actions to some extent though cues were
affected much more. As in with the CE group, the correlation in the VS condition
between cues and acts recalled was significant \((r(22) = 0.44)\) though not as strong. If the
VS task is not interfering with the actions to be remembered in an obligatory way (as
evidenced by different results for the VS group in Experiments 2 and 3), and it is not the
difficulty of the VS task that is underlying the results, one is left wondering what exactly
the VS task is affecting in PM performance. Perhaps what is seen here is that, with the
visuospatial sketchpad unavailable to aid in encoding the visuospatial nature of
coordinated movement in space required with the actions, the other functions of working memory compensate to remember what actions to perform. In particular, the PL could still assist in the process through rehearsal of the list of actions as verbal information, as was suggested occurred in Experiment 2.
CHAPTER 6

GENERAL DISCUSSION

The experiments presented here represent a first attempt to address working memory functioning in the encoding of intentions. The initial hypotheses proposed two main ideas: that binding the cue to the act was an important part of the encoding process, and that the central executive would most likely be involved in this process. The assumption was made that such a result would able to be determined solely in terms of overall prospective memory performance. However, it was the pattern of performance across experiments, coupled with the cue and act recall findings of Experiment 3, that not only gave credibility to some of the initial hypotheses, but also allowed for speculation about the specifics of how the other components of working memory are involved.

Differences were found among the working memory conditions, though these differences were not constant across experiments (for a summary of the findings refer again to Table 3). In Experiment 1 with three cues and one action, the VS condition showed higher performance than the CE and PL conditions. A similar pattern of results were found in Experiment 2, which had one cue and three actions, though no significant differences among the working memory groups were discovered. In Experiment 3 with three cues and actions, the VS group showed a dramatic decline in PM performance and was significantly lower than the CE and PL groups. In gauging the PM performance findings with respect to the recall results, the CE task seems to result in difficulty with cue/act discrimination, and the PL task seems to be causing problems specifically with
encoding of the cues. The VS task results in a detriment for encoding of actions, and effects a marked decline in PM performance when differentiation of cues and acts was required.

The Automatic Associative Activation model presented by Guynn, McDaniel, and Einstein (2001) was a fundamental motivation for this research, particularly in thinking about what might lead to the best ecphory between the cues and actions at retrieval and hence better PM performance. The thinking was that greater binding of the cue to the act at encoding would lead to more interaction between the cue and the memory trace of the action at retrieval. The evidence here does seem to suggest that binding a particular cue to a particular act is important in PM success, and it seems that the CE may be more important in that process in that, though the cues and actions to be performed are remembered for the most part, participants appear to have difficulty in terms of which cue to perform with which act. However the results of these experiments may also be evidence of more than a binding of cues to their appropriate actions. Rather, the results imply the possibility that there is also binding of cues into a cohesive unit of cues (i.e., a ‘calendar’) and actions into a cohesive unit of actions (i.e., a ‘to do list’).

The results from Experiment 1 suggest that the VS had little involvement in cue processing leading to very high overall PM performance even when it was engaged in the letter rotation task. Presumably the CE condition caused problems in discrimination and sufficient ecphory at recall, and in the PL condition, rehearsal of the cues was interfered with. In Experiment 2, one might have expected a drop in performance for the VS condition, as the VS would be unable to aid encoding of the spatial properties of
coordinated action. What may be the case is that with the PL freed from cue processing its resources are now available to rehearse the list of actions (or as some reported, the object names). Along with the preference for actions in memory almost no detriment is then seen for the VS condition. In the PL condition, the VS is once again free to aid in encoding the actions and so similar high performance results are obtained, and suggests that the PL is not typically needed for encoding of actions. Problems arise when the CE is limited, but the PL and VS are still available to aid in encoding of the actions, so no significant difference is seen with this condition.

With Experiment 3, the recall information provides more evidence to suggest such working memory processing in the encoding of intentions (see Figure 2). As before, the CE shows a detriment in PM performance. The PL and VS are available to aid in encoding the cues and acts, respectively, leading to the high recall rates of those items. However, PM performance still suffers terms of cue-act discrimination and deficient binding of the cues to their appropriate actions, leading to insufficient ecphory to trigger recall of the action at the time of performance or incorrectly bound pairs.

When the PL is engaged at the time of encoding by the working memory task, the cues are inadequately encoded. While the actions were able to be properly encoded by the VS (and later recall of actions was near perfect), problems still arose as participants forgot the cues, or the cues were not encoded sufficiently to allow for binding of the cue to its appropriate action by the CE, as cue-act discrimination problems still arose. The results may suggest that not only are cues separately processed from actions, but that these separate process are possibly taking place before the CE is able to bind the cues and
actions together. Another interpretation to consider may be that with the ISE resulting in heightened activation for actions, they are more easily encoded and it is the cues then that must be ‘piggybacked’ onto the actions. As such the PL alone may be causing a problem by not being able to make the cues available for this process, which mostly involves executive functioning.

