ABSTRACT

Intention Interference, Intention Superiority and Commission Errors in

Prospective Memory Tasks after Suspended or Finished Instructions

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Most prospective memory experiments focus on response times and overall task performance. Utilizing MouseTracker software (Freeman & Ambady, 2010), the intention interference effect and intention superiority effect are tested by analyzing data of mouse trajectories, velocities, acceleration, and angles. The evidence of the intention interference effect in this experiment further supports the multiprocess theory and the claim that spontaneous retrieval is the primary method of retrieval for suspend or completed prospective memory tasks (Einstein & McDaniel 2000). The primary focus of the current study was to examine the correlation between the intention interference effect in the presence non-salient prospective memory target words and the suspended or finished instructions the participants received. Results indicated 32% of all participants committed commission errors, indicating that there is still more research to be done to completely understand how we dissociate memories based on cue focality, instruction sets, context, and time delay.

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INTENTION INTERFERENCE, INTENTION SUPERIORITY AND COMMISSION ERRORS IN PROSPECTIVE MEMORY TASKS AFTER SUSPENDED OR FINISHED INSTRUCTIONS

A Thesis Submitted to the Faculty of

Baylor University

In Partial Fulfillment of the Requirements for the

Honors Program

By

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Waco, Texas

May 2016

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Introduction and Background- What is Prospective Memory?

When analyzing human capabilities of memory, there are two branches with which we define the memories we encode, retrospective and prospective memory (PM). Retrospective memory refers to any experiences, events, achievements, words, or people we have experienced or come in contact with in the past. Prospective memory, on the other hand, consists of an intention to perform a behavior after a delay of unspecified or specified length. For example: tomorrow morning I need to call my doctors office to set up an appointment. Over half of everyday forgetting comes in the form of prospective memory failure (Crovitz & Daniel, 1984). The study of prospective memory, and how humans encode, store, retrieve, and forget future memories, is important to improving our memory efficiency, and how we can better care for ourselves.

How is Prospective Memory Measured?

Prospective memory is measured in a laboratory setting by asking participants to associate a specific memory with a task. Then, participants are tested over a period of time (depending on the study) that assesses the ability of the participants to retrieve the correct intention at the proper time. The appropriate time could be at a literal time, or following a specific cue that was associated with the PM intention. There are many factors that can be assessed through prospective memory experiments- such as the performance of other ongoing tasks during a prospective memory experiment, the ability to forget an association, the longevity of prospective memories, etc.

Event Based vs. Time Based Prospective Memory

In prospective memory, there are generally two different modes of specifying when the action will be performed – event based and time based prospective memory. In event based PM tasks, some environmental cue will indicate the appropriate time to perform the task. In time based, the individual must rely on internal cues that might indicate how much time has elapsed before a task must be performed, or at what specific time of the day a task must be performed (Einstein & McDaniel, 1990, 1996; Katai, Maruyama, Hashimoto, & Ikeda, 2003). An example of an event based prospective memory task would be if you committed to memory that you needed to stop by the bakery next time you drove down Main Street by your house. There is no specified time when that will be, but the environmental cue of driving down the street and past the bakery should remind you of what your prospective memory task was. Time based tasks, however, are assigned to a specific time. An example could be that you put cookies in the oven, and you needed to take them out in 10 minutes. However, you decided to step outside and water the flowers while the cookies were baking, thus eliminating a potential reminder from the timer on the over. While outside, you may be internally monitoring the clock so that when approximately 10 minutes has passed. You then go back inside.

PAM Theory vs. Multiprocess Theory

When describing the cognitive functionality and basis for prospective memory, there are two theories: the preparatory attentional and memory process (PAM) theory (Smith, 2003), and the multiprocess theory (McDaniel & Einstein 2000). The PAM theory states that some level of attentional resources must be dedicated to monitoring for PM cues prior to the presentation of the target event (Smith 2003). Monitoring occurs when an individual is actively checking and searching for cues that will indicate when it is appropriate to perform the PM behavior (Smith, 2003; Smith & Bayen, 2004; Einstein et al., 2005; Smith, Hunt, McVay, & McConnell, 2007). The continual checking requires conscious attentional resources to be dedicated to the PM task, regardless of cue focality. Monitoring has been shown to have negative effects on other ongoing tasks that the individual has been asked to perform due to the detraction of attentional resources from the ongoing task that are in turn dedicated to the PM task. The impact on the ongoing task by the draw of attention elsewhere is known as task interference, or "cost" (Marsh, Hicks, Cook, Hansen, & Pallos, 2003). The task interference exhibited during the ongoing task is often measured in a lab setting by analyzing the difference in time it takes participants to complete the ongoing task under control settings, compared to when participants are prompted to monitor the ongoing task for a PM cue.

The multiprocess theory comes from the idea that multiple forms of processing are more advantageous for remembering in humans (Einstein & McDaniel, 2008; McDaniel & Einstein, 2000, 2007). In addition to the ability to recognize cues when monitoring one's environment (like the PAM theory suggests), the multiprocess theory also argues that spontaneous retrieval can bring prospective memories out of long term memory, into one's consciousness and working memory (Einstein & McDaniel, 2010). Spontaneous retrieval occurs when an individual is not devoting conscious attentional resources to the search and recognition of any cues to perform the task. Instead, if there is a sufficiently strong association between the cue and the intention, then, when a cue is presented, the intention is reflexively retrieved (Einstein & McDaniel, 1996; McDaniel, Guynn, Einstein, & Breneiser, 2004).

