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Improving Motion Imagery Analysis: Investigating Detection Failures, Remembering to Perform Deferred Intentions

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IMPROVING MOTION IMAGERY ANALYSIS: INVESTIGATING DETECTION FAILURES, REMEMBERING TO PERFORM DEFERRED INTENTIONS

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ABSTRACT

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Advances in automation have led to an increased prevalence of human multitasking in intelligence, surveillance, and reconnaissance operations. Despite advancements in computer-vision research, almost all video data collected must be processed by human analysts. Traditionally, analysts are plagued with the presence and possible overabundance of interruptions that fundamentally leads to multitasking while processing video data. It is currently unknown what factors influence decision making in completing primary tasks or handling interruptions. In this study, we investigated the performance effects and the resulting design implications of varying the number of concurrent prospective memory tasks and encoding of one large group of tasking information versus smaller, separate bits. Results indicate that working memory capacity significantly affects prospective memory performance and increasing concurrent targets degraded prospective memory performance. Target encoding format results failed to converge on a clear affect. This study demonstrates and highlights portions of the complex underlining mechanisms involved in human information processing and makes a case for the study and utility of prospective memory paradigms for human-machine interface design.

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I. INTRODUCTION

BACKGROUND

Unmanned aerial vehicles have been employed for decades, though almost exclusively for reconnaissance (Weatherington, 2002). Despite advancements in computer-vision research, almost all video data collected must be processed by flesh-and-blood analysts. In processing this data, analysts consequently make time-critical decisions in a dynamic work environment that tax their prospective memory. Due to the abundance of data, analysts are often tasked to monitor multiple displays and are consequently interrupted. This subset of elements affects the effectiveness of analysts. It is imperative to assist analysts in their time-critical decision making process. This experiment will study these variables in a simulated real-life surveillance environment.

RESEARCH OBJECTIVE

The objective of this study is to investigate the impact of prospective memory manipulations on visual search tasks. The study also hopes to provide guidelines for decision support systems for improving the effectiveness of analysts while multi-tasking. To achieve this objective, a research framework was formulated see Figure 1.

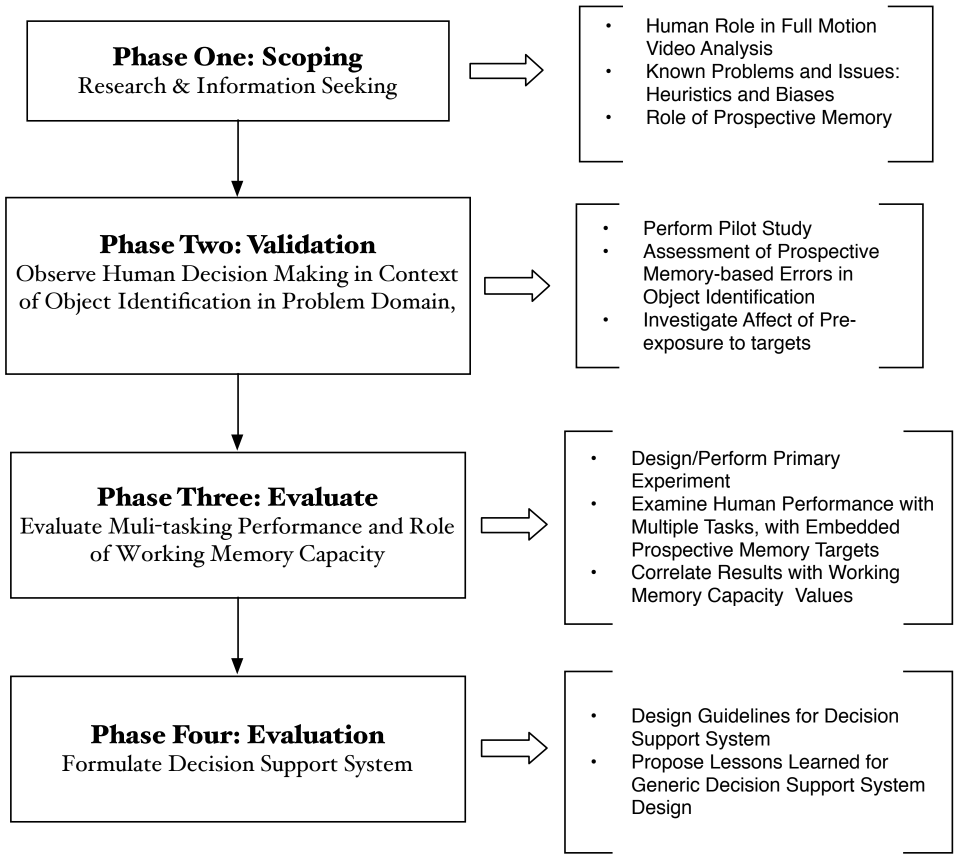


Figure 1 Research methodology framework

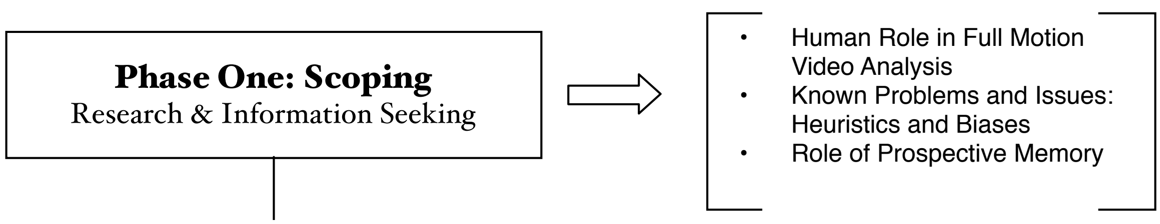


Figure 2 Research phase one details

II. PHASE ONE: LITERATURE REVIEW

In order to understand the cognitive demands of analysts, a thorough background understanding of prospective memory and its role in the decision-making process is needed. This section aims to scope and lay the groundwork for the main experiment, see Figure 2. The following sections outline the topics that are relevant to understand the domain and methodology for this research.

PROSPECTIVE MEMORY: REMEMBERING TO PERFORM DEFERRED INTENTIONS

Recent technological advancements have led to collecting data at astronomical rates that has ultimately led to a disparity between the demand for intelligence and the paucity of analysts. It is imperative to provide military and homeland security decision makers with timely, actionable, trusted, and relevant information necessary to ensure their decisions achieve the desired military/humanitarian effects (Bryant, Johnson, Kent, Nowak, & Rogers, 2008). Although the visual targets in full motion imagery are context specific, it is widely understood that these targets pose a threat to our national security—therefore—it is important to assist analysts in their decision-making. In order to improve the performance of video analysts in searching for threats, it is important first to understand fully the requirements of the demanding task.

Visual searches in experiments and real-world environments (Gibson, Li, Skow, Brown, & Cooke, 2000) often benefit from a variety of memory-based mechanisms that improve the efficiency of guiding ones' attention (e.g., (Chun & Jiang, 1998; Desimone & Duncan, 1995; Gibson et al., 2000; Maljkovic & Nakayama, 1994; Theeuwes, Kramer, & Atchley, 1998; Watson & Humphreys, 1997). Prospective memory mechanisms play a large role in guiding attention for closer examination (Peterson et al., 2007) and when objects are unclear (Piauilino et al., 2010; Uttl, 2008). When humans derive information from full motion imagery, analysts must discern signals (targets) from noise; terms derived from signal detection theory framework (Abdi, 2007). Analysts must often make time-critical decisions in determining the presence of targets. Upon making a decision, one of four outcomes is possible, the decision was a correct hit or miss, or incorrect hit or miss, shown in Table 1. Full motion imagery analysts need to be aware of the limitations of their information processing abilities because inaccurate decisions regarding target humans under study can easily be made (Rodgers, 2006). Airborne-based observation is typically a deadly dull process that strains the vigilance and morale of human pilots and makes poor use of their costly, hard-won skills (Freed, Harris, & Shafto, 2004). Most humans' performance drops in sustained attention tasks over time—this is known as the vigilance decrement. In order to combat the vigilance decrement and aid in making personnel more effective, it is necessary to find innovative ways to mitigate the vigilance decrement and aid the human visual system (Pavlas, Rosen, Fiore, & Salas, 2008). Consequently, we must discern what factors are correlated with target detection errors in order to mitigate visual search task-based errors. For example, if the conditions of an environment facilitate and/or foster erroneous decision-making, the individual would be notified and could elect assistance through the use of computer-vision intervention systems. These systems aim to assist humans by shifting the workload of resource-demanding tasks to computer systems that often include moving object detection and recognition, tracking, behavioral analysis and retrieval (Hogan, 2012; Valera & Velastin, 2005).

Table 1: Four possible types of responses in single detection theory based on (Abdi, 2007)

	Participant's Response	
	Yes	No
Signal Present	Hit	Miss
Signal Absent	False Alarm	Correct Rejection

In processing full motion imagery and consequently making decisions, two key aspects of memory can lead to erroneous decision-making: prospective memory and retrospective memory. In everyday life, people are constantly faced with a variety of prospective memory tasks such as remembering to call a friend to meet with at 3:00 p.m. (time-based tasks) or fill your car's gas tank when passing a gas station (event-based tasks) (Block & Zakay, 2006; Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995; Hicks, Marsh, & Russell, 2000; Khan & Sharma, 2007; Kvavilashvili & Ellis, 1996; Sarapata, 2001). 50-80% of all everyday memory problems, are in part, prospective memory problems (Kliegel & Martin, 2003). Einstein et al. (1995) and Sellen, Louie, Harris, and Wilkins (1997) have shown that people generally perform event-based intentions more reliably than time-based. The defining characteristics that distinguish prospective memory from other forms of memory include the following three main stages:

(1) *Encoding,* the individual must form an intention to perform an action at some later time when conditions (the target) are met

(2) *Retention*, the interval until execution is usually filled with one or many unrelated tasks. These ongoing tasks tax attention and working memory so that the individual does not maintain continual awareness of the deferred intention (avoiding it becoming a vigilance task)

(3) *Retrieval*, in which no agent overtly prompts the individual to retrieve the intention to act from memory at the appropriate time--he or she must somehow "remember to remember" (Dismukes, 2010; Einstein & McDaniel, 1990; Gilbert,

Armbruster, & Panagiotidi, 2012; Holbrook & Dismukes, 2009; Kvavilashvili & Ellis, 1996; Li & Laird, 2013; Scullin, 2010; Shelton et al., 2013).

Despite this self-cued aspect of prospective memory, each prospective memory task also consists of a retrospective component, which is usually simple (e.g. pick up bread on the way home from work) (Hannon & Daneman, 2007; Khan & Sharma, 2007; Maylor, 1990). Retrospective memory is memory for pas events (Glisky, 1996; Khan & Sharma, 2007; Titov & Knight, 2001). After having remembered that something needs to be done, one also has to remember ‘‘what’’ it is that needs to be done. This retrospective component is usually minimal and it is the prospective, ‘‘remembering to remember’’ aspect of the task that is problematic (Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2009; Meacham, 1977; Zimmermann & Meier, 2006). The most common failure of prospective memory is the failure to remember to perform an intention at the intended time, place or condition (Dismukes, 2010). In other words: retrospective memory is treated as a prerequisite for successful completion of prospective memory tasks because an individual searching for a particular target must be able to recall what he or she is on the lookout for (Lampinen, Arnal, & Hicks, 2009b). In our daily life, it is clear that both prospective memory and retrospective memory are needed (Khan & Sharma, 2007). For prospective remembering, there is no obvious and external cue to prompt an individual (McDaniel & Einstein, 1993);whereas retrospective remembering requires an external prompting (Dismukes, 2012; Khan & Sharma, 2007). See Table 2 to help disambiguate the three key aspects of prospective and retrospective memory and Table 3 for examples of experimental task conditions.

Table 2 Three key aspects of prospective and retrospective memory

	Prospective Memory	Retrospective Memory
Encoding	Requires planning, often linking a specific cue (sitting down to eat dinner) to an intention (taking medication)	Requires little or no planning
Storage	Retention may decrease, increase, or remain stable with increase in delays	Almost always decreases with increasing delay intervals
Retrieval	Retrieval self-initiated, must remember to remember; no obvious external cue to prompt retrieval of information.	External, often experimenter prompted retrieval

Encoding and retrieval stages of memory are two sources of variability of successful recall and interact in the sense that a cue may be effective in one situation, may or may not be effective in another (Tulving & Thomson, 1973). The way a focal task influences potential target cues to be processed greatly affects prospective remembering and may support prospective memory retrieval (G. I. Cook, Marsh, & Hicks, 2005; Nowinski & Dismukes, 2005). For example, an individual would be more likely to remember an intention to give a scholarly-related message to a peer when the peer is encountered at school than when the peer is encountered at a gas station. Cherry et al. (2001), Einstein et al. (1995) and Ellis and Milne (1996) have shown that prospective memory performance is higher when the cue is a specific item (e.g., shirt) than a semantic category (e.g., pieces of clothing) (Dismukes, 2012; Kliegel, Martin, McDaniel, Einstein,

& Moor, 2007; Sugimori & Kusumi, 2008).

Consider this additional example, participants might be given the ongoing task of naming famous individuals in a series of photographs and an prospective memory task of pressing a predetermined key when: (1) a man named Michael is identified or (2) when a man with a pocket book is identified (Maylor, 1993); performance is higher in the first condition because the ongoing task causes participants to process target cues explicitly—referred to as focal cues (Dismukes, 2010). In the focal prospective memory task, the prospective memory task and the ongoing activity share demands and engage in the same type of processing (Lampinen, Peters, & Gier, 2012). In some contexts, a target might be an individual. Prospective memory and its attributes have been noted in facial recognition tasks.

Table 3 Representative examples of task conditions, assumed high and low in focal processing (Einstein & McDaniel, 2005), reprinted with permission

Processing	Ongoing Task	Prospective Memory Task
Nonfocal	Words were presented in the center of a computer monitor and participants had to learn them for recall tests that occurred at unpredictable times.	Respond when you see a particular background pattern (background pattern changes every 3 seconds).
Focal	Participants had to keep track of the number of occurrences of each background screen pattern.	Respond when you see a particular background pattern (background pattern is changed every 3 seconds).
Nonfocal	Lexical decision task.	Respond to items from the ‘‘animal’’ category.
Focal	Lexical decision task.	Respond to the word “cat.”
Nonfocal	Pairs of words were presented and participants decided whether the word on the left was a member of the category on the right.	Respond to the syllable ‘‘tor.’’
Focal	Pairs of words were presented and participants	Respond to the word

	decided whether the word on the left was a member of the category on the right.	‘‘tortoise.’’
Nonfocal	Pictures of famous faces were presented, and the task was to name the face.	Respond when you see a face with eyeglasses.
Focal	Pictures of famous faces were presented, and the task was to name the face.	Respond when you see a face with the first name of ‘‘John.’’

The problem of finding missing children has been conceptualized as a special case of event-based prospective memory or prospective person memory (Lampinen, Arnal, & Hicks, 2009a; Lampinen et al., 2012). In a typical study, participants are presented with one or more prospective memory targets that they are on the lookout for during the experiment-representative of a visual search task. It is reasonable to assume that exposing participants to multiple images of a particular target before a visual search task would increase correct target identifications. However, when participants were shown multiple pictures of missing children on posters, participants showed an increased tendency to indicate that a child was previously seen—using retrospective memory—regardless of whether the child actually was previously seen (Sweeney & Lampinen, 2012). Also, this led to significantly more correct and incorrect identifications of targets. The additional images overwhelm one's memory and cloud their judgment; i.e., participants are more likely to respond yes a target is present and increase the overall hit rate for correct and incorrect hits.