In the VS condition, PM performance suffers greatly in Experiment 3. With the VS unavailable, the PL is now taxed even more to help also process the list of actions along with the list of cues, leading to similar performance in cue recall here as was seen in the PL condition, along with the decreased recall of actions to be performed compared to the CE and PL conditions (though for the VS condition, action recall was still higher than cue recall). Now with both cues and actions unable to be encoded appropriately, the CE was unable to perform its function in binding them together and this was why there was such a pronounced effect. Not only was the VS not available as it normally would be to encode the actions, the situation overextends the PL as it tries to compensate, and fewer cues and actions are encoded such that the CE can then work in binding cues and actions that have been processed together.

Alternatively one could suggest that perhaps that the CE is solely utilized in the binding process, and the PL and VS in processing of cues and actions respectively, with no processing of actions by the PL. However, such a scenario would not explain why in Experiment 2 the VS condition showed no relative PM performance deficit, nor would we have expected the drop in cue recall for the VS condition in Experiment 3. Furthermore, one would have perhaps expected a relatively flat PM performance from
one working memory condition to the next, or at least no major differences among them. Another alternative hypothesis would be that the PL is the only component involved in processing of cues and actions. However if this were the case, one would probably expect PL performance to be more comparable from Experiment 1 to 2. In addition, one would not expect near perfect action recall in Experiment 3, there should have been an even more dramatic drop in overall PM performance for the PL condition in Experiment 3 (rather than performance being similar to Experiment 1), and no performance problems for the VS condition in Experiment 3 should have exhibited themselves.

To summarize, the results suggest first and foremost that PM performance can be quite influenced by manipulations at the time of encoding. The central executive was most specifically involved with the binding of cues to the actions, and hence if it is otherwise occupied, problems arise in PM performance. It is possible that the CE may be involved in the separate binding of cues to cues and actions to actions. If that is the case it seems to lend itself to those processes equally. The phonological loop, if hindered, would result in difficulty in encoding cues, which are simply verbal information, and which by default is remembered through rote rehearsal. Furthermore, the phonological loop may be engaged in processing of actions if need be. The visuospatial sketchpad seems to be exclusively involved in encoding the actions. So, it seems that not only is there differential processing of cues and actions, but this initial processing may be necessary before the cues and actions can be bound successfully to allow for appropriate recall upon presentation of the cue. Furthermore, the initial processing of the cues seems most problematic.
These results were novel and offer a further understanding of prospective memory. To begin with, the findings lend further credence to the results of Einstein et al. (1997), who also found effects of dividing attention at encoding. Together the two studies suggest that encoding processes play a pivotal role in PM success. Perhaps now more emphasis will be paid to encoding processes, and such an approach could provide avenues for future research that will help gain a fuller understanding of PM.

The discoveries here may also offer a more elaborate understanding of Guynn, McDaniel, and Einstein’s PM reminders study (1998), especially in terms of recall performance. Assuming that the reminders are in a sense allowing for further encoding, we see comparable effects in this study and in their Experiment 3, where Guynn et al. gave no reminders, cue reminders, action reminders, or cue and associated action reminders before the participants engaged in the task in which the PM activities would occur. Cue only reminders led to perfect recall of cues but did not aid action recall, while the reverse was true for action reminders. When the cue + action reminder was given, recall was high for both cues and actions. Interpreted in light of the present study, the cue only and action only reminders may have aided in encoding those in distinct cue only and action only units of information respectively, which may have enhanced recall but, as their study shows, did not lead to the best PM performance. Only when cue and action reminders were given did PM performance show vast improvement. In that situation the cues and actions are processed further and thus more binding of the cues to their appropriate actions could take place, leading to high recall for both and greatest PM success.
Combined with Marsh and Hicks’ (1998) study, there is now a more complete understanding of working memory function in prospective memory. Whereas their study suggests that the central executive is perhaps the most important working memory component at retrieval (specifically in terms of monitoring for cues and task switching), the results here suggest that all components are influential at the encoding stage. With this more comprehensive picture, more specific models regarding PM may be able to take shape and be tested in the future.