The multiprocess theory argues that *cue focality* is important to whether a participant relies on spontaneous retrieval or monitoring. Cue focality indicates the nature of the PM task in relation to the ongoing task that consumes available attentional resources. A PM cue is considered focal if there is high similarity in the information relevant to performing the PM task and the ongoing task (Einstein & McDaniel, 2005). If the PM task and the ongoing task are different in nature, and the information relevant to perform each task have minimal or no similarities, then the PM cue are considered nonfocal (Einstein & McDaniel, 2005). The multiprocess theory indicates that attentional resources and monitoring will be used during nonfocal PM tasks due to the differing nature of the ongoing task and the PM task. However, spontaneous retrieval is more likely to be utilized during focal prospective memory tasks (Einstein & McDaniel 2005; McDaniel & Einstein, 2007; Brewer, Knight, Marsh, & Unsworth 2010; Scullin, McDaniel, Shelton, & Lee, 2010). In contrast, the PAM theory states that monitoring and attentinoal resources are utilized for both focal and nonfocal cues.

Environmental factors vs. Intrinsic factors

When retrieving intended prospective memory intentions, there can be many different types of cues, unrelated to focality, that will lead to successfully completing a PM task. Environmental cues could include seeing an individual whom you must pass a message along to, or looking at a clock and realizing it is time to leave for your meeting. External or environmental cues could also include reminders or timers set on your smartphone. Intrinsic cues might include your internal clock that keeps track of how much time you think has passed, and if it is time to perform the PM task.

Intention Interference Effect

Previous experiments have studied the *intention interference effect* as a way to demonstrate spontaneous retrieval. When participants are instructed to associate an intention with a prospective memory cue, they encode the memory association for later recall. However, when the participant is asked to no longer perform the specified intention when presented with the prospective cue, and instead perform another intention (such as the ongoing task intention) upon stimulus, there is some interference that can occur. When presented with a former PM cue, the spontaneous retrieval of the associated PM task momentarily pulls attention away from the ongoing task, thus slowing the overall response time for the PM cue trials (Cohen, Dixon, & Lindsay, 2005; Einstein & McDaniel, 2005; Marsh, Hicks, & Watson, 2002; Walser, Fischer, & Goschke, 2012; Cohen, Kantner, Dixon, & Lindsay, 2011).

Intention Superiority Effect

The intention interference effect may be (at least in part) attributed to the *intention superiority effect*. When an individual makes an association between a word, picture, or any other type of prospective memory cue, with a specific intention, then, in the absence of conscious monitoring, that prospective cue is kept at a higher state of activation within the individuals' mind (Penningroth, 2011). Therefore, both the cue and the intention have been shown to be more accessible in an elevated state of activation in comparison with cues and information that were not future-oriented, or intentions that were given for a broad, expansive, or categorical set of stimuli (Goschke & Kuhl, 1993; Marsh, Hicks, & Bink, 1998; Marsh, Hicks, & Bryan, 1999; Walser et al., 2012). It has also been shown that tasks which have not yet been performed are kept at an even higher state of activation than those that have already been completed or partially completed (Schiffman & Greist-Bousquet, 1992; Scullin, Einstein, & McDaniel, 2009; Scullin, Bugg, McDaniel, & Einstein, 2011).

Forgetting

Forgetting an intention can pose problems of varying degrees of severity-forgetting to pick up milk on your way home from work is not as serious as forgetting to take high blood pressure medication. However, not all forgetting is bad. Intentionally forgetting a prospective memory task can be useful in some scenarios. For example, in order to save time on your morning commute, it might be important that the route you usually take to work is under heavy construction. Therefore, forgetting to drive the normal route, and instead take a new route, is a beneficial form of forgetting. It is important to examine how well individuals can forget to perform intentions upon instruction. Although we have already mentioned the findings by Scullin et al. (2009, 2011), further investigation into how individuals forget prospective memories is warranted.

There have been various experiments that demonstrate differing data on the aftereffects of a prospective memory intention. Scullin et al. (2009), which, again, demonstrated that prospective memory cues impacted performance only when the PM intention was suspended and not when the intention was completed (Scullin et al., 2009). Accordingly, the intention interference effect disappears when participants are given finished instructions, but remains when they are given suspended instructions.

Additionally, Cohen, Dixon, and Lindsay (2005) found that completing a PM intention led to decreased interference in the subsequent task where the same cues were presented. However, Wasler et al. (2012) found that aftereffects were present after completed instructions, although the aftereffects demonstrated a decaying pattern throughout the duration of the subsequent trials. Further, Pink and Dodson (2013) demonstrated that the intention interference effect and commission errors were present in trials, even after finished instructions, when the participant was distracted with an ongoing task. *Commission errors* are made by failing to deactivate or forget PM intention, and erroneously repeating the intention when it is no longer relevant to the task at hand (Scullin, Bugg, & McDaniel, 2012).

According to Pink and Dodson, intentionally forgetting habitual behaviors, especially after repeated executions, requires conscious, effortful thought (Pink & Dodson 2013). The requirement for conscious thought to forget is displayed further by the notion that spontaneous retrieval may play a role in intention interference. When performing the PM task during a series of trials, participants exhibit some level of monitoring as they devote attentional resources to identify their target cues. However, upon instructing participants to forget the PM intention, participants tend to stop monitoring, but instead exhibit spontaneous retrieval of previously encoded PM intentions if presented with their target cue (Einstein et al., 2005; West, McNerney, & Travers, 2007). In the current study, we attempted to replicate the intention interference effect and intention superiority effect to examine their role in forgetting.