In a study investigating prospective memory for missing children in family abductions: participants studied mock missing child posters including a picture of a child, a picture of a child alongside a picture of their parent (correct or associated adult), or a picture of a child alongside a picture of an adult that is not their parent (incorrect adult). Participants then saw pictures of child/adult pairs with instructions to make a response to ‘alert authorities’ if the target individuals were seen. Including the picture of the correct adult on the poster, significantly improved recognition relative to the other two conditions. The correct adult/child condition had an overall higher identification score, the child only and the child and incorrect adult conditions did not significantly differ from each other. (Lampinen & Sweeney, 2013). In making the decision that a target is present, humans typically use cognitive heuristics that may lead to potential biases (Ash, 2009; M. B. Cook & Smallman, 2008; Fendley & Narayanan, 2012; Hayibor & Wasieleski, 2009; Kebbell, Muller, & Martin, 2010; McCann, 2006; Tversky & Kahneman, 1974; R. F. West, Toplak, & Stanovich, 2008).

Challenges arising from human errors and biases must be accounted for. There are a wide range of cognitive biases that impact the performance of full motion imagery analysts (Fendley & Narayanan, 2012; Heuer Jr, 1999). The following table, Table 4, lists the cognitive biases found to influence a decision maker during an object-identification task. More specifically, memory biases affect the accuracy of full motion imagery analysts in recalling, imagining, and searching for events/targets. These biases encompass prospective and retrospective memory and have been shown to exist as an issue in facial recognition tasks. Lebiere and Lee (2002) looked at the intention superiority effect—which I argue is a prospective memory-based bias—in which intentions are more easily recalled than completed intentions (Li & Laird, 2013). To investigate the manifestation of prospective memory-based errors in an object identification task, an experiment (Pilot Study 1) was conducted. This model represents the mental process by which knowledge is accessed and reflects the goals, steps, and sub steps of the analyst that results in active decision making. “How the decision process is structured influences how value is apportioned to the task objectives (Clemen & Reilly, 2001)” as cited in (Hendrickson, Fendley, & Kuperman, 2013). The decision process will allow identification of problem areas where decision support systems can impact and potentially improve decision-making and analyst performance. Paul (2013) reported a validated operator function model for locating potential threats for a convoy in full motion imagery; a majority of tasks inherently have prospective memory vulnerabilities.

Table 4: Potential biases in object identification (Fendley & Narayanan, 2012)

Bias category	Cognitive bias	
Memory biases	Imaginability	An event that is easily imagined is judged to be more probable
	Recall	An event may seem more probable if an instance is easily recalled
	Search	An effective search strategy may make an event seem more frequent
Statistical biases	Correlation	Probability of the co-occurrenceof events may be overestimated due to previous cooccurrence
Confidence biases	Confirmation	Confirming, rather than disconfirming, evidence is sought
	Redundancy	Redundant data may cause undue confidence in its accuracy and importance
	Selectivity	Expectation of the nature of an event influences what information is thought to be relevant
Presentation biases	Order	Undue importance may be placed on the first or last data point

PROSPECTIVE MEMORY IMPORTANCE

Remembering—and too often forgetting—to perform a delayed intention without prompting at a later time involves prospective memory (Bayen & Smith, 2008; Chan, Qing, Wu, & Shum, 2010; Cherry & LeCompte, 1999; G. Cohen, 1989; Crystal, 2013; Dismukes, 2010; Einstein & McDaniel, 2005; Ellis & Kvavilashvili, 2000; Freeman & Ellis, 2003; Gilbert et al., 2012; Harris, 1984; Hicks et al., 2000; Khan & Sharma, 2007; Kliegel et al., 2007; Kvavilashvili & Ellis, 1996; McAllister, Baiamonte, Ory, & Scherer, 2011; Sarapata, 2001; Scullin, McDaniel, & Shelton, 2013; Scullin, McDaniel, Shelton, & Lee, 2010; Shelton et al., 2013; Titov & Knight, 2001). Prospective memory intentions (and associated failures) are ubiquitous and embedded in daily life in everyday actions and activities (see, e.g., (Baddeley & Wilkins, 1984; G. Cohen, 1989; Crovitz & Daniel, 1984; Einstein & McDaniel, 1996; Gilbert et al., 2012; Harris, 1984; Kvavilashvili & Ellis, 1996; Meacham, 1982; Morris, 1992; Terry, 1988; R. L. West, 1984). Our daily lives are filled and sometimes overflowing with prospective memory demands from managing work activities (e.g., remembering to finish last minute paperwork in the morning) to coordinating social activities (e.g., remembering to attend a friend's party) to maintaining personal health-related needs (e.g., remembering to take blood sugar levels); it is surprising there is virtually no interest in this memory type until recently (Einstein & McDaniel, 2005). In fact, Crovitz and Daniel (1984) found that half of everyday forgetting can be attributed to prospective memory failures that can have severe consequences (such as a pilot forgetting to lower landing gears) and may play a significant role in the medical field (Dembitzer & Lai, 2003; Gawande, Studdert, Orav, Brennan, & Zinner, 2003). Prospective memory failures can cause social damage with supervisors and co-workers (Meacham, 1988; Sarapata, 2001). Given that prospective memory failures have contributed to serous accidents in industry and everyday life (Dismukes, 2008; McDaniel & Einstein, 2007), it is peculiar that it has received little study in professions outside aviation (see Grundgeiger & Sanderson, 2009, and Dembitzer & Lai, 2003, for a few examples from medicine).

A prospective memory failure occurs when an individual fails to retrieve an intended action at an appropriate moment (Kvavilashvili & Ellis, 1996). Prospective memory failure can occur for various reasons (1) inadequate or absent encoding of the intention into memory, (2) failure to maintain it effectively over time (memory decay), and (3) changes in context between encoding and retrieval (Gilbert et al., 2012). If a person fails to properly encode a prospective memory target cue, then the action may never occur (Ellis, 1996); however, if the information is encoded but encoded improperly, then the prospective memory task may occur, but will not be in the right way or time (Sarapata, 2001).

Many assume that they may be exempt from forgetting to perform an important delayed task. However, research with skilled airline pilots reveal that the most skilled operators are vulnerable to occasional lapses (Loukopoulos, Dismukes, & Barshi, 2009). This raises an important question, how does one improve their prospective remembering? Therefore it seems necessary to investigate the possible causes of prospective remembering errors, which may enhance our understanding of prospective memory and its underlying mechanisms (Rummel, Hepp, Klein, & Silberleitner, 2012). In order to improve prospective memory, we must first obtain a better understanding of the supporting cognitive processes.

MEMORY RETRIEVAL

The most discussed theoretical issue in prospective memory, currently, concerns how delayed intentions are retrieved. In resolving this issue, details are gained in creating practical countermeasures to reduce vulnerability as well as ascertaining factors that affect forgetting to perform deferred intentions. Retrieval is self-initiated (Craik, 1986), embedded in ongoing activity and supported by self-initiated tests (Shelton et al., 2013). There are two general cognitive processes that have been theorized to support prospective memory retrieval: spontaneous retrieval and monitoring (McDaniel & Einstein, 2007).

According to one theoretical perspective, the process is automatic: encountering target cues triggers retrieval of intentions through a reflexive associative process (Einstein & McDaniel, 2005; Einstein et al., 2005; McDaniel & Einstein, 2000, 2007; Meier & Rey-Mermet, 2012; Scullin, McDaniel, & Einstein, 2010; Sugimori & Kusumi, 2008). This automatic process requires little, if any, cognitive resources due to the retrieval of the delayed intention being spontaneous. When forming an intention, an association between the target cue and the intended action is made. When the target cue is encountered, the memory association provides adequate activation for the intention to be retrieved directly into memory. This is consistent with Reese and Cherry (2002) who discovered that participants rarely thought about the prospective task while performing an ongoing task. A few studies have shown that intentions are activated when participants do not intend to respond, which suggests an automatic, or spontaneous response (Einstein et al., 2005; Holbrook, Nowinski, & Dismukes, 2005) in diary studies (Kvavilashvili & Fisher, 2007) and workplace studies (Sellen et al., 1997) participants reported thoughts of delayed intentions during low activity (Dismukes, 2010).

In direct contrast to the spontaneous retrieval perspective, monitoring retrieval argues that monitoring for target cues requires the consumption of limited cognitive resources (Dismukes, 2010; Einstein & McDaniel, 2005, 2010; McBride, Beckner, & Abney, 2011; McDaniel & Einstein, 2000, 2007; Meier & Rey-Mermet, 2012; Smith, 2003, 2010; Smith & Bayen, 2004; Smith, Hunt, McVay, & McConnell, 2007; Sugimori & Kusumi, 2008). This monitoring process often comes at a cost of performance slowing in the ongoing task (Feresin, Brandimonte, Ferrante, & Delbello, 2001; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; Meier & Rey-Mermet, 2012; Smith, 2003, 2010; Smith & Bayen, 2004; Smith et al., 2007). Smith (2003) found that participants were slower when performing a lexical-decision task when they also had a prospective memory demand than they were when they had no prospective memory demand (Einstein & McDaniel, 2005). This indicates that resources are in competition between being prepared to perform the prospective task with the ongoing task.

More recently, McDaniel and Einstein (2000) have proposed a hybrid perspective—multiprocess theory (Chen, Huang, & Yuan, 2010; Einstein & McDaniel, 2005; McDaniel, Guynn, Einstein, & Breneiser, 2004; Meier & Rey-Mermet, 2012; Rummel et al., 2012; Scullin et al., 2013; Smith, 2003; Sugimori & Kusumi, 2008). This theory asserts that in some situations individuals rely on the spontaneous retrieval process but in others, devote resources to monitoring to improve performance. The relationship between retrieval methods is dynamic and individuals vacillate resources as necessary.

There have been several studies that opine experimental conditions may dictate whether one process is more manifested than the other (G. I. Cook, Marsh, Hicks, & Martin, 2006; Meier & Rey-Mermet, 2012; Rummel et al., 2012; Scullin, McDaniel, & Einstein, 2010; Sugimori & Kusumi, 2008). McDaniel and Einstein (2000) posits that one relies on spontaneous retrieval or monitoring dependent on the ongoing task, the prospective memory task, and the individual (Meier & Rey-Mermet, 2012). Kliegel, Martin, McDaniel, and Einstein (2001) and Kliegel, Martin, McDaniel, and Einstein (2004) have shown that participants allocate resources (measured by lexical decision-making speed) to prospective memory tasks or ongoing tasks as a function of task importance. When the prospective memory task was emphasized, the ongoing task was slowed with more error occurrences—indicating resources were allotted. Performance only improved if the target cue was nonfocal, which Dismukes (2010) suggests that focal target cues retrieval is automatic and does not benefit from additional resources. (Einstein & McDaniel, 2005; Harrison & Einstein, 2010; McDaniel & Einstein, 2000, 2007) argue that one utilizes spontaneous retrieval processes depends on the quality of the cue. “If a cue s highly salient or focal so that the relevant features of the cue are processed by performing the ongoing task, people rely heavily on spontaneous retrieval processes”

(Rummel et al., 2012, p.352). Prospective memory performance is higher when the target cues are strongly associated with the intention (Loft & Yeo, 2007; McDaniel et al., 2004) and salient, distinctive, or unusual (Brandimonte & Passolunghi, 1994; Dismukes, 2012; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Uttl, 2005). In a study by Loft and Yeo (2007), it was found that less-frequent prospective memory cue presentations resulted in less monitoring and lower prospective memory performance. Notebaert et al. (2009) found that less-frequent prospective memory cues may cause attentional capture that would require reorientation to the ongoing task, which also explains why slowing occurs after infrequent events (Meier & Rey-Mermet, 2012). One can argue that spontaneous retrieval processes are always operative and individuals elect to supplement those with a monitoring process. The way an ongoing task guides attention significantly affects prospective memory performance (Dismukes, 2012).

Another facet of prospective memory that has been briefly investigated, and not completely understood, is the time effect of prospective memory; although it is known prospective memories differ in temporal aspects (Brubaker & Herrmann, 1998; Sarapata, 2001). A typical laboratory paradigm for studying prospective memory elicit delayed intentions with a few commonalities: (1) instructions are provided for an ongoing task (e.g., pleasantness ratings), (2) the prospective memory cue is encoded to an intention (e.g, press a designated key whenever you see the word dog in the context of the ongoing task), (3) a delay is introduced while the ongoing task (e.g., pleasantness ratings) is performed without reminding participants of the prospective memory task, (4) the prospective memory target occurs in the ongoing task and prospective memory performance is measured by the proportion of times a participant remember to press the designated key when the target occurs (Einstein & McDaniel, 1990, 2005; McAllister et al., 2011; McDaniel & Einstein, 2007; Scullin, 2010; Shelton et al., 2013). A participant makes a mistake when he fails to retrieve a deferred-intention (Crystal, 2013). Harris and Wilkins (1982) explain that target cues may be active (such as a beeping sound or flashing light) or passive; the likelihood of remembering increases across natural cues, passive cues, and active cues. The duration between the time of encoding and the occurrence of the target prospective memory cue is referred to as the retention interval, see Figure 3. It is well known that memory degrades over time.

Retrospective remembering has been shown to decay resembling the classic decay curve, does prospective remembering share this feature? Due to the scarcity of data investigating this question, results seem to be contradictory in nature, most likely due to variations inherent in experimental designs. Although there is no uniform agreement on the consequences of increasing retention intervals (Hicks et al., 2000). The retention interval may last several hours, days, or weeks (Ellis & Nimmo-smith, 1993; Wilkins, 1979), and may include periods of sleep (Diekelmann, Wilhelm, Wagner, & Born, 2013; Scullin & McDaniel, 2010; Scullin et al., 2013).

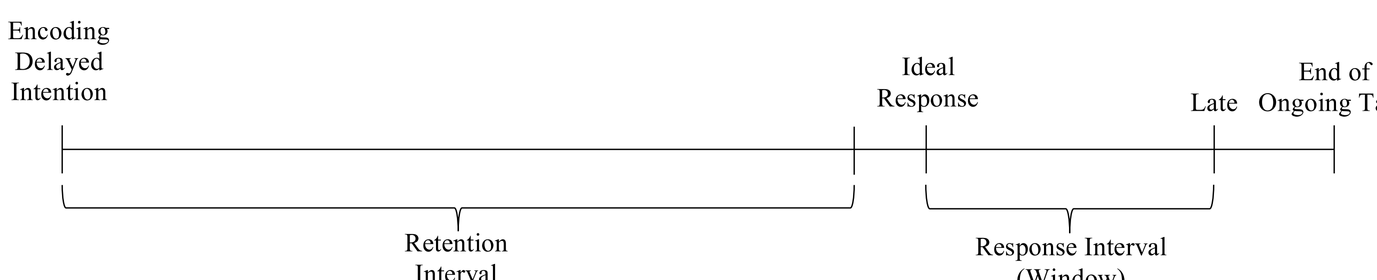


Figure 3: Typical prospective memory experimental timeline based on (Sarapata, 2001)

RETENTION INTERVAL

The retention interval is the time from when the task is encoded to the time that the cue is presented also referred to as a postponed-intention paradigm (Dismukes, 2010; Freeman & Ellis, 2003; Hicks et al., 2000; Sarapata, 2001; Shelton et al., 2013). A typical retention interval is around 5 to 10 min with a spacing of prospective memory trials within an experiment ranges from less than a minute to several minutes (Dismukes, 2010). Research has demonstrated that characteristics of the delay interval, such as the length and number of a filler tasks can affect prospective remembering (Hicks et al., 2000; Martin, Brown, & Hicks, 2011; Shelton et al., 2013). Various types of tasks performed during delay intervals have been investigated such as vocabulary tests (Einstein et al., 2005), fluid intelligence tests (Scullin, McDaniel, Shelton, et al., 2010), working memory span tests (Scullin & McDaniel, 2010), puzzles (Marsh et al., 2003), retrospective memory tasks (Einstein, Holland, McDaniel, & Guynn, 1992) and cartoon ratings (Hicks et al., 2000). Several studies have reported prospective memory performance is worse with longer retention intervals (Hicks et al., 2000). However, Hicks et al. (2000) found that prospective memory performance increased significantly when breaks occurred in retention-interval tasks and even more so when those breaks did not make task demands at all (Dismukes, 2010). In contrast, Finstad, Bink, McDaniel, and Einstein (2006) found the opposite: both task switching and breaks impaired prospective remembering (Dismukes, 2010). However, in this study, the breaks occurred during an ongoing task whereas in Hicks et al. 2000 study the breaks occurred during the retention intervals. Hicks et al. (2000) also reported that a longer retention interval resulted in higher prospective memory performance.