Across experiments the results show that having multiple actions alone does not result in as noticeable decline in PM performance compared with having multiple cues. Instead having multiple cues and actions resulted in the worst performance. This result was expected, but it is interesting to see how the performance trend was somewhat similar for Experiments 1 and 2 (in terms of increasing performance from CE to PL to VS conditions), perhaps suggesting that having the same number of PM elements (cues and actions) should result in somewhat comparable outcomes. However what this study also shows is that the experimental paradigm chosen for research into PM will need careful consideration. Experiment 1 was designed in keeping with typical PM research instigated by McDaniel and Einstein (1990). Experiment 2, though valid as a possible PM situation, is perhaps less likely in real world circumstances such that we intend to respond differently to the same stimulus, which we expect to be presented on multiple occasions. Experiment 3 seems the most likely scenario to be encountered in daily life, and we see that different encoding processes occur under these circumstances compared to the other situations. Further research will be needed to see if having multiple cues for
multiple actions will regularly bring about different results compared with the other
situations such as those presented here and in past PM research. If so, thought will have
to be put into what design will be most productive for further investigation of prospective
memory.

Importantly, the AAA model of Guynn, McDaniel, and Einstein (2001) that is
based on Moscovitch’s (1994) model of retrospective memory still seems a viable
explanation of PM as the results provided here seem consistent with the notion that
sufficient ecphory between the cue and action is necessary for PM success. The
interpretation here is that the central executive would be more important in allowing for
sufficient ecphory to take place at the time of retrieval, but that activities of both the
phonological loop and the visuospatial sketchpad can be important in allowing that
binding and hence later ecphory to take place. The multiprocess framework suggested by
McDaniel, Guynn, Einstein, and Breneiser (2004) incorporates the AAA model, and
holds promise as an explanation of the processes involved in PM.

Some limitations of this study present themselves readily. One important
omission from these experiments includes a discussion of Baddeley’s new working
memory component- the episodic buffer. The main reason for this lack is that the
component is still in its infancy in being worked out in a specific manner. The
interesting aspect of the component, as it is now being proposed, is that the buffer might
serve in binding various bits of information together and in integrating information
processed by the phonological loop and visuospatial sketchpad. Along with this task,
which was previously assigned to the central executive, the component has a short term
store not unlike the loop and sketchpad components. Such a role in working memory would quite probably have direct consequences to the processes underlying the concepts proffered above, giving a more specific account of the results. It may be that the episodic buffer specifically, rather than the central executive in general, is responsible for the results above. However, as the episodic buffer can be seen as a partitioned part of the central executive and, at the very least, directly accessed by it, then should further research find the component to be at work in the encoding of intentions, the episodic buffer may only offer slightly more detail in interpretation to the results seen here rather than a reworking of them.

Another point of contention mentioned earlier regards the Experiment 2 manipulation to provide one cue for three actions. In a sense, ‘a word in all capital letters’ can be seen as a perceptual rather than verbal cue (i.e., a word that looks a certain way), or is now a general rather than specific cue, a manipulation which has been studied in the past (e.g., Ellis & Milne, 1996). While valid concerns, in order to have one cue for three actions, the other alternative would be to have the same word appear on multiple occasions, or the ongoing task itself be changed which would be unacceptable for reasons outlined previously. Not only does this not make sense in the rating task, one now would have to worry more about the effects of priming as earlier presentations of the cue could facilitate recognition of later cues (Mäntylä, 1993). In terms of cue specificity one would have expected even better performance had specific cues been used (Einstein, McDaniel, Richardson, Cunfer, & Guynn, 1995; Ellis & Milne, 1996; Cherry et al., 2001). Furthermore, it would be just as possible to interpret such instructions as ‘whenever you
see a word that looks like dog’ for example. In the end, the above manipulation allowed for no changes to the overall design and experience on the part of the participant compared to the other experiments.

This study in addition raises several questions that would need to be addressed in future research. To begin with, it would be interesting to see whether the effects seen above are representative of what is happening at the moment the intentions are received or involve an extended retention interval or critical period in which the cues and acts are encoded. One other attractive avenue of research would involve further investigations of the cue-act relationship. In fact, McDaniel, Guynn, Einstein, and Breneiser (2004) just recently found that a more associated cue-act pairing (e.g., ‘thread’- write the word ‘needle’) is more likely to result in PM success than an unassociated pair (see also Nowinski & Dismukes, 2004). In addition, current research carried out by others in the author’s lab is already yielding large effects in terms of whether cues and acts are unrelated, cues are related, acts are related, or cues are related to acts (as in the McDaniel, Guynn, Einstein, and Breneiser study). Such findings are encouraging in light of the interpretation of differential processing of cues and actions. The next step is to determine what role the intention superiority effect plays in this processing. One wonders whether it is simply the ISE that results in better processing of the actions, or there is something about the cues that makes them more difficult to retain, as was seen here.

The current research can be seen as a success in determining the characteristics of encoding intentions in terms of working memory, and these findings must be incorporated into existing PM models if we are to have a more accurate description of
prospective memory. Practical applications may now be made to help enhance PM in
everyday situations. However, much is left to discover regarding this unique aspect of
human memory, and endeavors must be made to answer the questions that now arise
from the results of this study.
ENDNOTES

1. Formula for Cohen’s d for paired samples equals t divided by the square root of the degrees of freedom (Rosnow & Rosenthal, 2003).