Experiment Basis

The current study is based on previous experiments published by Scullin, Einstein and McDaniel (2009) and Abney, McBride, Conte, and Vinson (2014). In Scullin et al. (2009), two experiments were performed that measured the response times of participants performing a prospective memory. They also measured response times to PM cues after participants had received suspended or finished instructions regarding the PM intention. In those trials, participants were asked to perform the ongoing task when presented with the PM cues. In Experiment 1 of Scullin et al. (2009), they found that response times were slower PM cue trials during the blocks of trials with suspended PM intention instructions. The slower response times were attributed to spontaneous retrieval of the PM intention when stimulated with the PM cue, thus indicating intention interference. Monitoring was not perceived to be of any cause because the instructions for the PM intention were suspended, therefore removing any reason for the participants to utilize attentional resources. In Experiment 2 of Scullin et al. (2009), participants in the suspended instruction group were compared against participants in the finished instruction group to examine the effects of instructions on the ability of participants to deactivate a prospective memory intention. In Experiment 2, participants in the finished instruction group showed no evidence of intention interference, while such interference was present in the suspended instruction group. The findings supported to the idea that finished instructions stimulate deactivation of PM intentions.

In Abney et al. (2014), a new type of software was utilized to measure prospective memory intention: MouseTracker. MouseTracker software, developed by Freeman and Ambady (2010), provides more data on the response dynamics of participants when performing prospective memory tasks. The software offers data on initiation times, response times, cursor trajectories, velocities, acceleration, and angle of movement. The versatility of MouseTracker offers a new way of testing and observing participants in their performance of prospective memory intentions. Therefore, for the current study, the questions studied in the experiments conducted by Scullin et al. (2009) were reexamined using MouseTracker software utilized in Abney et al. (2014).

Hypothesis

In the current study, shorter initiation times are expected on trials presenting target cues, which would serve as evidence of the intention superiority effect. Additionally, longer reaction times are expected, which would demonstrate intention interference as evidence of spontaneous retrieval for PM intentions. The mean trajectories and angle values should also indicate intention interference. Few, if any, commission errors are expected, because of the previous experiments conducted outlining the ability of participants to deactivate PM intentions, and because of the longer duration participants have to decide the correct response- moving the cursor across the screen to select the PM task response takes more time and commitment than clicking one key quickly out of habit of a previous intention/cue association.

Methodology

In this experiment, participants were invited to participate in the experiment in Baylor's Cognition Laboratory in the Baylor Science Building. Participants were invited to partake in the study via SONA, a website that lists experiments for students to sign up and participate in, and receive partial course credit. All of the participants were students currently attending Baylor University, between the ages of 18 and 25. In total, 34 participants were used in this study, with 17 individuals in each of the experimental groups- suspended instructions of finished instruction.

The primary materials utilized for the experiment were computers setup in a quiet laboratory workspace. The computers each had dividers between them, and the workspace was kept quiet and clean to eliminate as many distractions for the participants as possible. Each of the four computers had a monitor size of 23 inches, and a mouse with an adjustable cursor speed. Each computer was set to the exact same specifications for cursor speed, screen size, brightness, etc. Although each mouse had a button to manually adjust cursor speed, the speed was checked before, during, and after the experiment to ensure the user had not manually changed speeds. The computers ran the experiment using MouseTracker software (Freeman & Ambady, 2010). This software was used because of its ability to measure initiation time, reaction time, cursor velocity, acceleration, and angle of movement, as well as compile mean trajectories of cursor movements. The amount of data available for analysis and the implications for discovering evidence of intention interference, monitoring, and spontaneous retrieval made MouseTracker the best software for this study. MouseTracker software collects data at a rate of 70 Hz, or roughly every 15ms. In addition to the computer program, participants were given a (demographics) form to complete midway through the computerized test. The form was also presented as a means of an to distract participants from actively monitoring for their PM cues by taking their attention off of the PM cue and devoting attention to the forms they needed to complete. The PM cues were effectively removed from working memory.

For this experiment, event-based focal PM cues were used. The participants were instructed to remember a specific task when presented with a specific target cue word that was displayed at predetermined trial number. However, the participants were unaware when the word would appear, making the appearance of the stimulus event based. The PM target words are considered focal cues because they overlap with the ongoing task being performed of determining whether a string of letters constitutes a word or a nonword.

By presenting the PM target words and control words in an unexpected context, ideally, there were no intrinsic factors that should confound the data. If a participant cannot preemptively anticipate when a PM cue will be presented, then the only way they are prompted to perform the PM task is by an extrinsic, or environmental factor. The intrinsic clock is nullified. As a result, a majority of the factors are controlled by the experimental design. The computer program is what prompts the participants. Therefore, only these environmental factors may influence cognition of the participants.

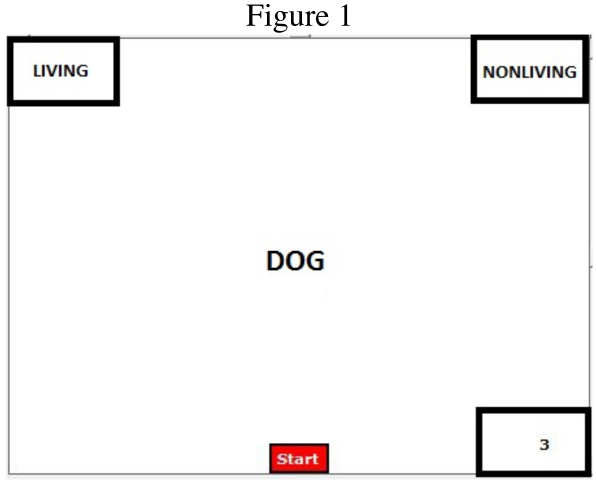
To further control influencing factors, control and PM target words were presented the same number of times throughout the experiment. This was done to eliminate the possibility that commission errors or intention interference was due to a familiarity effect of seeing the same words repeated throughout the experiment (Pink & Dodson, 2013). Eliminating or diminishing any familiarity effect gives more validity to the presence of commission errors, and the role of intention interference, and intention superiority.