Brandimonte and Passolunghi (1994) also found that forgetting in an event-based task declined rapidly over certain types of 3-min intervals as compared with being tested immediately (Hicks et al., 2000). A shorter retention interval enables a participant to remember the correct moment to respond to a task more than a longer retention interval (Sarapata, 2001). Brandimonte and Passolunghi (1994) discovered that prospective remembering was disrupted when the retention interval was filled by a demanding verbal or motor task, but not when it was filled with a verbal task (Freeman & Ellis, 2003). In contrast, Stone, Dismukes, and Remington (2001) found no prospective remembering differences in retention intervals of 1, 3, and 5 minutes, Einstein et al. (1992) found no differences between 15 and 30 minutes, and Guynn, McDaniel, and Einstein (1998) found no difference between 4 and 20-minute intervals (Dismukes, 2010). Meacham and Leiman (1982b) found when a reminder is provided for the prospective remembering task during delay intervals, prospective memory performance improves as the retention interval increases however without the reminder, performance was better at shorter delays (Hicks et al., 2000). Shelton et al. (2013) reported that in four experiments, prospective memory performance was immune to depletion manipulations. Despite these conflicting results, a theory has been proposed to describe prospective memory improvement with increasing retention intervals.

During retention intervals, it is possible revisiting or refreshing intentions might preserve their status in memory, thus inoculate them from rapid forgetting (Hicks et al., 2000). Sellen et al. (1997) argued that people may mentally consider unfulfilled intentions during natural breaks in ongoing activities (Hicks et al., 2000). This downtime may provide participants an opportunity to reflect on upcoming tasks. Nigro and Cicogna (2000) found prospective remembering did not differ between 10-min, 2-day, and 2-week intervals for a more realistic task of remembering to give a message to an experimenter (Dismukes, 2010). Although there seems no direct census on the effect of retention intervals on prospective remembering, there is considerable data available; see (Kvavilashvili & Ellis, 1996) and Table 5. Additionally, a few variables have been explored for their effect on prospective remembering, see Table 6. Prospective remembering can depend on a variety of factors including the imputed task significance and ongoing tasks (Marsh, Hicks, & Cook, 2005), the clarity and number of cues, subject's personal disposition, and the delay between instruction of the intention and the occurrence of the target event (Einstein & McDaniel, 2010; Grundgeiger, Sanderson, MacDougall, & Venkatesh, 2010).

Table 5. Summary of Event-based or Activity-Based PM Publications in Which Retention Interval Has Been Manipulated adapted from (Martin et al., 2011) reprinted with permission

Publication	Experiment and/or Condition	Effect	Time frame	Retention activity
Activity based task:				
Loftus (1971)	No cue	Decrease	~30 seconds vs. ~3 min	Ongoing task questions
Guajardo and Best (2000)	High and low int. High and low int.	None None	20 min vs. ~48 hr	Computer game filler (20 min) or everyday activities
Event based task:				
Somerville, Wellman, and Cultice (1983)	EB cue No prompt Visual prompt	Decrease Decrease Decrease	~1–5 min vs. ~8–10 hr	Everyday home activity
Meacham and Leiman (1982a)	Exp. 2 tag/all dates Exp. 2 no tag/all dates Exp. 2 tag/first date Exp. 2 no tag/first date	Increase* Decrease* Decrease* Decrease*	~8 days vs. ~24 days ~2 days vs. ~14 days	Everyday activities
Einstein et al. (1992)	Exp. 1/1 target word Exp. 1/4 target words Exp. 1/1 target word Exp. 1/4 target words	None None None None	15 vs. 30 min	Various filler memory tasks
Brandimonte and Passolunghi (1994)	Exp. 1 Exp. 5 practice Exp. 5 unfilled Exp. 5 artic. Suppression Exp. 5 motor suppression	Decrease Decrease None None Decrease	0 vs. 3 min	Practice ongoing task trials Practice ongoing task trials Wait for experimenter Atric. Suppression filler Motor suppression filler
Guynn et al. (1998)	Exp. 3 no reminders Exp. 3 target reminders Exp. 3 target/action reminders	None None None None	4 vs. 20 min	One filler memory task vs. four filler cognitive tasks
Kvavilashvili (1998)	Exp. 2	None	0 vs. 5 min	Face rating filler task
Nigro and Cicogna (2000)	Primary Study	None	10 min, 48 hr, or 2 wk	Word association filler (10 min) or everyday activities
Hicks et al. (2000)	Exp. 1A Exp. 1B Exp. 3 single activity Exp. 3 five task	Increase Increase Increase Increase	2.5 vs 15 min 2.5, 5, or 15 min	Cartoon rating filler (2.5 min) or various intelligence tests One of five paper-and-pencil filler taks of varying length
Meier, Zimmermann, and Perrig (2006)	Exp. 2 generalized context Exp. 2 specific	Decrease Decrease	5, 15, or 45 min	Two filler tasks of varying length
Scullin and McDaniel (2010)	Living/20 m v. wake Lexical decision/ 20 m v. wake Categorization/20 m v. wake Living/20 m v. sleep Categorization/20 m v. sleep	Decrease Decrease Decrease Decrease Decrease None	20 min vs. 12 hr awake 20 min vs. 12 hr sleep	Rest break (20 min) or daily activities (sleep/awake)

*No specific comparisons were made for these data, thus nominal tends are noted.

Table 6 Variables that affect prospective memory performance (Dismukes, 2010), reprinted with permission

Variable	Effect
Implementation intentions—encoding a specific time and place to perform a deferred intention and identifying environmental cues likely to be present	Improves performance
Cues that are salient, distinctive, unusual, or highly related to the prospective task	Improves performance
Importance of prospective memory task	Can improve performance if it leads the individual to allocate increased attention to the prospective task or adapt compensatory strategies, such as creating reminder cues
Degree to which ongoing task focuses attention on cues related to the prospective task	Improves performance
Degree to which ongoing task causes prospective cues to be processed in the same manner in which they were encoded	Improves performance
Age	Impairs performance of tasks in which target cue is not focal; no effect when target cue is focal
Divided attention	Impairs performance for some tasks but not others

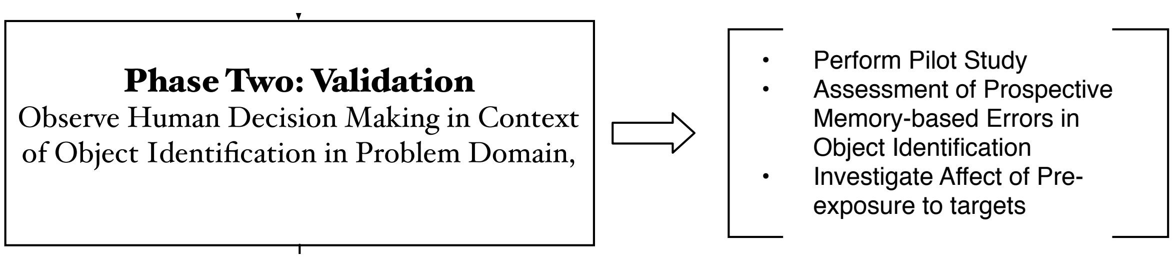


Figure 4 Research phase two details

Previous research has been performed in strictly controlled laboratory environments using still imagery that may not be fully representative of many operating environments. The experiment will be composed of a visual search task that will investigate human analyst's performance in locating targets in full motion imagery to examine the effect of prospective memory on identifying target objects, Figure 4; which has been omitted in previous research. The optimal conditions in which to present these images to human eyes are not well understood—exploring prospective memory's role partially address this knowledge gap.

PHASE TWO: PILOT STUDY

Sweeney & Lampinen (2012) reported that when presented multiple images of a missing child on a poster, participants exhibited a higher rate of correct and incorrect identifications. This leads credence to the notion that prospective may be effected (positively or negatively) by previously exposure of future target objects. Previous exposure to prospective memory targets (for a lexical decision task) has been shown to increase reaction time performance (Dismukes, 2010; Goschke & Kuhl, 1993; Marsh, Hicks, & Bryan, 1999). However, literature has omitted prospective memory-based errors in object identification tasks. The optimal conditions in which to present these images to human eyes are not well understood—this study aims to partially address this knowledge gap—while investigating the effects of temporal factors on the accuracy and precision of prospective remembering. Given the research above, the following null hypothesis was generated: there will be no difference for task accuracy by previously exposing individuals to similar targets.

Methodology

The objective of this research is to determine if prospective memory-based errors are manifested in a target search task by implicitly presenting targets using aerial video footage on days preceding the experiment. It is hypothesized that observers' accuracy for identifying targets will increase for a target search task after being previously exposed to similar targets.

Because practical and security constraints limit the control and use of events in field studies, simulated analyst environments provide a powerful tool for developing and testing theories of context-conditioned human activity, such as theories like distributed cognition. Simulated environments make it possible to investigate more specific task resumption points.

Participants

Nineteen subjects, whose ages ranged from 20 – 39 years, participated in the study. The 12 male and 7 female subjects were graduate and undergraduate engineering students at Wright State University. All participants had normal or corrected to normal vision. No special skills or background were required for participation in the study, however all subjects verified having experience with computers.

Design

The experiment was a 2x2 mixed-factorial design consisting of two independent variables: previous exposure of target cues (between subjects) and target category (within subjects) with two levels each: previously exposed to targets and not previously exposed to targets; manmade and non-manmade/naturalistic targets. There is one response or dependent variable, accuracy, defined as the number of target hits divided by the number of target events for a summary of responses (Scullin, Bugg, & McDaniel, 2012).

Subjective workload Measure

The NASA Task Load Index (TLX) was utilized to obtain and measure workload ratings (Hart & Staveland, 1988). The NASA-TLX consists of six subscales to assess the contributions of task, behavior, and subject related experiences with six dimensions of workload: effort, frustration, performance, mental demand, physical demand, and temporal demand. The NASA-TLX questionnaire was administered after both search trials.

TESTING FACILITY, ENVIRONMENT, AND APPARATUS

Testing was performed in the Human Performance and Cognition Laboratory in Russ Engineering Center at Wright State University. The lighting, subject-relative head height, ambient noise level, and ambient temperature were maintained constant for all participants. The aerial footage was presented on a liquid crystal computer display with a resolution of 1280x1024 pixels on a table approximately 24-36" from the subjects' seated position.

PROCEDURE

One half of test participants were randomly selected for previous exposure of target objects. The participants were presented a consent form and asked to observe a single 5-minute segment of aerial video three days prior to the experiment. Upon completion, the participants were thanked for their time and released. The 5-minute video contained similar—but not identical—manmade and naturalistic targets that would be tested later.

The videos were obtained from UAvisions, a Dayton, OH unmanned aerial research powerhouse and contained footage from the downtown Dayton region; see sample image in Figure 5. Participants were tested in a randomized sequence and presented a consent form before testing (if not previously). A pre-test questionnaire was administered to obtain fundamental demographic information. A single piece of 8.5x11” paper was provided for each target that contained images of the target objects for referencing during testing. The manmade target was a relatively large blue storage container. The naturalistic target was a burning bush (Euonymus alatus). Participants were asked to observe two 4-minute segments of aerial video and instructed to indicate if they see any target objects by pressing any key on the keyboard. After each of the two videos, participants rated their confidence on the preceding search task. Upon completion of the two search tasks, a NASA-TLX survey and post-test questionnaire (with a 7 point likert scale) were administered and participants were thanked for their time and released.

Figure 5: Sample screen shot of aerial video stimuli

RESULTS

This experiment was conducted to determine if prospective memory-based errors are manifested in objected identification tasks (omitted in previous research) by implicitly presenting targets in full motion imagery on the days preceding the experiment (referred to as previously exposed or pre-exposed) compared to a control group. The prospective memory task was to identify targets from one of two-target categories, manmade and naturalistic objects.

Data Collection. A computer application—Tobii Studio—was utilized to collect participant's keystrokes. The software exports the participant data in milliseconds. Excel was then utilized to calculate reaction times, false positives, and hit rates for all participants under each video condition. Unless otherwise stated, all statistical testing was performed at the alpha = 0.05 level.

Hit Rate

An ANOVA was performed with input factors of previous exposure to aerial footage and target object category with the percentage of correctly identified targets as the response. There was not a significant effect of a main factor or interaction. Similarly, there was not a main effect of target type $F(1,17) = 0.1069$, $p = 0.7478$. There was not a significant effect for previous exposure $F(1,18) = 1.6983$, $p = 0.2088$. There was not a significant effect of the interaction of target type and previously exposed type $F(1,17) = 0.7695$, $p = 0.3930$. This may be due to the saliency of the selected target objects, number of target objects, and/or the lack of an additional focal task.

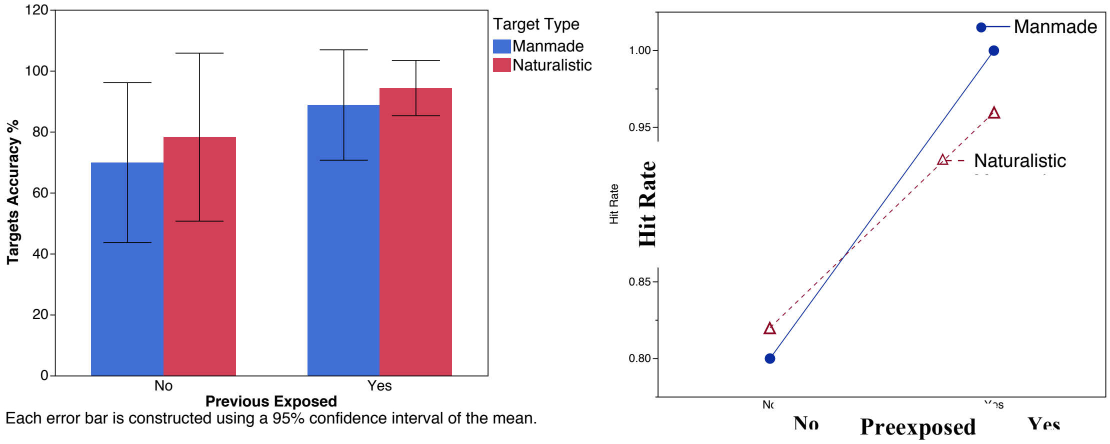


Figure 6. A) (left) Mean target accuracy percentage of target categories (manmade and naturalistic) by previous exposure, B) (right) hit rates of target categories (manmade and naturalistic) by previous exposure

Response Time

An ANOVA was performed with input factors of previous exposure to aerial footage and target object category with average response time (per subject for both video conditions) as the response. There was not a significant effect of a main factor or interaction. Similarly, there was not a main effect of target type $F(1,17) = 2.0419$, $p = 0.1704$. There was not a significant effect for previous exposure $F(1,17) = 2.3891$, $p =$ 0.0.1298. There was not a significant effect of the interaction of target type and previously exposed type $F(1,17) = 0.2463$, $p = 0.6258$.