2. Recognition scores were not analyzed here as actions were recognized perfectly for the CE and PL groups.

3. This might explain why the PL condition is not worse in Experiment 1 and overall PM performance is better in Experiment 2. In Experiment 1 the CE helps to bind the cues to some extent, while in Experiment 2 the PL and CE are able to compensate when the VS is not available.

4. The component was first introduced in 2000, and even now a PsycInfo search will return only six results for ‘episodic buffer’.
### Table 1

**General Procedure**

<table>
<thead>
<tr>
<th>WM component</th>
<th>Distraction Task</th>
<th>Description of task</th>
<th>Cover Task</th>
</tr>
</thead>
<tbody>
<tr>
<td>Central Executive</td>
<td>Random number generation</td>
<td>Key in number at a ‘+’ prompt</td>
<td></td>
</tr>
<tr>
<td>Phonological Loop</td>
<td>Articulatory Suppression</td>
<td>Read a story as it appeared on screen; Repeat single word</td>
<td>Word-rating</td>
</tr>
<tr>
<td>Visuospatial Sketchpad</td>
<td>Letter Rotation</td>
<td>Respond whether a rotated letter was correct or its mirror image</td>
<td></td>
</tr>
</tbody>
</table>
Table 2

*Comparison of Experiments*

<table>
<thead>
<tr>
<th></th>
<th>Number of Cues</th>
<th>Number of Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experiment 1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Experiment 2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Experiment 3</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 3

Experimental Results: Prospective Memory Performance. Means are Presented with Standard Errors in Parentheses.

<table>
<thead>
<tr>
<th></th>
<th>Experiment 1</th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>.69 (.06)</td>
<td>.82 (.07)</td>
<td>.74 (.07)</td>
</tr>
<tr>
<td>PL</td>
<td>.74 (.06)</td>
<td>.88 (.04)</td>
<td>.69 (.07)</td>
</tr>
<tr>
<td>VS</td>
<td>.87 (.04)</td>
<td>.91 (.06)</td>
<td>.47 (.07)</td>
</tr>
<tr>
<td>Total</td>
<td>.77 (.03)</td>
<td>.87 (.03)</td>
<td>.63 (.04)</td>
</tr>
</tbody>
</table>
Table 4

*Difficulty Ratings for the Working Memory Task*

<table>
<thead>
<tr>
<th></th>
<th>Experiment 2</th>
<th>Experiment 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean (SE)</td>
<td>Mean (SE)</td>
</tr>
<tr>
<td>CE</td>
<td>7.63 (.40)</td>
<td>7.69 (.26)</td>
</tr>
<tr>
<td>PL</td>
<td>7.28 (.31)</td>
<td>6.98 (.33)</td>
</tr>
<tr>
<td>VS</td>
<td>5.44 (.38)</td>
<td>5.55 (.41)</td>
</tr>
</tbody>
</table>
Table 5

*Mean Proportion of Cues and Actions Recalled and Recognized. Means are Presented with Standard Errors in Parentheses.*

<table>
<thead>
<tr>
<th></th>
<th>Recall Cue</th>
<th>Recall Act</th>
<th>Recognition Cue</th>
<th>Recognition Act</th>
</tr>
</thead>
<tbody>
<tr>
<td>CE</td>
<td>.92 (.05)</td>
<td>.92 (.05)</td>
<td>.97 (.02)</td>
<td>1.00</td>
</tr>
<tr>
<td>PL</td>
<td>.78 (.06)</td>
<td>.99 (.01)</td>
<td>.94 (.03)</td>
<td>1.00</td>
</tr>
<tr>
<td>VS</td>
<td>.76 (.05)</td>
<td>.89 (.05)</td>
<td>.86 (.03)</td>
<td>.97 (.02)</td>
</tr>
<tr>
<td>Total</td>
<td>.82 (.03)</td>
<td>.93 (.02)</td>
<td>.93 (.02)</td>
<td>.99 (.01)</td>
</tr>
</tbody>
</table>
Figure 1. Examples of letters used in the letter rotation task.
Figure 2. Outline of working memory processing in the encoding of intentions.
REFERENCES


Cedrus (2001). SuperLab Pro (Version 2.01) [Computer Software]. San Pedro, CA.

Cherry, K. E., Martin, R. C., Simmons-D’Gerolamo, S. S., Pinkston, J. B., Griffing, A., & Gouvier, W. D. Prospective remembering in younger and older adults: Role of the prospective cue. Memory, 9(3), 177-193.