The words and nonwords used for the lexical decision task were generated using The English Lexicon Project (Balota et al., 2007). A set of criteria were used to select exactly the words and nonwords that would be used, in order to maximize effectiveness of the ongoing task, and require sufficient engagement of the participants attentional resources. The criteria were as follows: length between 4-7 letters long; orthographic neighborhood of between 0-2; bigram sum ranging from 5000-15000; bigram frequency by position ranging from 1500-2500. An orthographic neighborhood indicates how many words can be created by changing only one letter in the word, while all other letters remain the same, and in the identical place. An example would be *ring* and *sing*. A bigram is any adjacent two-letter pairing within a word. An example within the word *dog* would be the bigrams *do* and *og*. A bigram sum is a sum of the frequency of occurrence of each bigram in the entire English language. The bigram frequency by position is the frequency with which those bigrams appear at the same place in any given word in the entire English language. The words were then screened to eliminate any profane, violent, or otherwise poignant words that might elicit dramatic emotional responses in the participants.

Design

The MouseTracker software presents each trial the same way- with a white background and black text for the duration of the experiment. Figure 1 displays the programmer view of the design of the experiment. A 'START' button is located at the bottom, middle portion of the screen. When participants click on the 'START' button, the cursor automatically relocates to the center of the 'START' button text box. This is to ensure uniform data by having an identical cursor starting point for each trial. Immediately following the click on the 'START' button, a word or string of letters appears in the middle of the screen. There are two responses for the participants to choose from – one in each of the upper corners of the screen labeled LIVING and NONLIVING in Figure 1 below. The participant then moves the mouse cursor to hover over one of the two choices based on their answer. The block boxes around the answer choices were added in to illustrate the size of the answer field that participants must move the cursor within to register the response.

Figure 1



Design layout- 3 indicates PM invisible box response

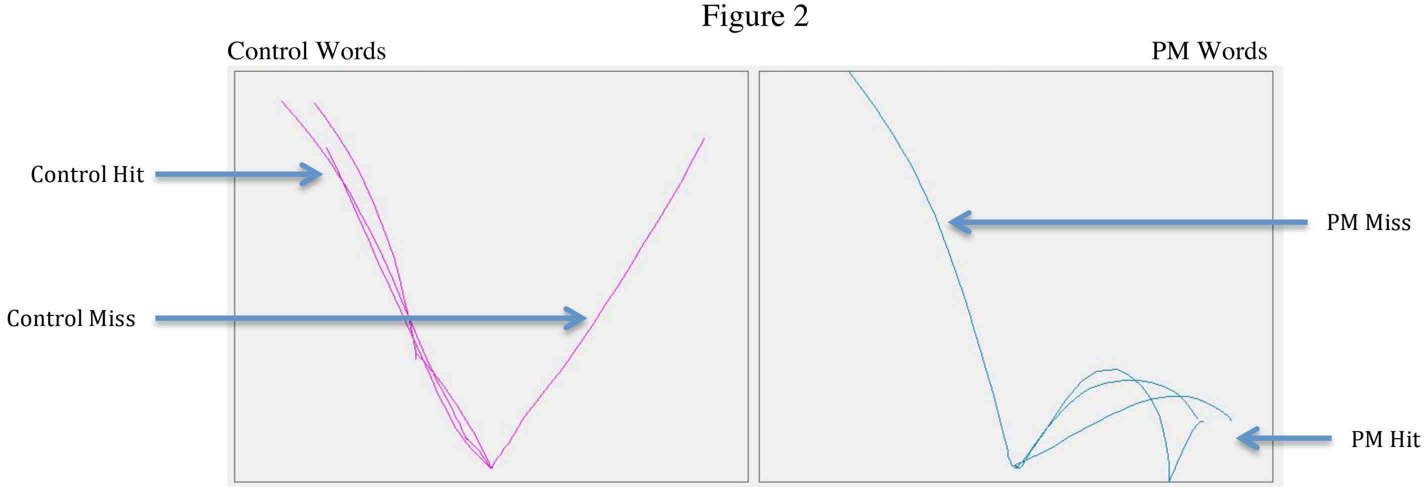
After a selection is made, the stimulus disappears and the 'START' button reappears to begin the next trial. The third answer selection in the lower right hand corner indicated by the number 3 is the PM task response. The program was set to record responses if the participant hovered the mouse over the response field instead of requiring the participant to actually execute clicking the mouse.

The reason for the hover response setting is to increase the experiments sensitivity to commission errors and intention interference.

The participants began with a practice block of the first ongoing task, which asked participants to determine if the word that appears on the screen represents a living or nonliving object (LNL task). The practice block provided feedback to the participants as to the accuracy and speed of their responses. If their response initiation time was above 700ms, or their final reaction time was above 2000ms, participants were prompted to speed up their movements. The message indicated that they should begin moving the mouse, even if they have not yet made a decision as to which answer to select. The purpose for this message was to induce participants to move the mouse in the direction of their initial instincts to a stimulus. Moving the mouse early should decrease monitoring, and provide trajectory data representative of participants' spontaneous and preliminary decisions. Ideally, the trajectory data would then demonstrate more prominent intention interference as participants exhibit inhibition midtrial, instead of prior to moving the cursor.