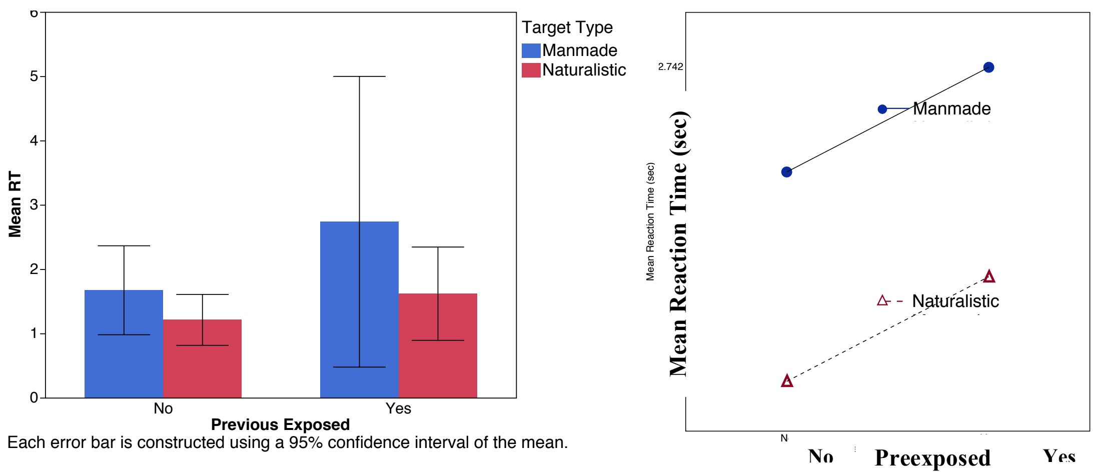


Figure 7. A) (left) Mean reaction time (secs) of target categories (manmade and naturalistic) by pre-exposure. B) (right) Mean reaction time (secs) of target categories (manmade and naturalistic) by pre-exposure

False Positive

An ANOVA was performed with input factors of previous exposure to aerial footage and target object category with false positive rate (per subject for both videos) as the response. There was not a significant effect of a main factor or interaction. Similarly, there was not a main effect of target type $F(1,18) = 3.3437$, $p = 0.0839$. There was not a significant effect for previous exposure $F(1,18) = 0.2579$, $p = 0.6176$. There was not a significant effect of the interaction of target type and previously exposed type $F(1,18) = 0.1300$, $p = 0.7226$.

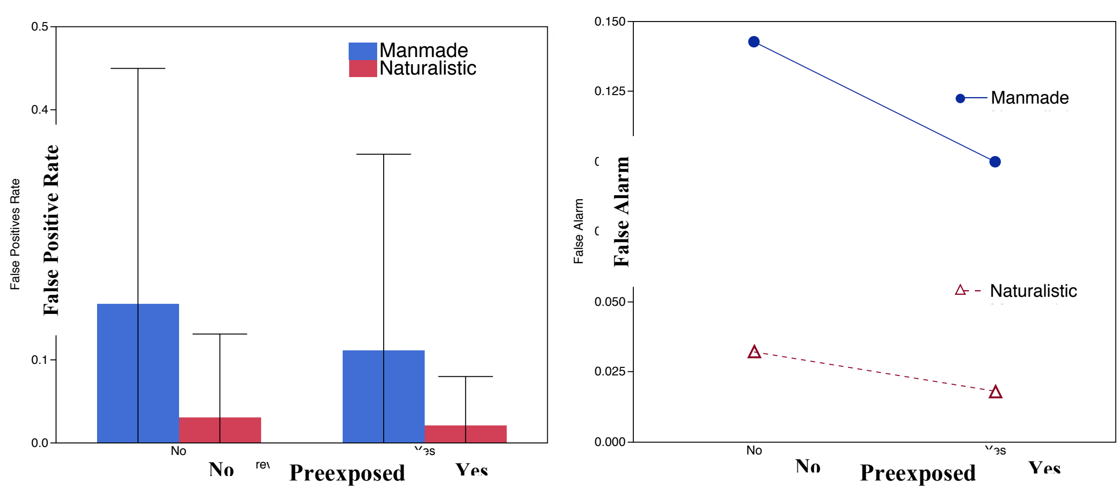


Figure 8. A) (left) False positive rate of target categories (manmade and naturalistic) by pre-exposure, B) (right) False positive rate of target categories (manmade and naturalistic) by pre-exposure

Accuracy

Accuracy was defined as the number of target hits divided by the number of target events, see Table 7 for a summary of responses (Scullin et al., 2012). Prospective memory accuracy for both the naturalistic and manmade target objects was 0.89, which is comparable with previous studies composed of salient cues (accuracy 0.80 - 0.90) (Harrison & Einstein, 2010; Smith et al., 2007), with non-focal and non-salient cues, accuracy between 0.50 and 0.60 is typical(Marsh et al., 2003; Meiser & Schult, 2008; Rummel, 2010). Figure 6 depicts higher hit percentage for pre-exposed group for both target object categories which agrees with recent research (Guynn & McDaniel, 2007). The hit percentage can be complemented by the pre-exposed group's high average reaction times, Figure 7. Pre-exposed also exhibited a lower false positive rate for both target categories, Figure 8. A "standard approach in cognitive psychology is to analyze confidence data by plotting the receiver operating characteristic curves (ROC) for each condition" (Sweeney & Lampinen, 2012, p.239). ROC curves reveal the accuracy of individuals for different conditions; i.e., did participants' accuracy truly improve, or simply increase by pure chance. A ROC curve was formulated, Figure 9. ROC curve for both previously exposed and not previously exposed groups with a reference line of pure chance. Perfect target classification points would have a false positive rate of zero and a true positive rate of one and lie near the top left of the graph. Both the pre-exposed and control groups exhibited exceptional target classification with evidence of a more conservative response bias for both conditions.

Table 7 Proportion of responses to prospective memory cues, target accuracy mean(SD)

	Manmade		Naturalistic	
Previously Exposed	Yes	No	Yes	No
Hits	1.0	0.80	0.96	0.82
Misses	0.00	0.20	0.04	0.18
False Alarms	0.11	0.16	0.02	0.03
Target Accuracy	88(23)	70(36)	94(11)	78(38)

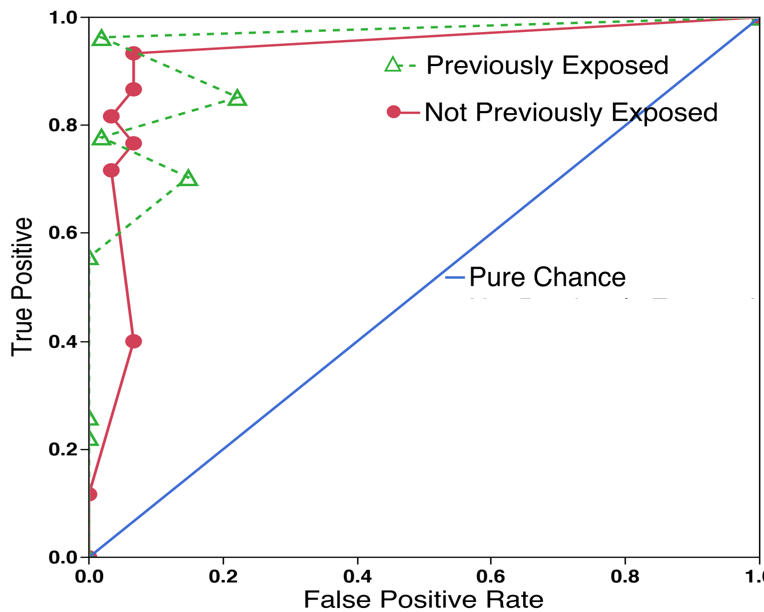


Figure 9. ROC curve for both previously exposed and not previously exposed groups with a reference line of pure chance.

NASA-TLX

The NASA Task Load Index (TLX) was utilized to obtain and measure workload ratings (Hart & Staveland, 1988). The NASA-TLX questionnaire was administered after both visual search tasks and results were aggregated, see Figure 10. The pre-exposed group reported an overall higher level of mental workload including the following categories: temporal demand, mental demand, and effort. A post-experiment questionnaire was administered with a scale of 1 (strongly disagree) to 7 (strongly agree) for each question and notable results are included in Figure 7. The pre-exposed group reported a higher median score for the following phrases: “the task became easier over the course of the session, the search task was intuitive, and I completed the search task quickly.”

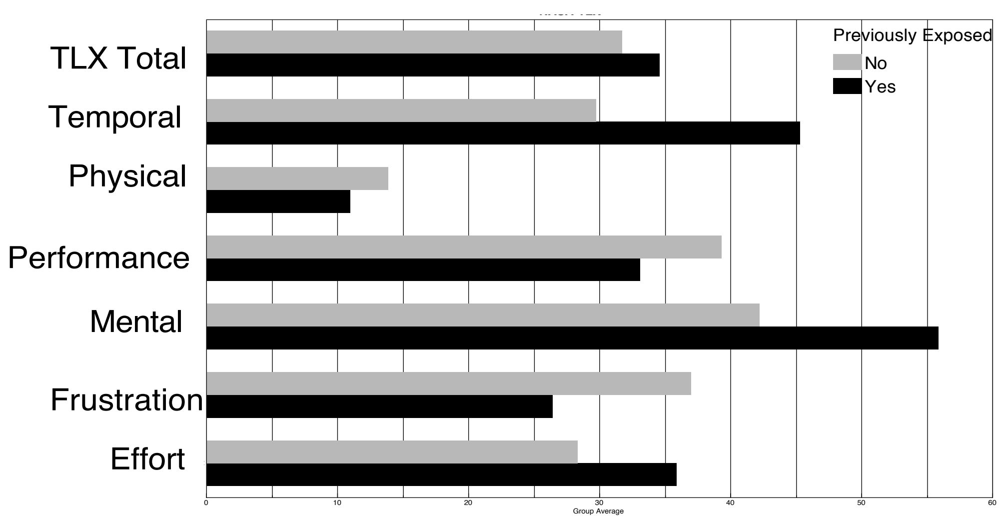


Figure 10 NASA-TLX mean results by previous exposed and not previously exposed groups.

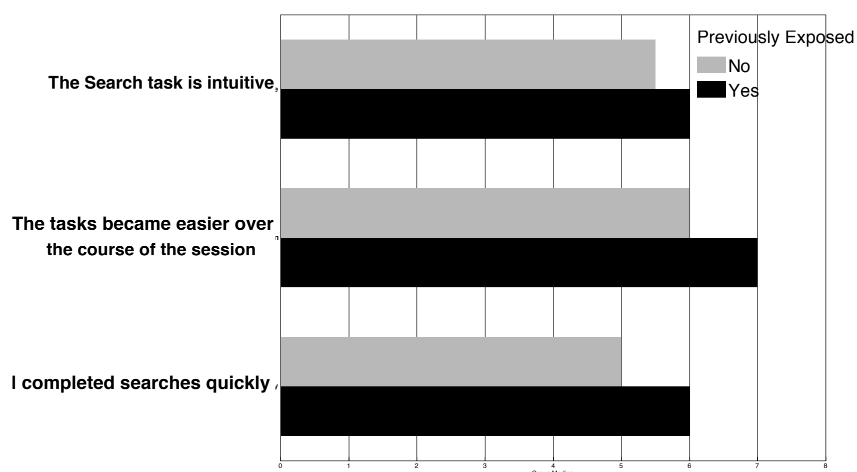


Figure 11 Post-test questionnaire median scores with a 1 (strongly disagree) to 7 (strongly agree) scale by pre-exposure.

DISCUSSION

The purpose of this research was to explore the possibility that prospective memory-based errors are manifested in a target search task (omitted in previous research) by implicitly presenting targets using aerial video footage on days preceding the experiment.

Although statistical significance was not found, there are many notable takeaways that should not be marginalized. Prospective memory accuracy for both the naturalistic and manmade target agrees with previous studies regarding salient cues (Harrison & Einstein, 2010; Smith, Hunt, McVay, & McConnell, 2007). The previously exposed group, as a whole, had a higher hit rate for both target categories than the not previously exposed group, Figure 6. This high rate of identifying targets seems to come at a cost: overall higher mean reaction times for both target categories, Figure 3. The taxing of prospective memory resources may consume additional time, but apparently did so while overall preserving—and effectively lowering—false positive rates, Figure 4.

Previous laboratory paradigms for studying prospective memory retrievals share a main commonality in utilizing lexical tasks to cue prospective memory intentions (Einstein & McDaniel, 2005; Marsh & Hicks, 1998; Marsh et al., 2005; Shelton et al., 2013; Smith, 2003). Although the present study used aerial video footage to investigate prospective memory-based errors that seemed more advantageous (due to the naturalistic and realistic qualities), there are caveats to its usage.

The specific aerial video footage selected for the experiment repeats or circles over an area in a semi-elliptical path. In choosing stationary targets, participants were more likely to tag specific locations and anticipate its arrival. Each pass may have a cumulative effect (effectively allowing rehearsals), this is also referred to as the inhibition of return (Klein, 1988); within trials in a visual search task, the role of memory for locations has been shown (Kristjánsson, 2000). It has been shows that “memory guides attention during visual search (Gilchrist & Harvey, 2000; Hoffman & Reiss, 2001; Kristjánsson, 2000; McCarley, Wang, Kramer, Irwin, & Peterson, 2003) and can prevent reexaminations for search sets of at least 12 items (Peterson, Kramer, Wang, Irwin, & McCarley, 2001)” as cited in (Peterson, Beck, & Vomela, 2007, p. 123). This also agrees with the notion that prospective memory targets act as reminders and may encourage subsequent monitoring for future targets (Meier & Rey-Mermet, 2012) which has been demonstrated by Scullin, McDaniel, and Einstein (2010). Due to this repetitive nature and pure serendipity, relatively large accuracies were observed. This also helps explains the points near the top left in the ROC curve.

Although statistical significance was not found, the results generally agree with literature: prior target exposure increased the overall likelihood of prospective memory success as previously shown (Hannon & Daneman, 2007; Logie & Maylor, 2009) and correct target identifications were significantly greater than the false positive identifications (McAllister et al., 2011).

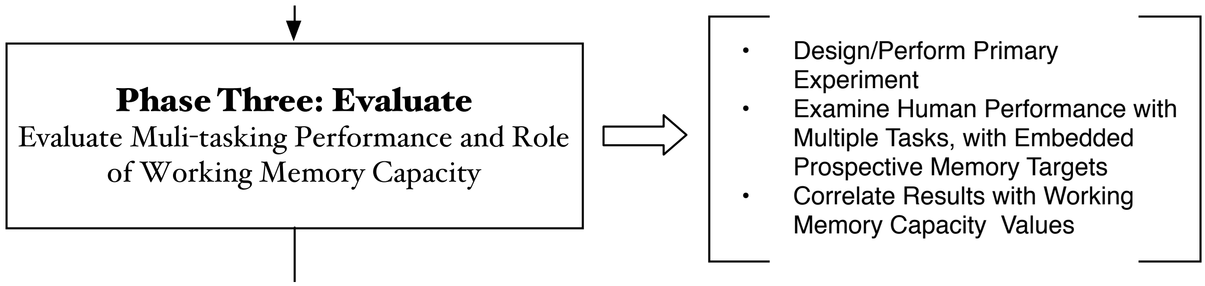


Figure 12 Research phase three details

SUMMARY

The previous study showed the depth with which prospective memory is interwoven with visual search tasks. Previous research has found that intelligence analysts face many challenges during a mission (Paul, 2013). Due to recent advances in data acquisition and storage technologies, intelligence environments regularly require multi-tasking ability and are plagued with interruptions. The next few sections describe relevant multitasking with embedded prospective memory demands with respect to the research framework, Figure 12. Section 5 outlines the methodology for the experiment for decoupling a subset factors inherent in the complex analyst-working environment followed by results and discussion.

CONCURRENT TASK INTERRUPTION

Consider the example, automobile driving involves situations that incorporate aspects studied in prospective memory. To successfully maneuver a vehicle to a destination, one must juggle out-side-the-window visual-motor tasks—steering, interpreting road signs, reacting to movement of other cars and pedestrians—with tasks that move attention inside the vehicle: checking instrument displays, tuning the radio, adjusting climate controls, talking with a passenger, or talking on a cell phone. Some tasks, such as accelerating and reacting to other cars, are closely related and practiced together consistently enough to fuse into a single task, but other tasks are more vulnerable to prospective memory failures. Have you ever become so absorbed in a verbal conversation driving that you fail to take a planned exit from a highway?

This absorption or engagement in an ongoing task, termed cognitive tunneling, is amplified when the current ongoing task makes high demands on executive functions (Wickens & McCarley, 2007), p. 153). Note that this situation differs from typical prospective memory laboratory paradigms in that the ongoing task becomes synonymous with a secondary prospective task; i.e. harder to differentiate between the two tasks. For the driving example, the individual fails to fully execute attention switching in a timely fashion—failure of prospective remembering. The frequency with which attention must vacillate between tasks is extremely task specific and is not well defined. The limited extent that this attention switching has been studied has discovered that skilled operators seem able to perform well most of the time, but performance can deteriorate during high-workload situations (Dismukes, 2010; Loukopoulos et al., 2009; Wickens & McCarley, 2007, chapter 9). Marsh and Hicks (1998) found that when participants had fewer cognitive ongoing tasks to complete, there were fewer prospective memory failures (Sarapata, 2001). However, this absorption has not been studied in the context of prospective memory, primarily because of the difficultly of creating objective measures (Dismukes, 2010).

Brixey et al. (2007) defines interruptions as an “external intrusion of a secondary, unplanned, and unexpected task, which leads to a discontinuity in task performance” (Grundgeiger, Liu, Sanderson, Jenkins, & Leane, 2008, p. 1). It is well known and understood that work in today’s world is plagued with unavoidable interruptions, which cause stress and disrupt performance (Lohr, 2007; Monk, Boehm-Davis, & Trafton, 2004; Trafton & Monk, 2007) as cited in (Dismukes, 2010). For example, Dismukes, Berman, and Loukopoulos (2007) outline several airline catastrophes that have occurred when pilots were interrupted while preparing an aircraft for takeoff (Dismukes, 2012). Failures to carry out intentions—due to interruptions and multitasking for example—also exist in health care: Westbrook, Woods, Rob, Dunsmuir, and Day (2010) showed that interruptions increased the chance of medication administration errors (Grundgeiger et al., 2010). This study also found that the nurses were cued by the environment to resume tasks which agrees with Kvavilashvili and Fisher (2007) and Grundgeiger et al. (2008) who found individuals think more about prospective memory tasks because of external cuing rather than conscious remembering (Grundgeiger et al., 2010). A few distinguishing phases of an interruption and resumption task have been incorporated with prospective memory processes, Figure 13. Grundgeiger et al. (2010) also found that when given the choice, nurses elected to finish a primary task before being interrupted (68% of all distractions) and there was no prospective memory demand—or resumption lag—and the length of the interruption had a significant effect in the study as well as context changes. For example, a doctor may be performing an examination on a patient (primary task). A medical assistant knocks at the door (*distraction/alert*) and the doctor eventually pauses the examination and speaks to the assistant. The time between the first knock and the start of the conversation is the *interruption lag*. The time spent with the assistant is the *interruption length*. After tending to the interruption, the doctor needs to resume the examination task; this time period is referred to as the *resumption lag*.

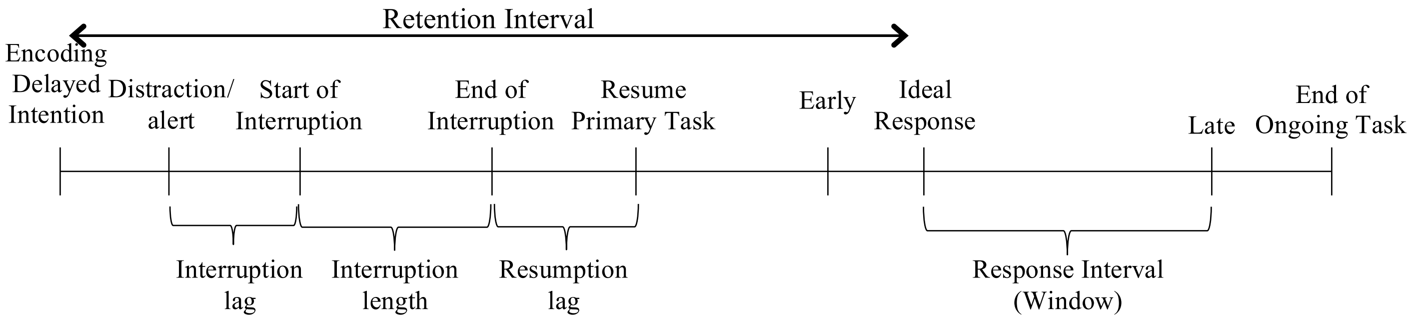


Figure 13: Prospective memory, interruption, and resumption processes, adapted from (Grundgeiger et al., 2010; Sarapata, 2001; Trafton, Altmann, Brock, & Mintz, 2003)

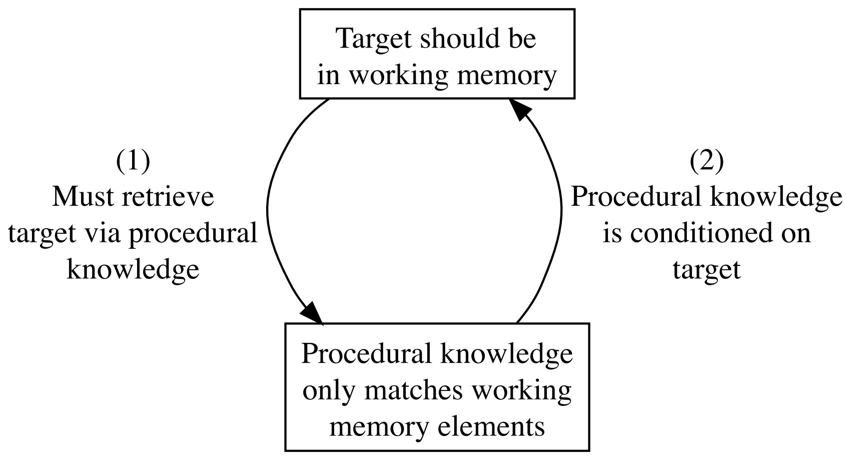


Figure 14: Knowledge dependency cycle (Li & Laird, 2013), reprinted with permission

The knowledge dependency cycle, **Figure 14**, of the prospective memory retrieval problem (Li & Laird, 2013) in which the authors opine critical features of prospective memory tasks and must be embedded for any complete model of prospective memory. This study aims to investigate this paradigm. If this were the case, one would assume that as the number of concurrent prospective memory tasks increases, upon interruption, the interruption and resumption lags would increase proportionally. This supports the notion that prospective memory tasks are encoded as *separate* memory items. Alternatively, the interruption and resumption lags may not scale proportionally, which provides evidence that delayed intentions storage and/or retrieval process involves more complex mechanisms than the current dependency cycle **Figure 14**. This dependency cycle allow us to explain the classes of human strategies (monitoring strategies/spontaneous retrieval/anomaly trigger) and mapping of them in cognitive architectures, Figure 15.

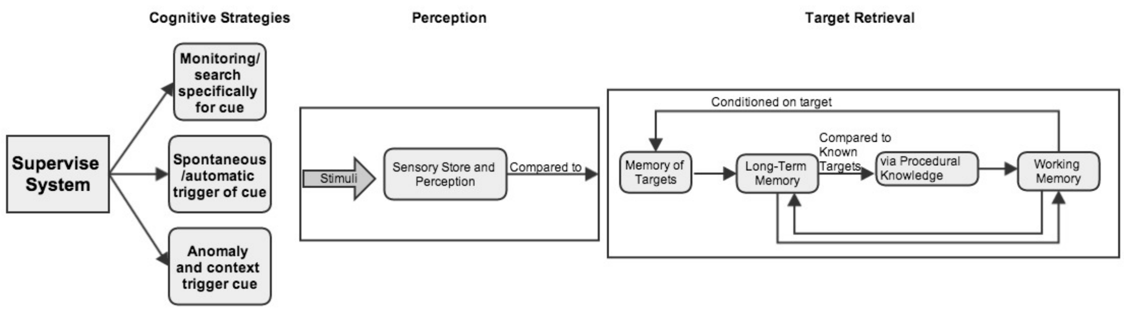


Figure 15: Cognitive search strategies with target retrieval process and Li and Laird (2013)'s knowledge dependency cycle integrated, which shares similarities with the three-level model of SA in (Endsley, 1995)

There are a number of variable that can complicate this simple timeline of the interruption/resumption process. For instance, D. McFarlane (2002) states that in some contexts, the operator may or may not have the ability to control the length of the interruption lag (Trafton et al., 2003). Given the opportunity, people show a tendency to finish a primary task (Grundgeiger et al., 2010) or reach a logical stopping point (Edward Cutrell, Mary Czerwinski, & Eric Horvitz, 2001; Trafton et al., 2003; Zijlstra, Roe, Leonora, & Krediet, 1999). The distraction (which may be visual, auditory, etc.) must be perceived appropriately as it may provide information about urgency (Stanton & Edworthy, 1999) especially in a dynamic, complex system where failures can cascade quickly (e.g. Three Mile Island; (Rubinstein, 1979) (Trafton et al., 2003). Speier, Valacich, and Vessey (1999) report that the dissimilarity of the primary and interruption task content (or missing context (Grundgeiger et al., 2010)) and frequency of interruptions have been found to exacerbate performance.

Prospective memory tasks are intrinsically created by interruptions—after the interruption ends, one must remember to resume the interrupted task (Brandimonte, Einstein, & McDaniel, 1996; A.-L. Cohen, Jaudas, & Gollwitzer, 2008; Dismukes, 2010; Dismukes & Nowinski, 2006; Dodhia & Dismukes, 2009; Ratwani, McCurry, & Trafton, 2010; Trafton et al., 2003)). Once interrupted, a delay (or retention interval, Figure 13) exists between the time of intention creation until the response window and there is no external prompt to execute the intention. Although interruptions usually exacerbate performance of the ongoing task (Edward Cutrell, Mary Czerwinski, & Eric Horvitz, 2001; Gillie & Broadbent, 1989; D. C. McFarlane, 2002; Zijlstra et al., 1999)—especially on complex tasks (Speier, Valacich, & Vessey, 1997; Speier et al., 1999)—counter intuitively, they can also be beneficial by combating boredom, increasing arousal, and assist performance (Speier et al., 1997; Speier et al., 1999; Trafton et al., 2003). Once interrupted, individuals are susceptible to forgetting to resume the interrupted task (Dismukes & Nowinski, 2006; Dismukes, Young, & Sumwalt, 1998; Dodhia & Dismukes, 2009) upon resuming the interrupted task, error rates may increase significantly (Altmann, Trafton, & Hambrick, 2013; Coiera & Tombs, 1998; Dodhia & Dismukes, 2009; Monk et al., 2004; Speier et al., 1999; Trafton et al., 2003) and in some contexts, be catastrophic (Ratwani, McCurry, & Trafton, 2008). Surprisingly, relatively short interruptions (averaging 4.4 seconds) have been shown to triple sequence errors rates on post-interruption tasks compared to a baseline (Altmann et al., 2013). Similarly, situation awareness can be lost when tasking switching/multitasking (Ratwani et al., 2010). Research has shown that multi-tasking while driving can increase the rate of accidents (Gugerty, 1997, 2011; Gugerty, Rakauskas, & Brooks, 2004; Horrey, Wickens, & Consalus, 2006). In real-world situations, the end of an interruption is often followed immediately by other task demands (Dodhia & Dismukes, 2009; Holbrook & Dismukes, 2005; Loukopoulos, Dismukes, & Barshi, 2003). Previous literature has investigated interruptions as a cost of ongoing performance (Grundgeiger et al., 2010) rather than resumption of the interrupted tasks. Interruptions have been shown to cause increasing error rates (Speier et al., 1999), slower performance (B. P. Bailey, Konstan, & Carlis, 2001; Czerwinski, Cutrell, & Horvitz, 2000), impaired memory for the status of the interrupted task (Edwards & Gronlund, 1998), increase frustration and perceived task difficult (Adamczyk & Bailey, 2004; Dodhia & Dismukes, 2009). Grundgeiger et al. (2010) reported a change of context and length of interruption significantly effecting resumption times. The study was performed with nurses and the context change of the interruption task may have introduced alternative task demands causing longer resumption times (Altmann & Trafton, 2002; Dismukes & Nowinski, 2006).

Most experimental studies of interruptions (similar to task-switching paradigms) focus on the delay in resuming the interrupted task (Monk et al., 2004; Trafton et al., 2003). Dodhia and Dismukes (2009) outlines three aspects of prospective memory tasks—caused by interruptions—that have not been well captured in laboratory studies: (1) abrupt interruptions may prevent adequate preparation to resume the interrupted task; (2) upon resuming the interrupted task, additional new task demands prevent the individual from remembering their position when interrupted; (3) the end of an interruption task may not be clearly defined, because it is defined conceptually. Dismukes

(2012) provides four examples of prospective forgetting in aviation situations not well captured in laboratory studies: (1) interruptions, (2) multitasking, (3) absence of a cue that normally prompts users of habitual tasks, and (4) habit capture. Prospective remembering is improved during context switching due to refreshing procedural knowledge that directs individuals to search long-term memory for unfulfilled intentions (Li & Laird, 2013). Thus, procedural knowledge that refreshes intentions periodically could postpone the forgetting of a target cue. Grundgeiger et al. (2010) states that further research is needed on factors that influence decisions—to finish a primary task or handle a distraction—such as the properties of the ongoing or interruption task, or the cognitive demands of prospective memory tasks (Gray & Fu, 2004). This study aims to address a majority of these concerns.

The goal of this approach is to understand the components that make interruptions intrusive and mitigate or avoid the abruptness while preserving the benefits of interruptions (Grundgeiger & Sanderson, 2009; Grundgeiger et al., 2010). Dodhia and Dismukes (2009) state that it is important to study this type of situation given the real-world consequences.

WORKING MEMORY CAPACITY

Working memory is broadly defined as a general-purpose system responsible for actively managing task-relevant information while facing internal or external distractions (Baddeley, 2007; Ball, Knight, Dewitt, & Brewer, 2013; Engle & Kane, 2003; Kane, Bleckley, Conway, & Engle, 2001). In actively managing task-relevant information, one needs to direct attention in a flexible manner (Conway & Kane, 2001; Norman & Shallice, 1986) and Unsworth and Engle (2007b) model of working memory includes the controlled retrieval of displaced information (Ball et al., 2013). Thus, a high working memory capacity indicates that one is more able to retrieve information after being distracted (Brewer & Unsworth, 2012; Unsworth & Brewer, 2009; Unsworth & Engle, 2007b) and is important constituent to prospective remembering (Ball et al., 2013; Brewer, Knight, Marsh, & Unsworth, 2010; Unsworth, Brewer, & Spillers, 2012). Recently, Ball et al. (2013) found that prospective memory performance was better for high working memory capacity participants than for lower and the high group performance increased with longer retention interval delay. Hambrick, Oswald, Darowski, Rench, and Brou (2010) and (Konig, Buhner, & Murling, 2005) reported working memory capacity a strong predictor of multitasking for a synthetic work scenario.

In a study to examine working memory deficits in individuals with schizophrenia, participants performed a working memory test. This test flashed colored squares on a computer screen and subjects were to recall the color of a randomly selected box following a delay of a few seconds. Subjects also completed a series of intelligence tests—known as the Measurement and Treatment Research to Improve Cognition in Schizophrenia (MATRICS). Consistent with prior research (Colom, Rebollo, Abad, & Shih, 2006; Jarrold & Towse, 2006; Unsworth & Engle, 2007a), Gold et al. (2010) and H. Bailey, Dunlosky, and Kane (2008) indicate that the widespread interest in working memory tests is driven by their success in predicting other higher-order cognitive abilities, such as reasoning, comprehension, and memory (e.g., Ackerman, Beier, & Boyle, 2005; Kane, Hambrick, & Conway, 2005). More specifically, research has indicated working memory processes as being essential to fulfill delayed intentions (Einstein, McDaniel, Williford, Pagan, & Dismukes, 2003; Kelly, Hertzog, Hayes, & Smith, 2013; Kliegel & Jager, 2006; McDaniel, Einstein, Stout, & Morgan, 2003) (prospective memory tasks) (Ball et al., 2013). Individuals who had a high working memory may be better at keeping relevant information in memory and irrelevant information out (i.e. ignoring distractors) (Minkel, 2010). To investigate this relationship, participants working memory capacity scores will be correlated with prospective memory task performance.