After the first practice block, participants were given a pair of PM target words- 'corn' and 'dancer', or 'fish' and 'writer'. Whichever pair the participant did not receive as PM target words was used as a control pair. These words were presented in a non-salient, or non-prominent manner, with black lettering on a white background. When presented with their target words, the participants were asked to move the mouse cursor to the lower right hand corner of the screen where an invisible box was used to record their response. The significance of the invisible box is to prevent a continuous reminder from appearing throughout the experiment that a PM task of some kind needs to be performed. The absence of a reminder means the participant must rely on their own memory, unprompted external cue, to perform the PM intention in the presence of the target cues. The participants were instructed to perform the prospective memory intention during all the living or nonliving categorization tasks. The program then prompted participants to explain the PM task instructions along with their target words to the experimenter in order to check proper encoding. The participants were asked to perform the action of the prospective memory intention one time in order to move on to the next block of trials – which was a short round of practice for the living or nonliving task containing 12 total trials (including 2 target word trials). Example trajectories from the practice block are shown in Figure 3. Feedback was provided, and participants were expected to practice performing the PM intention when presented with the target words. The target words were presented once each on trials 4 and 11.

Figure 2



PM Encoding Practice – visualizing the PM response path (right) compared to the control words (left)

After this practice block, a long block of 111 trials performing the same task with no feedback was given. In the long block of living or nonliving categorization, participants were asked participants to perform the PM intention whenever they saw the target words. The control words were presented on trials 11, 48, 68, and 94. The PM target words were presented on trials 25, 35, 56, and 79. Upon completion of this block, participants were asked to complete a participant information form, and a vocabulary test. Following completion of these forms, participants continued on to the Lexical Decision Task (LDT), or Word or Nonword (WNW task) categorization task section of the experiment. At this time, they were given new instructions based on which group they were randomly assigned to- suspended or finished. The suspended group was instructed that the task they were told to remember earlier, the PM Task, and the accompanying target words, were not to be executed during the upcoming LDT, but that they would be asked to do so later in the experiment. Thus, their execution of the action was still active, but suspended. The finished group was given instructions that they no longer needed to remember the PM task or their target words, as they would not be asked to perform the PM action at any point throughout the remainder of the experiment. Following these instructions, the participants performed a practice block of LDT trials with feedback.

Then they were given a long experimental block of 264 trials for the LDT. During the experimental block, all four of the PM target and control words were presented 5 times each. The control words were presented on trials 26, 47, 81, 92, 113, 139, 152, 179, 201, and 209. The PM target words were presented on trials

17, 37, 57, 70, 102, 128, 167, 194, 227, and 243. After the LDT experimental block, participants reached the conclusion of the experiment and were excused. Overall, the PM target words and the control words were each presented the same number of times throughout the experiment.

Results

All data for trials with response times higher than 1500ms were excluded. The trials with such high response times were likely due to the participant not paying attention to the task or becoming distracted mid-trial, and should not be considered in the data. Participants also demonstrated these high response times when they assumed that they had registered a response and began moving back towards the START location, when in fact they had not moved the cursor to the response field to register a response- which caused a significant delay in the trial, and should thus be considered an outlier. Additionally, all computed values excluded incorrect responses to avoid skewing the data. Data was exported from the MouseTracker program and into excel spreadsheets automatically, where the data was amassed and analyzed using simple algorithms to find the averages, differences, etc.

Additionally, all MouseTracker velocities and accelerations are computed without units. This is because the program automatically rescales all trajectories and movements to a standard coordinate space to normalize the aspect ratio of all monitors used in this study, which can then be used to compute the data. The rescaled coordinate space is not given units, but there is a ratio of 2.5:23 for the rescaled coordinate space in comparison to the monitor size. This means that a

1.0 unit of distance in the MouseTracker standard rescaled coordinate space equates to roughly 9.2in on the monitors used in this study.

Initiation and reaction times are listed by group according to the instructions that group received (suspended or finished) in Table 1. The average initiation time for the target words during the lexical decision task experimental block (when participants were NOT supposed to perform the PM task) was 209ms. The average initiation time for the control words during the lexical decision task experimental block was 219ms. This equates to a difference of 10ms. A Paired Samples T Test was conducted and the difference in IT's was determined to be insignificant, but more data should be acquired.

Table 1

Avg. IT for Control Words		**Avg. IT for PM Words**	
Group	**IT (ms)**	**Group**	**IT (ms)**
Suspended	248	Suspended	219
Finished	190	Finished	198
Avg.	219	Avg.	209
	Difference:	**10**	

Avg. RT for Control Words		**Avg. RT for PM Words**	
Group	**IT (ms)**	**Group**	**IT (ms)**
Suspended	606	Suspended	668
Finished	623	Finished	689
Avg.	615	Avg.	679
	Difference:	**64***	

* indicates statistically significant data; $p<0.05$

The reaction time for the target words during the experimental block was 679ms, and 615 for the control words. This equates to a difference of 64ms, $t(16) = -3.54$, $p = .003$. Suspended groups showed slower initiation times than finished groups regardless of trial type (PM or control words). However, there was no significant correlation between the finished or suspended groups and the corresponding reaction time data. In fact, average reaction times showed no correlation with either the PM word pair, or the instruction set.

The data in table 2 was computed by taking the average velocity, acceleration, and angle values for both the PM words and the control words during the LDT experimental block, and subtracting the control data from the PM data. Therefore, any positive values demonstrate that the average data for the PM words was greater than the control, and vis versa if the value is negative.