To gauge individuals' working memory capacity, the operation span task—an established method "gold standard" to measure working memory (H. Bailey et al., 2008; Conway, Cowan, Bunting, Therriault, & Minkoff, 2002; Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Conway, Miura, & Colflesh, 2007; Mogle, Lovett, Stawski, & Sliwinski, 2008; Shelton, Elliott, Matthews, Hill, & Gouvier, 2010; Wilhelm, Hildebrandt, & Oberauer, 2013). Specifically, the automatic operating span procedure, Figure 16, was utilized as it has advantages over previous operating span tasks in that it collects two *separate* reaction measures. One for the processing of the operations as well as reaction time measures for recall (Unsworth, Heitz, Schrock, & Engle, 2005). The procedure to obtain a participant's *Aospan* score requires participants to solve/verify a simple math problem while trying to remember a set of unrelated letters. For each trial, they read aloud and solve the math problem and then read aloud the letter. Immediately after the participants read the letter, the next math operation is presented. The operation letters are presented in sets of 2 to 7 items. Following each complete set the participant recalls the letters in the order presented. For example, a three-item set might be:

Is (5/5) – 1 = 1?   A

Is (8/2) + 2 = 7?   L

Is (4*5) - 7 = 9?   Q ???

The question marks cue participants to click the letters in the correct order. Two trials of each set size are presented, with the order of set size varying randomly to inhibit participants from predicting the number of items. A participant's *Aospan* score is calculated by adding the number of items in perfectly recalled trials. For example, a participant who correctly recalled two sets of three-item trials and one set of two-item trials would have a score of eight. An 85% accuracy criterion on the math operations is required to ensure that participants are not trading off solving the operations and remembering the letters. Along with the *Aospan* score, the software records problem, answer, and recall mean reaction times that have been shown to correlate with one another and will be included and explored in this experiment (Unsworth et al., 2005).

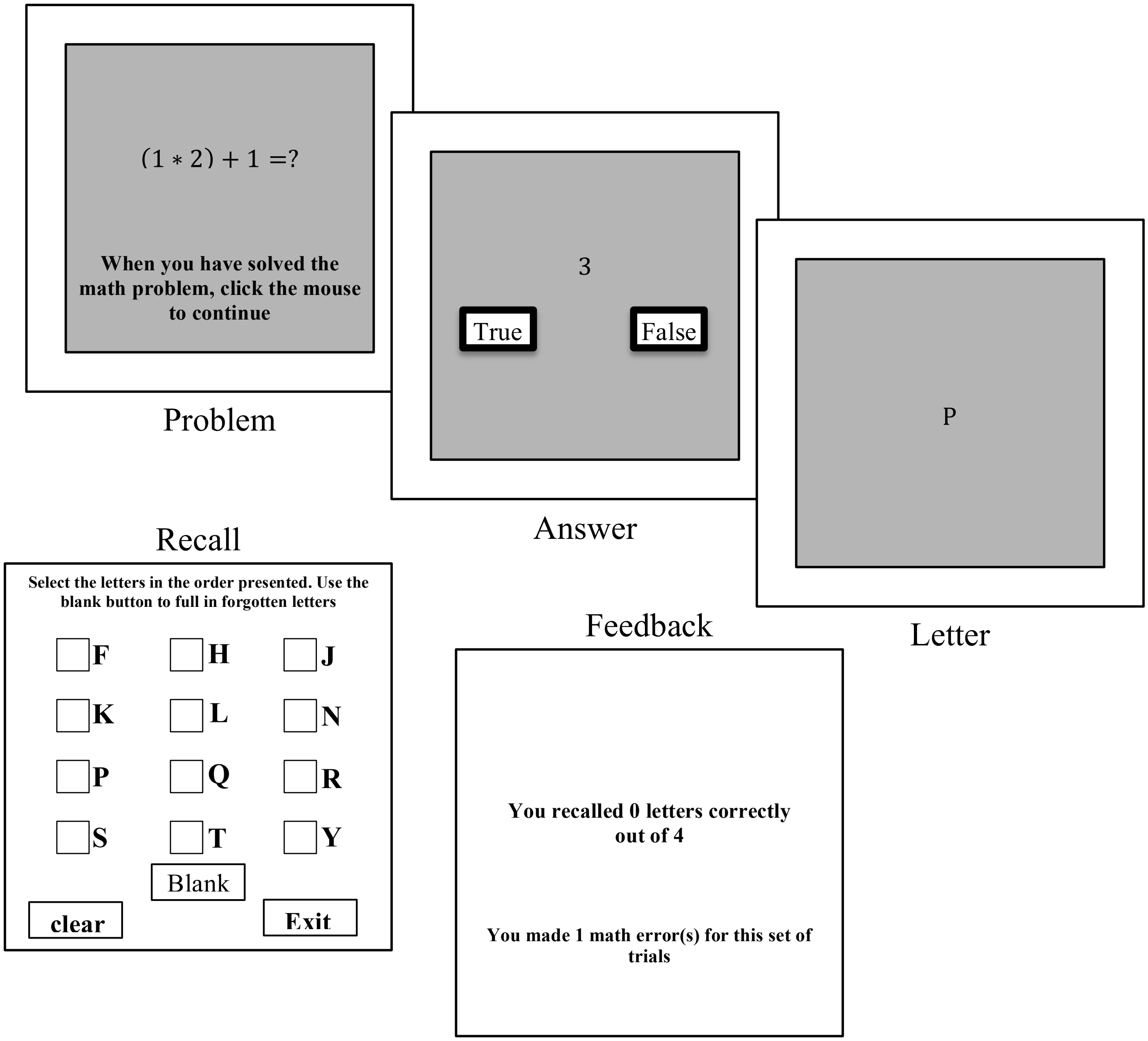


Figure 16: Illustration of the automated operation span task. In the task, a math operation is presented. After it is solved, participants click the mouse and a digit is presented, which is judged to be either correct or incorrect. This is followed by a letter for 800 msec. For recall, the correct letters from the current set are selected in the correct order. After recall, feedback is presented for 2 seconds (Unsworth et al., 2005) reprinted with permission

Springer and the original publisher, volume 37, 2005, pages 498-505, An automated version of the operation span task, Unsworth, Nash, Heitz, Richard P., Schrock, Josef C., Engle, Randall W., figure 1, original copyright notice) is given to the publication in which the material was originally published, by adding; with kind permission from Springer Science and Business Media.

III. RESEARCH COMPONENTS

The research questions and experimental outline will narrow the scope and focus of the study.

RESEARCH QUESTIONS

AIMS AND SCOPE

Based on the review of literature, many factors exist which affect human multitasking performance with delayed intentions and mental workload. The ability to predict human performance with respect to intelligence analysts would have significant applications in the military domain. In making contact with literature, this study investigates interruption effects and role in executing delayed intentions. Although multitasking has been studied greatly, considerably less research has been performed in real-world situations; and typically do not investigate delayed intentions (Dismukes & Nowinski, 2006). However, there is a need to examine how prospective tasks interact or complete with ongoing tasks (Dismukes, 2012; Dismukes & Nowinski, 2006). This exploratory study aims to address four primary questions:

1. Does working memory capacity correlate with prospective memory performance?
2. Does prospective memory performance change significantly when the number of concurrent targets changes from 2 to 3?
3. Does prospective memory task performance significantly vary by target encoding: single encoding of large amount of information versus smaller, *separate*d bits within the different task combinations?

4. Does the interaction of number of targets and target encoding significantly affect prospective memory performance, including interruption and resumption lag?

Subjective mental workload will be assessed to compare the effect of number of tasks on mental workload. Additionally, eye fixations will be evaluated as they have been shown to be indicators of cognitive processing (Just & Carpenter, 1976; Rayner, 1998; Rayner & Morris, 1990). The results will help to improve information presentation, interface design, and analyst tasking.

The goal of this experiment is to manipulate the number of targets and target encoding method, introduce an interruption task and to measure the cost in terms of the interruption and resumption lags and primary task performance differences. The primary task will consist of counting task to identify how many groups of people are walking together. The second task will interrupt the primary by means of a picture in picture; sample screen shot Figure 17. A brief lag (15 seconds) will be provided to facilitate resumption (i.e. lay cognitive groundwork for returning to primary task) (Dismukes, 2010; Dodhia & Dismukes, 2009; Trafton et al., 2003). There have been other studies that have investigated length of interruptions (Grundgeiger et al., 2010), however we wish to provide a more fine grained analysis of interruption lengths. Eye tracking will be utilized to observe fixations and calculate resumption times. Fixations are well correlated with attention (Hayhoe & Ballard, 2005; Just & Carpenter, 1976) and humans rarely show task irrelevant fixations in everyday tasks (Findlay & Gilchrist, 2003; Land, Mennie, & Rusted, 1999). A major challenge for this study was to design an experiment that would capture critical aspects of real-world intelligence analyst-related interruptions and allow us to systematically explore the potential sources of variability described above.

Given the research questions above, the following null hypotheses were generated:

1. Prospective memory performance will not vary by working memory capacity
2. There is no difference in prospective memory performance for 2 versus 3 prospective memory targets
3. There is no difference in prospective memory performance for separate versus at-once target encoding format
4. There is no difference in prospective memory performance by the interaction of number of targets and target encoding format

IV. Methodology

PARTICIPANTS

Twenty (11 males, 9 females) participants ages 20 to 34 (M=25, SD=4.3) took part in the present study. All participants were volunteers from Wright State University who signed consent forms approved by the Wright State University Institutional Review Board. Participants all had computer experience and were screened to ensure they were not color blind. Each participant was given an introduction to the experimental tasks followed by a brief practice session before the experimental trials began.

EQUIPMENT

All motion imagery simulations were conducted on a Tobii T120 17 inch LCD monitor with an integrated off body eye tracking system that was calibrated for each participants' gaze. The working memory capacity test was performed on a Dell Precision T5500 desktop computer with a 2.13 GHz, dual-core Intel Xenon processor running the Windows 7 (x64) operating system, and displayed on a 17-inch Tobii T120 monitor and eye tracking system. Subjects responded using a Logitech mouse and a Dell keyboard.

PROCEDURE

Following a brief practice session, subjects were asked to complete a working memory capacity test and four task combination trials. All trials lasted three minutes. Each trial consisted of an ongoing counting task and prospective memory targets. The targets were embedded in the counting task to induce variability inherent in real world settings. Previous research shows that more than three prospective memory targets come at a cost of ongoing task performance (A.-L. Cohen et al., 2008) while three-targets agrees with pervious prospective memory research (e.g., Dismukes, 2010; Einstein et al., 2005; Guynn et al., 1998). Thus with two and three number of targets, we expect that the trials will not be so easy that operators may respond to all stimuli, yet not so hard that the processing demands are beyond the operators' capacities. Our interest is to explore the effect of number of prospective memory targets while preserving or unaltering primary task performance. Multitasking was induced with a secondary task that interrupted the primary. The secondary task was a *separate* counting task for four differing videos (one for each trial) that intervened the primary task in the form of a picture in a picture, see Figure 17. Participants were informed of each trials' requirement before initiating a simulation. They were instructed to give priority to the interruption task until completion; similar to priority training that has shown task management skills importance in multi-tasking performance (Gugerty, 2011). Instructions were provided in one of two formats: in a single grouping (at-once) and *separate* bits (each target instruction *separate*d by a 10-15 seconds). These instructions help to prompt participants to encode prospective memory targets. After each simulation, participants were asked to complete a NASA-TLX (Hart & Staveland, 1988) to assess their *subjective workload*. Upon completion of the four trials, participants were briefly interviewed and released. Trial order was counterbalanced and randomized with a Latin square design. Participants' primary and secondary task performance was observed and recorded under the four treatment conditions.

Figure 17: Sample screen shot of video stimuli

STIMULI

The primary task videos originated from BIWI Walking Pedestrians dataset by (Pellegrini, Ess, Schindler, & Van Gool, 2009), which contains a recording of a train station and sidewalk in front of Hotel Schweizerhof (Zurich) in Bahanhofstr, Zurich, by Stefano Pellegrini and Andreas Ess in 2009. Each of the four videos for the experiment were 3 minute segments from the 12 minute source video. The scene primarily consisted of individuals and groups of people walking from one edge of the sidewalk in the video to the other. The *primary task* was to keep count of the number of groups of individuals; additional video content information is included in Table 8. While performing the primary task, participants were to be on the lookout for prospective memory targets. These targets were only embedded in the primary task video. When participants perceived a prospective memory target, they pressed a key to indicate when that particular target entered the scene and exited (*target in* and *out*). Each video also had an *interruption task* similar to the primary task in which participants were to keep a count of specific items. The interruption tasks were approximately equal duration segments from four separate source videos. Interruption task videos for video 1 and 2 were obtained from the crowd segmentation data set by (Ali & Shah, 2007) and contained an overhead view of two different intersections with heavy traffic. Interruption task for video 3 included a street-level view of an outdoor shopping mall sidewalk that contains traffic passing by and was captured with an Arecont HD IP Camera. Interruption task for video 4 included a street-level view of a Taiwan intersection with heavy traffic flow captured with an ACTi ACM-4201 high resolution Megapixel IP camera. Sample screen shots, graphical timelines, and instruction scripts for all 4 videos are included in APPENDIX A.

Table 8. Video stimuli content information. Time values are elapse time in seconds from the beginning of each video.

Video	Groups of Individuals (count)	Prospective Memory Targets	Target in time (sec)	Target out time (sec)	Interruption task (count)	Interruption task		
						Correct value	Beginning time (sec)	Ending time (sec)
Video 1	26	Person pulling rolling luggage	20.02	27.02	Red cars traveling straight through the intersection	7	65.05	114.16
		Person pushing a stroller	129.05	138.13				
Video 2	26	Person pushing a stroller	63.01	78.2	White cars traveling straight through the intersection	7	65.08	112.08
		A different person pushing a stroller	113.03	124.02				
		Person with an orange coat getting off a train	180.11	187.2				
Video 3	20	Person walking a dog	95.04	102.15	People carrying paper shopping bags	6	65.09	112.08
		Person pulling rolling luggage	105.04	114.09				
		Person with red coat	108.05	118.17				
Video 4	27	Person pushing a stroller	104.12	112.24	Cars that drive past camera	10	65.18	110.02
		Person walking a	143.03	152.02				

dog

EXPERIMENTAL DESIGN

The experiment was a 2 x 2 within-subject design consisting of two independent variables with two levels each: instruction/target presentation method (*separate*ly, *at once*) and number of targets (2, 3). There were seven primary dependent variables, see Table 9: primary task accuracy (percentage of groups identified), target-in latency, target-out latency, secondary task accuracy (percentage of items identified), interruption and resumption lag, and NASA-TLX workload ratings. Secondary dependent variables include *Aospan* score, problem, answer, and *recall* reaction times (RT).

Table 9. Experiment metrics, dependent variables with measure details

Dependent Variable	Measure
Primary task performance	Percentage of groups identified
Target-in latency	Response time from target entering video and participant key press
Target-out latency	Response time from target exiting video and participant key press
Interruption task accuracy	Percentage of items identified
Interruption lag duration	Time from interruption task beginning and participant performing interruption task (measured by eye tracking)
Resumption lag duration	Time from interruption task ending and participant resuming primary task (measured by eye tracking)
Workload levels	NASA-TLX score

Working memory capacity	Aospan score, problem, answer, and recall reaction times

V. Results

Statistical tests were performed using JMP® by SAS® (Institute, 2014). Multiple two-way ANOVA analyses were conducted to determine which dependent variables significantly affected performance. *Subjective workload* was assessed using the raw, unweighted NASA-TLX ratings. Unless otherwise stated, all statistical tests were performed at $\alpha = 0.05$; marginally significant p-values are in included as well. Although statistical significance was not obtained in this experiment, future studies might be able to reach significance and benefit from their inclusion. Tobii eye tracker was used to calculate interruption and resumption times. Correlation tables include variable that are statistically significant and theoretically expected to be correlated.

WORKING MEMORY CAPACITY VARIABLES

For notable working memory variable correlations, see Table 10. Correlations were explored for the primary dependent variables primary task accuracy (percentage of groups identified), target-in latency (time in seconds between target arrival and key press), target-out latency (time in seconds between target departure and key press), secondary task accuracy (percentage of items identified), interruption and resumption lag, and NASA-TLX workload ratings. Overall, working memory capacity measures play a role in and show that there are individual differences in both task skill and prospective memory performance. Future analyses will explore factors that might explain the individual differences in both skill and susceptibility to prospective memory effects.

Table 10. Notable working memory variable correlations

Variable	By Variable	Correlation	p-value
Aospan	Interruption lag	0.1094	0.1231
Aospan	Resumption Lag	0.2064	0.0034
Aospan	Interruption Task Performance	0.1371	0.0529
Resumption Lag	Interruption Task Performance	0.1538	0.0297
Problem RT	Resumption Lag	-0.1494	0.0348
Problem RT	Interruption Task Performance	0.2349	0.0008
Recall RT	Primary Task Performance	-0.106	0.1351
Recall RT	Resumption Lag	0.111	0.1177
TLX Score	Resumption Lag	-0.1523	0.0313
TLX Score	Problem RT	0.2477	0.0004
TLX Score	Answer RT	0.4077	<.0001

NUMBER OF TARGETS AND TARGET ENCODING FORMAT

ANOVA results for target encoding format, number of targets, and the interaction by dependent variables are included in Table 11. See Table 12 for notable prospective memory variable correlations. For statistically significant effect of number of targets and target encoding conditions, see Table 11. For summary statistics of prospective memory performance for target encoding format and number of targets, see Table 13. For full statistical test tables, see APPENDIX B. For Least-squares means plots of target encoding format and number of targets, see APPENDIX C.

Table 11. Summary of ANOVA results of independent variables and interaction by 7 primary dependent measures

	Target Encoding Format			Number of Targets			Interaction of Target Encoding Format and Number of Targets		
	F (1,19)	*p*	η_p^2	F (1,19)	*p*	η_p^2	F (1,19)	*p*	η_p^2
Primary task performance	30.09	<.0001	.613	12.84	.0020	.403	7.17	.0149	.274
Target in latency	2.06	.1675	.098	28.54	<.0001	.600	8.43	.0091	.307
Target out latency	3.16	.0914	.143	3.14	.0921	.142	3.27	.0862	.147
Interruption task performance	0.40	.5323	.021	21.63	.0002	.532	0.09	.7572	.005
Interruption lag duration	0.24	.6305	.012	1.56	.2271	.076	29.79	<.0001	.611
Resumption lag duration	0.23	.6347	.012	0.36	.5510	.019	4.10	.0571	.177
Subjective workload	0.29	.5990	.015	11.49	.0031	.377	0.13	.7243	.007

Table 12. Notable prospective memory variable correlations.

Variable	by Variable	Correlation	p-value
Interruption lag	Interruption task fixation duration	-0.2466	0.0004
Interruption lag	Primary Task Performance	0.2048	0.0036
Interruption Task Performance	Target 1st fixation	-0.1706	0.0213
Interruption Task Performance	Target In	-0.1693	0.0273
Interruption task fixation duration	Primary Task Performance	-0.3458	<.0001
Interruption task fixation duration	Target 1st fixation	0.1442	0.0522
Interruption task fixation duration	Target fixation duration	0.1454	0.0502
Resumption lag	Interruption Task Performance	0.1538	0.0297
Resumption lag	Primary Task Performance	-0.2585	0.0002
Resumption lag	Target Out	0.1383	0.0746
Target 1st fixation	Target In	0.7348	<.0001
Target fixation duration	Primary Task Performance	-0.3643	<.0001
Target fixation duration	Target 1st fixation	-0.2613	0.0004
Target fixation duration	Target In	-0.1717	0.026

Primary task performance: *Primary task performance* varied significantly dependent upon target encoding format ($p < .0001$), number of targets ($p = .0020$) and the interaction of target encoding format and number of targets ($p = .0149$). A Student's t-test to compare means between treatments shows the *at once* target encoding (mean = 79.3%, SD = 17.3%) had significantly higher primary task performance compared to the *separate* target encoding (mean = 66.1%, SD = 16.6%).

Target in latency: *Target in latency* varied significantly dependent upon number of targets ($p < .0001$) and the interaction of target encoding format and number of targets ($p = .0091$). A Student's t-test to compare means between treatments shows the *at once* target encoding (mean = 2.9, SD = 2.3) had significantly higher target in latency compared to the *separate* target encoding (mean = 2.6, SD = 2.2). The three-target condition (mean = 3.3, SD = 2.7) had significantly higher target in latency compared to the two-target condition (mean = 2.1, SD = 1.3).

Target out latency: *Target out latency* varied significantly dependent upon target encoding format ($p = .0914$), number of targets ($p = .0921$) and the interaction of target encoding format and number of targets ($p = .0862$). A Student's t-test to compare means between treatments shows the *separate* target encoding (mean = 1.7, SD = 3.9) had marginally higher target out latency compared to the *at once* target encoding (mean = 0.9, SD = 0.66). The three-target condition (mean = 1.7, SD = 4.0) had significantly higher target out latency compared to the two-target condition (mean = 0.9, SD = 0.6).

Interruption Task Performance: *Interruption Task Performance* varied significantly dependent upon number of prospective memory targets ($p = .0002$). A Student's t-test to compare means between treatments shows the two-target condition (mean = 102.9, SD = 36.6) had significantly higher *Interruption Task Performance* compared to the three-target condition (mean = 64.7, SD = 35.1).

<u>Interruption lag duration</u>: *Interruption lag duration* varied significantly dependent upon the interaction of target encoding format and number of targets ($p < .0001$). A Student's t-test to compare means between treatments shows the three-target condition (mean = 0.75, SD = 0.72) had significantly higher *Interruption lag duration* compared to the two-target condition (mean = 0.6, SD = 0.42).

<u>Resumption lag duration</u>: *Resumption lag duration* varied significantly dependent upon the interaction of target encoding format and number of targets ($p = .0571$). A Student's t-test to compare means between treatments shows the *at once* target encoding (mean = 5.1, SD = 3.6) had significantly higher *Resumption lag duration* compared to the *separate* target encoding (mean = 4.5, SD = 2.9).

<u>Subjective workload</u>: *Subjective workload* varied significantly dependent upon number of prospective memory targets ($p = .0031$). A Student's t-test to compare means between treatments shows the three-target condition (mean = 50.4, SD = 14.0) had marginally higher workload scores compared to the two-target condition (mean = 46.9, SD = 12.9).

By their definitions, *target in*, *target out, interruption lag,* and *resumption lag* are measured in seconds and are latencies values, a duration of time after an event occurred. Their values seem relatively comparable; see Table 13 for means and standard deviations. To verify these measures are truly different, a three-way-all-within subjects ANOVA was conducted. The four dependent measures are significantly different, F (3, 57) = 45.70, *p* = <.0001. A Student's t-test to compare means between measures indicated *resumption lag* is the largest with a least squared mean of 4.80. This highlights and confirms the utility of utilizing *resumption lag* as a measure of prospective memory; individuals take a while to remember what they should have remembered to do.

Table 13. Summary statistics of prospective memory performance for target encoding and number of targets conditions.

Measure	Primary Task Performance (%)		Target in latency (sec)		Target out latency (sec)		Interruption Task Performance (%)		Interruption lag duration (sec)		Resumption lag duration (sec)		Subjective workload	
	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD	M	SD
Target Encoding														
Separately	66.1	16.6	2.6	2.2	1.7	3.9	77.9	41.1	0.72	0.79	4.5	2.9	48.6	14.0
At once	79.3	17.3	2.9	2.3	0.9	0.66	82.1	39.4	0.66	0.38	5.1	3.6	49.4	13.4
Number of Targets														
Two	68.6	20.4	2.1	1.3	0.9	0.6	102.9	36.6	0.6	0.42	5.0	3.7	46.9	12.9
Three	75.4	16.0	3.3	2.7	1.7	4.0	64.7	35.1	0.75	0.72	4.6	2.9	50.4	14.0

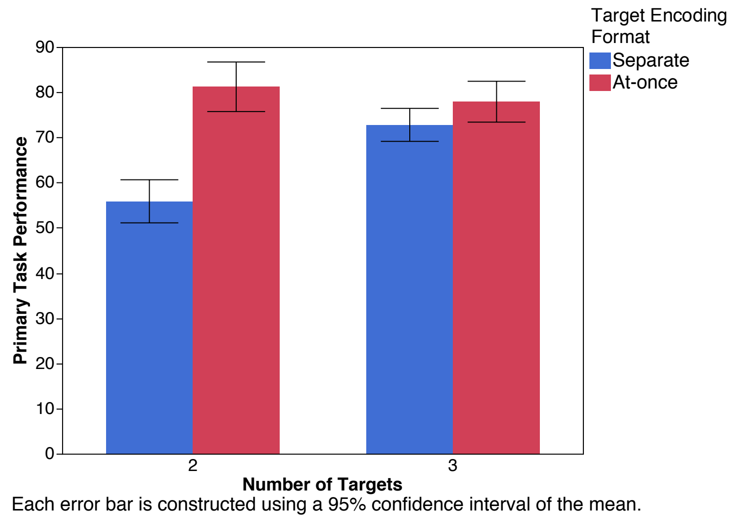


Figure 18. Mean *primary task performance* of number of prospective memory targets by target encoding format

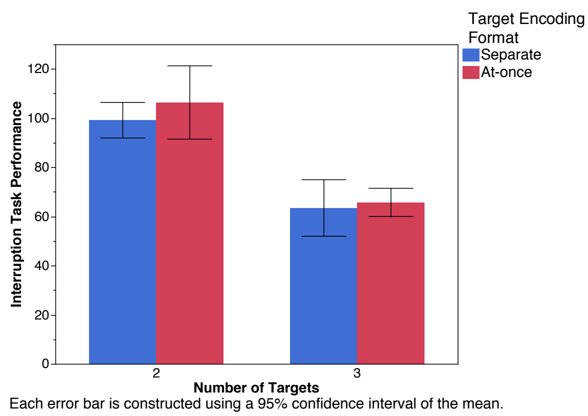


Figure 19. Mean *Interruption Task Performance* of number of prospective memory targets by target encoding format

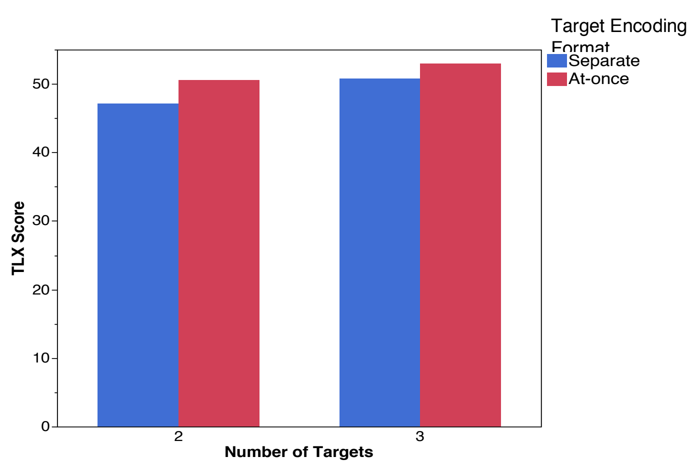


Figure 20. Median workload scores by number of targets and target encoding format

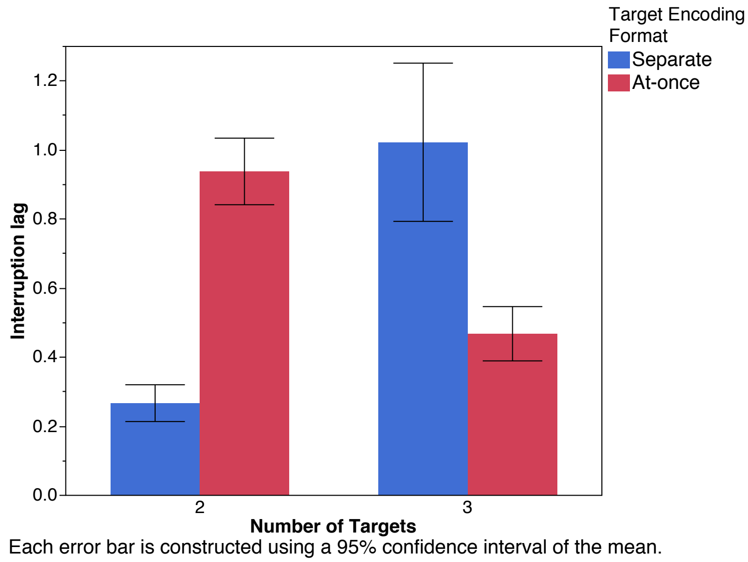


Figure 21. Mean interruption lag by number of targets and target encoding format

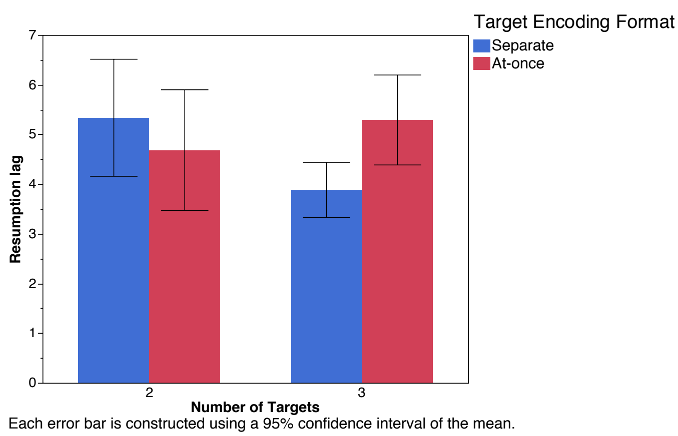
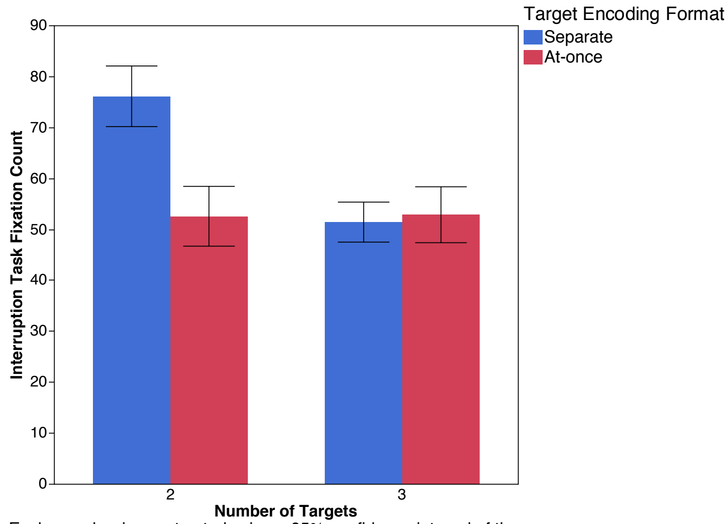
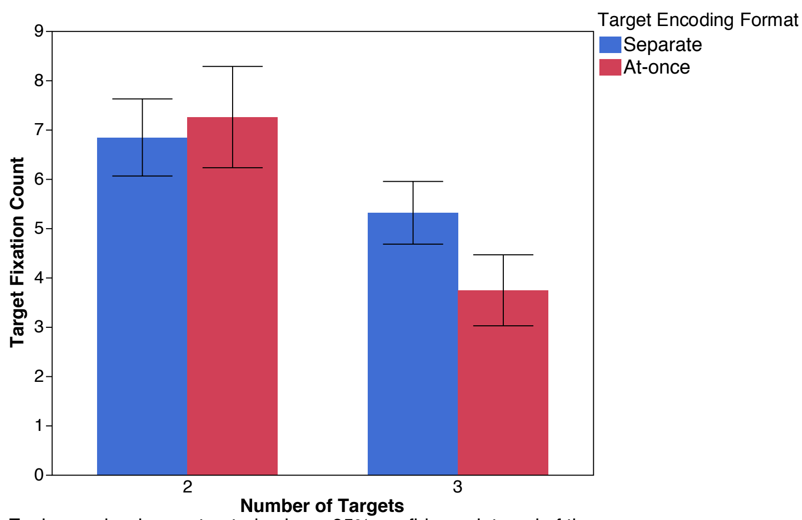


Figure 22. Mean resumption lag by number of targets and target encoding format



Each error bar is constructed using a 95% confidence interval of the mean.