Average velocities for the PM target words were faster through the first 450ms of each trial in comparison to the control words during the LDT experimental block. At the 451-525ms mark, the average velocity of the control words became faster, and remained faster through the remainder of the average response time of 614.57ms (for the 451-525ms time, $t(33) = 3.12$, $p = .004$; for the 526-600ms time, $t(33) = 3.45$, $p = .001$). Average acceleration for the PM target words demonstrated the same effect. Acceleration was higher for the PM target words in comparison with the control words during the LDT experimental block, until the 451-525ms mark was reached. At that point, the acceleration was greater for the control words throughout the remainder of the time until the average RT. The mean angle of the trajectories recorded by the software also demonstrates an interesting trend. At the 376-450ms mark, the mean angle for the PM target words drifts further away from the correct response – "WORD" – and further towards the PM response, in comparison to the control words. The greatest significant differences were observed at the 451-525ms (t (33) = 2.25, p =

.031), 526-600ms (t (33) = 2.08, p = .046), and 601-675ms (t (29) = 2.31, p = .028) marks. The mean trajectory for the control words, in fact, makes a sharper turn towards the "WORD" response, as the PM mean trajectory moves in the opposite direction. The difference in the angles remains through 800ms.

Table 2

Time (ms)	1-75	76-150	151-225	226-300	301-375	376-450	451-525	526-600	601-675
Velocity Difference	0.00	0.0005	0.0055	0.0071	0.0099	0.0112	-0.0604*	-0.1031*	-0.1054
Accel. Difference	0.00	0.0005	0.0046*	0.0011	0.0037	0.0013	-0.0629*	-0.0490	-0.0524
Angle (°) Difference	N/A	N/A	2.7669	6.6280	0.7597	-1.3417	-7.3102*	-5.8258*	-4.4513*

* indicates statistically significant data; p<0.05

Monitoring may have been present during the LNL task – demonstrated by the comparison between IT and RT of the control words from the LNL experimental and LDT experimental blocks. The average initiation and reaction times for the control words of the LNL experimental block were 256ms and 806ms, respectively. The average IT and RT for the control words of the LDT experimental block were 221ms and 628ms, respectively. Participants had an initiation time 35ms faster, and a reaction time 177ms faster in the LDT block than in the LNL block. The difference in response times was statistically significant, $t(33) = 8.26$, $p < .001$.The faster initiation and response times of the LDT control words could be accounted for by repetition and priming from the previous LNL blocks. Also noteworthy, the task had changed between these experimental groups, and the LDT may have been easier for participants to perform than the LNL task, leading to varying data in the IT's and RT's. Additionally, the practice effect may have some implications here. However, participants had already experienced 2 practice blocks of the LNL task before beginning the experimental block, which should have been adequate time to practice using the software and performing the LNL task.

Commission errors were observed for 11 (32%) participants in total- most of whom made more than 1. The finished instruction group contained 5 participants who committed commission errors (29%), and the suspended instruction group contained 6 participants (35%). It did not appear that commission errors were more prevalent earlier in the experimental block than later, but more data should be collected to determine whether there was any correlation, or whether PM aftereffects decay with time (Walser et al. 2012).

Data Analysis

The IT and RT disparity between the control and target word groups in the LDT experimental blocks demonstrates both the intention superiority effect, and the intention interference effect. Participants demonstrated a faster initiation time for the PM target words than for the control words during the LDT experimental block. The disparity can likely be attributed to the intention superiority effect. The PM words that had previously been associated with a future-oriented intention had remained at a heightened level of activity. Therefore, participants recognized these words faster, and began their movements sooner than for the counterbalanced control words. The intention superiority effect may also have contributed to the spontaneous retrieval of the PM intention during the LDT experimental block, which would induce intention interference.

The data indicate that reaction times were slower for PM target words than for control words, which is likely attributed to the intention interference effect. Participants may have experienced spontaneous retrieval of a past intention when viewing the word, which caused them to hesitate or even move the cursor towards the PM response while sorting out the correct answer in their minds. The participants had to utilize inhibition upon spontaneous retrieval of the no-longer relevant PM intention in order to make the correct response.

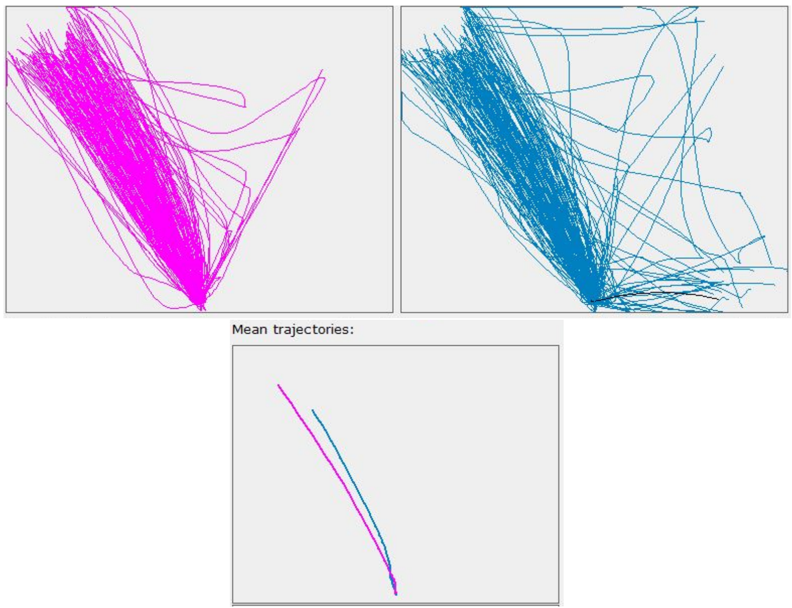
The evidence of the interference and subsequent inhibition is noticeable when viewing the average velocities, accelerations, and angles. Participants initially moved their mouse faster in response to PM words, which is noted by the positive value in both the velocity and acceleration difference numbers in Table 2. The interference and inhibition begins to be noticed when participants slowed down their movements at the average time slot of 451-525. At this point, we see both the velocity and acceleration difference values transition to negative numbers, which indicates that the participants were moving faster for the control words in comparison to the PM words. It is at this time period during the trial when the participant was deciding between the spontaneously retrieved PM intention and the current instruction to simply categorize the stimulus as word or nonword. The shift in velocity and acceleration is substantial between the control and PM words at this point given the sizeable change in the difference.

Next, when we examine the angle differences between PM and control words during the LDT experimental block, we see more evidence of spontaneous retrieval, intention interference, and intention inhibition. Similar to the acceleration, the angle difference also changed rather dramatically during the 376-450ms mark, at which point participants began to move their cursor further from the correct response, and closer to PM intention response. We also see another statistically significant shift in the angle differences from the 526-725ms range. It appears that participants are already starting to correct for their mistakes, as the difference between the control and PM cue responses begins to decrease, presumably after applying inhibitory cognitive resources to the spontaneously retrieved intention.

Evidence of the intention interference effect is also apparent by examining the mouse trajectories, as in the suspended instruction group shown in Figure 3, and finished instruction group in Figure 4. When viewing the graphs displaying the trajectories of all trials for the PM versus control words for each instruction group during the LDT experimental block, we can see several instances of motions towards the PM response. Indeed, some participants committed commission errors, while others exhibited inhibition of the PM intention partially through the execution of the PM task intention, and were able to correct themselves before committing an error. These participants then moved the cursor to the correct response in the upper left corner. From viewing Figures 3 and 4, there are slight differences in the mean trajectories of the PM words and the control words. Although there was not a significant difference computed between the suspend and finished groups angle average angles of movement, it is interesting to note that the finished instruction group did not appear to show as much deviation from the path of the control words in comparison to the suspended instruction group when examining the mean trajectory graphs. However, when examining the data, both the finished and suspended groups showed significant differences in average angles when compared with the control words of their respective group.

Figure 3

Control Words PM Words

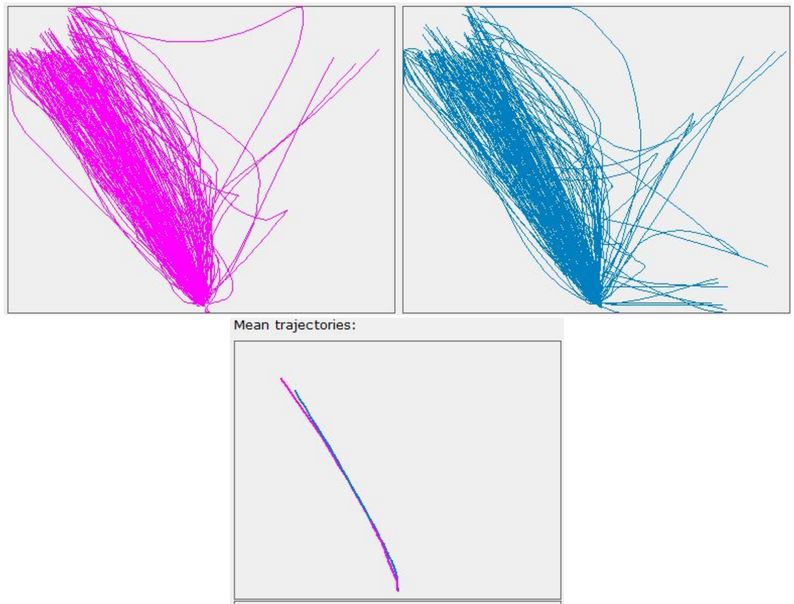


Control words (left) compared to PM words (right) for all trials of Suspended Instruction group, with mean trajectories graphed below

In Figures 3 and 4, commission errors are clearly visible. Some participants committed commission errors on more than 50% of the PM trials in the LDT experimental block. Such a high number of commission errors could indicate that some participants were unclear on the instructions, and indeed thought they were supposed to continue performing the PM task when presented with target words. Without a post-experiment questionnaire, it is impossible to know for certain if some of the participants did not fully understand the instructions, and thought they needed to perform the PM intention.

Figure 4

Control Words PM Words



Control words (left) compared to PM words (right) for all trials of Finished Instruction group, with mean trajectories graphed below

General Discussion

The trends in the data of the velocity, acceleration, and angle analyses indicate a unique pattern that should be outlined. From the averages of all of the participants, regardless of instruction set (finished or suspended), during the LDT experimental block, roughly 300-400ms of time elapsed before participants spontaneously retrieved and recognized the prior PM intention, followed by a deliberation period of roughly 150-200ms before participants had made up their mind on which answer to select, and a final 50-100ms to move the cursor in that direction and make the response. This proposed mental thought process and timing is in accordance with the overall reaction times falling around 600-700ms. The pattern may be unique only to this study, but it is interesting to note. If the pattern could be replicated, then there would be a better understanding of the evolution of the mental process that may be uniform across all participants who exhibit spontaneous retrieval and intention interference for the LDT task.

The evidence for the intention interference effect offers support to the multiprocess theory and use of spontaneous retrieval to recall PM intentions in response to target words (Einstein & McDaniel, 1996; McDaniel et al., 2004; Einstein & McDaniel, 2008; McDaniel & Einstein, 2007). The multiprocess theory seems to be the best fit theory for the data collected, as demonstrated by the spontaneous retrieval of the PM task, which caused a slowing of the responses. As Cohen et al. (2005) documented, there is a correlation between the intention superiority effect and the intention interference effect. Using MouseTracker initiation times as a way to measure intention superiority, further research should be conducted to determine if there is, and to what degree, a correlated or causal relationship between the two effects.

The current study lends evidence that the intention interference effect, as a byproduct of spontaneous retrieval, should be perceived as evidence for the multiprocess theory, and not the PAM theory. Monitoring did not appear to be present during the LDT. The findings of this study do not discredit monitoring or the PAM theory, but that they were not likely to be present during the recall of PM tasks after participants were told the task was suspended or finished. The lack of monitoring is consistent with the idea that devoting attentional resources to a task that is no longer relevant is evolutionary disadvantageous. The evolutionary advantages of spontaneous retrieval are already proposed in literature (Einstein & McDaniel, 1996; McDaniel et al., 2004; Einstein &

McDaniel, 2008), however, there are also advantages to intentionally forgetting. From an evolutionary standpoint, our nomad ancestors encountered changing environments. It is likely that general rules or principles of survival applied in some areas or climates, but not in others. Therefore, those more able to easily dissociate previous memories or habits may have been more adept to survive. Just as in modern society, there are many instances where intentional forgetting is incredibly important. For example, switching medications and the timing at which they are taken can be vital to one's health, or remembering the new location of a fire extinguisher or AED in emergency situations. Intentionally forgetting to prepare for new information can be significant to important and menial tasks. It is important to know how our mind encodes new memories, but also how we dissociate previous memories to make room for that information.

The presence of commission errors is consistent with the study of Pink & Dodson (2013), and not consistent with the study of Scullin (2009). There was also evidence of the intention superiority effect, as demonstrated by Goschke and Kuhl, (1993), Marsh, Hicks, and Bink (1998), Marsh, Hicks, and Bryan (1999), Walser, Fisher, and Goschke (2012), and Penningroth (2011). Further research should be conducted to clearly demonstrate the impact of completed/finished instructions compared to suspended instructions on PM tasks. There are many factors that can alter the impact of instruction sets on the performance of these tasks- such as cue focality, context, time delay, distractor tasks, ongoing tasks, etc. It is challenging to identify which, and to what degree, each of these factors has on the brain when instructing individuals to intentionally forget a task.

There is still much for us to learn about prospective memory. The intention interference and intention superiority effects are still being studied, and MouseTracker software offers additional resources to study these effects. If we continue to study more about these effects on our memory, we can better improve how we remember, and how we intentionally forget. Research is still conflicted regarding the aftereffects of prospective memories beyond finished or suspended instructions, and how long these memories persist before they decay (Cohen et al., 2005; Scullin et al., 2009; Walser et al., 2012; Pink & Dodson, 2013). Learning more about the decay of memories or how long the intention superiority effect persists would be useful in understanding how long after a previous encoding period we should wait before we begin a new, related task. We also might be able to put into place better barriers for ourselves that prevent us from making commission errors or exhibiting intention interference. The more we learn about how cue focality, task similarity, completed instructions, etc. impact our performance on subsequent tasks, the more effective we can be with preventing erroneous errors.

Limitations

The sample size for the current experiment was rather small at 34. In order to draw better, more accurate conclusions, additional participants would need to be included. Due to the small number of participants, the averaged data could still have been skewed or biased by poor results or potential outliers. Also, the current study only focused on college students, which is a very specific group.

Additional testing should be performed on a wider array of individuals for a more representative study of how individuals process prospective memory intentions.

PM target words were presented and practiced within the context of the LNL task. The instructions regarding the performance (or lack thereof) of the PM task changed when the task was switched to the LDT, which could have some impact on the participant. It is possible that, because the context changed in addition to the instructions, there may have been decreased intention interference and/or intention superiority effect. If the PM target words were presented and practiced amongst a LDT task, then the data may have looked different by showing increased intention interference and intention superiority effects (Scullin et al., 2012).

Additionally, there was only one experimenter check to identify if the participants actually understood the instructions – immediately following the PM task instructions. Based on the high number of commission errors, it may be better suited in the future to include an additional experimenter check right before participants begin the LDT block. An alternative to an additional experimenter check would be to have participants fill out a survey or questionnaire following the final experimental block, and ask them to write their understanding of the instructions during that final block. If it became clear from their response that they did not remember the correct instructions, then their trials can be removed from examination so as not to skew the data with commission errors that were performed out of a lack of *knowing* the correct instructions, not just a lack of *following* the instructions incidentally.

Finally, there may have been some confounding in the form of repetition priming of the control words, which were repeated through many of the blocks of trials throughout the experiment. Scullin et al. (2009) eliminated the possibility of repetition priming in their study by introducing new control words into the final experimental block during the finished instruction set of trials. They found that there was no difference in performance on these new control words when compared to the control words that had been repeated in each block since the first block of trials at the start of the experiment.

Conclusion

The findings in this experiment were consistent with and demonstrative of: the intention interference effect, intention superiority effect, spontaneous retrieval of suspended or finished intentions, inhibition of former prospective memory tasks, and commission errors in suspended and finished instruction participants. MouseTracker is a useful tool in studying prospective memory due to its wide range of functions and applications, extensive data collection, and easily designable nature. Experimenters can create a program to meet their testing specifications, and glean a vast amount of data that may be useful in discovering more about the cognitive processes involved in prospective memory. Prospective memory is a growing area of study as new information is released discovered about the cognitive processes of the brain, and how we remember future intentions. The purpose of this study is to further the interest in this field, examine literature, replicate past results, and promote new methods of examining the current theories of prospective memory

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