Figure 23. Mean interruption task fixation count by number of targets and target encoding format



Each error bar is constructed using a 95% confidence interval of the mean.

Figure 24. Mean prospective memory targets fixation count by number of targets and target encoding format

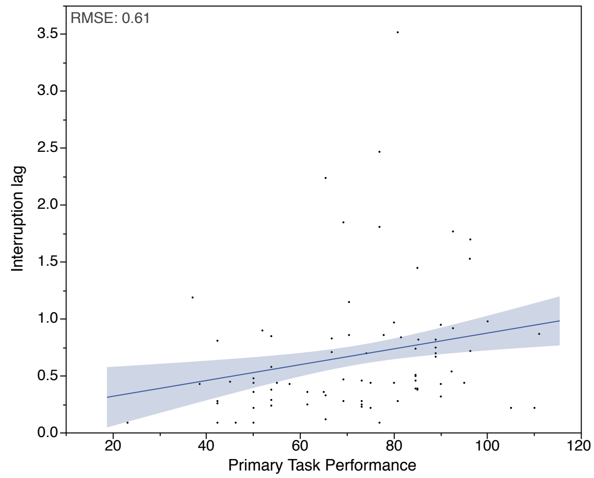


Figure 25. Interruption lag by primary task performance with line of best fit and root squared mean error value

Figure 25 shows a positive, increasing trend of increasing *Interruption lag duration* and primary task performance. It can be inferred that some individuals were more active in the ongoing task and delayed task switching.

VI. Discussion

This experiment set out to explore the seemingly ubiquitous requirements of analyst-related multitasking by addressing four key questions:

1. Does working memory capacity correlate with prospective memory performance?
2. Does prospective memory performance change significantly when the number of concurrent targets changes from 2 to 3?

3. Does prospective memory task performance significantly vary by target encoding: single encoding of large amount of information versus smaller, *separate*d bits within the different task combinations?
4. Does the interaction of number of targets and target encoding significantly affect prospective memory performance, including interruption and resumption lag?

Additionally, subjective mental workload was assessed to compare the effect of number of tasks on mental workload.

The results of this study show that working memory capacity measurements are correlated with prospective memory measurements. The ANOVA results agree with prior literature: working memory capacity can be a predictor of monitoring performance (Brewer et al., 2010), indicates that one is more able to retrieve information after being distracted (Brewer & Unsworth, 2012; Unsworth & Brewer, 2009; Unsworth & Engle, 2007b), and is an important component to prospective remembering (Ball et al., 2013; Brewer et al., 2010; Unsworth et al., 2012). Surprisingly, parts of the correlation results, Table 10, seem to conflict with research. A positive correlation of *Aospan* by interruption and resumption lag indicates that as working memory capacity increases, so does each lag. Although individuals with a higher working memory capacity took longer to switch tasks upon being interrupted, they had higher *primary* and *Interruption Task Performance*; implied by positive correlation of *Aospan* and *Interruption Task Performance* and negative correlation of recall RT and primary task performance.

The number of concurrent targets changing from 2 to 3 had a negative effect on prospective memory performance by means of increasing target in and out latencies, *Interruption lag duration*, and decreasing *Interruption Task Performance.* This supports the knowledge dependency cycle in that interruption lags increase proportionally with the number of concurrent prospective memory targets. This complements research that performance costs are apparent when cognitive demands of the tasks are increased (via interruptions or task switching/divided attention conditions) (Einstein, Smith, McDaniel, & Shaw, 1997; Logie, Law, Trawley, & Nissan, 2010; Marsh, Hicks, & Watson, 2002; McDaniel, Robinson-Riegler, & Einstein, 1998; McDaniel & Scullin, 2010). Additionally, increasing targets resulted in an increased workload which is agrees with recent literature (Eziolisa, 2014). *Separate* target encoding format resulted in higher prospective memory performance by means of decreased target in latency and resumption lag; while moderately increasing mental workload and—conversely—target out latency. The effect of target encoding format and number of targets resulted in slightly conflicting—seemingly inverse—results for the interruption and resumption lags. Illustrated well by Figure 21 and Figure 22, while keeping in mind that number of targets and target encoding format had a statistically significant effect on interruption and resumption lag respectfully. On average, the interruption lag was lower with two targets than three and resumption lag was lower with *separate* encoding than at-once. Although targets were embedded in the ongoing tasks, perhaps some individuals may have employed a speed-accuracy trade-off. Another possible explanation for differing effects on both lag measurements found here was a unique methodology used in the experiment in which the interruption task abruptly appeared on the screen, whereas individuals had to rely on their intentions to return to the primary task upon interruption task completion. That is, attention may have been diverted from the primary task not by monitoring per se, but rather by spontaneous retrieval as a cognitive mechanism utilized to respond to prospective memory targets. Relatively small interruption lags agrees with recent research that indicates delayed intentions maintain a privileged status in memory (Freeman & Ellis, 2003). Overall, ongoing task performance is consistent with previous research, (e.g., (Einstein et al., 2005)) and seemed inoculated by thoughts about having to perform prospective memory tasks. It is interesting that both *primary* and *Interruption Task Performance* show similar effects from the task conditions (i.e., for 2 and 3 targets, both exhibited higher task accuracy for the at-one target encoding format, see Figure 18 and Figure 19).

It is interesting that the mean interruption task fixation count—Figure 23, relationship of task conditions (number of targets and target encoding format)—is reminiscent of mean resumption lag, Figure 22. While prospective memory targets fixation count, Figure 24, is reminiscent of the mean interruption lag. Although, in retrospect, this relationship is expected and they complement each other: the more resources one devotes to the interruption task would be reflected as increased duration of resumption lag. As one fixates on prospective memory targets less, they inherently facilitate a lower interruption lag (i.e. more cognitive resources are available for the interruption task).

Graphing the average resumption lag, Figure 26, and interruption lag, Figure 27, by confidence yielded a direct relationship trend between both lag measurements and confidence (can be located in APPENDIX D). Therefore, in general, the more confident the subjects were, the longer it took them to switch tasks. Suggesting that they were devoting more resources to the ongoing task and/or searching for the prospective memory targets. A plot of average resumption and interruption lags by NASA-TLX also yielded a trend. As subject reported higher workloads, resumption lags decreased while interruption lags seemed relatively consistent.

RELEVANCE TO THE INTELLIGENCE SURVEILLANCE AND RECONNAISSANCE DOMAIN

Findings in this study are of great relevance to understanding the human intelligent analyst's performance on visual search tasks with delayed intentions and interruptions. These results advance our understanding of utilize prospective memory in a simulated real-life environment; excluded by previous research. These results refine knowledge of the effect of target presentation format and number of prospective memory targets on analyst's performance. Both target presentation format and number of targets are fundamentally encapsulated in instructions provided to analysts to direct their attention and what items/people are of interest by means of essential elements of information. This provides a starting point for workload suggestions for tasking intelligence analysts.

This study showed trends between perceived task difficulty and task switching performance by means of interruption and resumption lags. Visual search trial with two targets lowered perceived difficulty while three targets increased perceived difficulty. This can be interrupted that efficiency in visual search of motion imagery is moderately dependent on the human's perceived workload. *Separate* target encoding lowered perceived difficulty while at-once encoding increased perceived difficultly. This indicates that presenting target information to analysts in smaller—digestible bits—is more advantageous than presenting all of the target information *at once*. That is to say, when an analyst is more confident in their ability to complete a task, they are more likely to perform better. This exemplifies and highlights the importance of proceduralizing and encouraging proper resources management training. Although cumbersome, an analyst's work/results may be independently cross-checked and verified by tasking multiple individuals with same or similar objectives.

The findings regarding working memory capacity measurements correlated with prospective memory performance is supported by literature. This is also useful information to the intelligence surveillance and reconnaissance domain. The data captured in this experiment suggest that as working memory capacity increases, task-switching speed decreases (higher interruption and duration lags) and both task accuracies increase as well. Working memory capacity metrics could be utilized to screen intelligence analysts and/or indicate user fatigue during tasks or 'down' days. These findings provide a format for conducting visual search experiments with full video imagery while integrating prospective memory targets and multi-tasking, representative of many real-world working environments using intelligence analysts.

Governmental agencies are under extreme pressure to cut costs, and results of changes to training and operations are not always immediate. Collaborative research may alleviate human-centered issues while focusing on improving knowledge for a greater good. Although modern intelligence communities operate at extremely high levels of secrecy, academic institutions may provide the necessary resources to provide advancements to and disseminate knowledge to improve analyst effectiveness.

FUTURE WORK

This study was an exploratory study to examine variables associated with visual search tasks in full motion video with prospective memory theoretical perspectives while multi-tasking and helps disambiguate a subsection of the underlying cognitive processes. The findings highlight aspects of analyst work that can be improved. That in turn helps us understand the vulnerability inherent in prospective memory-based errors and suggest countermeasures to increase human analyst efficiency and overall safety.

Although a relatively new topic on researcher's radars, prospective memory is of huge importance for effective and safe human performance in numerous real-world applications (Dismukes & Nowinski, 2006). Continued expansive experimental studies are need to disambiguate the underlying cognitive mechanisms involved in prospective remembering. Future studies may expand on this experiment by increasing the number and types of targets, include multiple concurrent video motion imagery, analyst personality types (e.g., Myers-Briggs), and differing age groups (comparing ages sheds light on specific cognitive processes (Dismukes, 2010). Additionally, the intelligence community would benefit from exploring technological attention management systems utilizing eye tracking metrics such as frequency of fixation to event relevant and non-relevant cues in real time to provide feedback to the user; similar to (Ratwani et al., 2010) as various measures of cognitive processes have been used in real-time feedback systems (Ratwani et al., 2008; Wilson & Russell, 2003; Wilson & Russell, 2007). One key axiom in the intelligence analysis environment is the presence and possible overabundance of interruptions. Given that interruptions cannot be removed entirely, managing these events is key. Augmenting human performance through the use of intelligent, robust computer vision models could directly, or indirectly guide an operator's gaze to a critical area or subsection of full motion video when the likelihood of missing an event is high (i.e., counteract cognitive tunneling or too sporadic/rapid eye movements). To improve analyst efficiency and reduce costly errors, future work must investigate reducing operators' stress level. Multi-tasking, by its very nature, creates stress and ironically, prolonged stress damages: (a) "executive" part of the brain (prefrontal cortex) which is where we mark spots in a task when interrupted to return to it later and (b) the hippocampus, which is critical to form new memories (Healy, 2004). Stressful multi-tasking environments are fundamentally in some ways, self-destructive. These points are a humbling lesson in the limits analysts face and reemphasizes the importance of additional research in this field.

Some aspects of performance can be tested independently from real world operations. However, many other aspects of performance can be demonstrated through relevant real-world experiments. In order to induce variability and further examine—and possibly exacerbate—characteristics of prospective memory-based errors, future studies should study individuals outside of laboratory settings as their attention undoubtedly varies greater in real-world environments (Marsh et al., 2005). Moreover, laboratory settings involve experimenter defined intentions and cues whereas naturalistic settings involve self-generated intentions that may be embedded in an overall goal structure and cues that may not be anticipated. Further studies could investigate effect of the nature of the ongoing task—how the task directs attention and causes information to be processed, repeated trials, the role of rehearsal and reminders, self-generated versus experimenter intentions, strategies individuals use improve performance, and experience on performance. The main challenge is distilling prospective remembering from the underlining heterogeneous cognitive processes into specific situations. Computational models of multitasking and task switching may be adapted to prospective remembering.

Adapting traditional signal detection statistical analysis methods to aerial video footage seems to be a relatively unexplored realm. Signal detection statistics may provide numerous benefits, especially when paired with additional statistical analysis methods. Additionally, researchers are interested in working memory is primarily due to its connection to higher-level cognition as it functions as a mental workspace for temporary storage and processing of information (E. E. Smith et al., 2001). More focus exploring Li and Laird (2013)'s dependency cycle may results in a deeper understanding of the cognitive mechanisms. I opine that additional research is need in expansive real-life situations (simulated or conceptual) (e.g., health care, driving tasks, aviation) to obtain a robust understanding of the implications of variables that effect prospective memory. Given the self-evident benefits inherent in prospective memory, it is surprising the paucity of research.

IMPROVING PROSPECTIVE MEMORY

The risks and potential consequences of analyst performance errors are substantial and the safety-related benefits of mitigating them are self-evident. Without effective countermeasures, human cognitive vulnerabilities and operational urgencies will allow data entry related errors (Berman, Dismukes, & Jobe, 2012). One proven method of improving prospective remembering is through the use of implementation intentions. They have been explored for various everyday tasks such as exercising (Milne, Orbell, & Sheeran, 2002), breast self-examination (Orbell, Hodgldns, & Sheeran, 1997), taking medication (Sheeran & Orbell, 1999) and completing homework assignments (Gollwitzer & Brandstätter, 1997). These intentions are believed to improve performance by creating a cognitive shortcut between task cues and the delayed intention; thus facilitating automatic target retrieval (A.-L. Cohen & Gollwitzer, 2008; Gollwitzer, 1999).

Dismukes and Nowinski (2006) provides two suggestions to improve prospective remembering when multitasking: (1) pause after completing a task, analyze and prioritize what task should be before next, (2) when interrupted, pause to form an explicit intention and/or create clear cues that would be encountered when resuming the interrupted task, (3) making and regularly reviewing a list of deferred intentions. There may be a solution to improve interruption performance by preventing cognitive disruptions, however this may not be practical because interruptions are an important way to communicate critical information in a timely fashion (Coiera & Tombs, 1998; Grundgeiger & Sanderson, 2009; Grundgeiger et al., 2010). Dodhia and Dismukes (2009) found that the following three items significantly improved remembering to resume an interrupted task: (1) at the beginning of the interruption: providing a prompt to remind individuals; (2) at the beginning of the interruption, provide a brief pause; and (3) clearly indicate the end of the interruption. Giving the operator control of the interruption lag (or a brief warning) might benefit performance as the individual may finish key tasks prior to interruption.

Obermayer and Nugent (2000) for a Navy alerting and attention management system recommend: minimize interruption frequency, match cues to urgency of information, and allow operators control over when to process interruptions. Dismukes (2012) recommends the following to improve prospective memory performance: avoid deferring a critical task altogether, avoid concurrent multitasking, form explicit intentions, link prospective memory tasks to habitual tasks (e.g., taking a shower), utilize external memory aids such as post-it notes, use checklists, establish formal procedures for monitoring and cross-checking. Grundgeiger et al. (2010) reports that to effectively construct a prospective memory support system, we must consider tasks, coworkers, and the work environment. Warning systems help prevent pilots from forgetting (Dismukes, 2010) and may be adapted to other domains.

Further recommendations/countermeasures to improve prospective memory for intelligence procedures and organization policies are as follows:

- Challenging existing requirements and procedures (explore groups working together/agencies sharing information)
- Revise and reduce checklist items involving multiple subtasks
- Regular reviews of intelligence operation procedures should be conducted to find and eradicate prospective memory and concurrent task demands are high

Similarly, there are recommendations for improving the training, checking, and mentoring:

- Analysts should be trained on their vulnerabilities to prospective memory errors s and practical techniques to counter it. Analysts would be better prepared to handle error-prone situations if they are aware of the situations in which it occurs.
- Support team analyst work to crosscheck each other. Team-based intelligence processes may provide necessary prospective to combat biases.
- Provide detailed real-time metrics on operators vigilance
- Provide on the job mentoring for new analysts

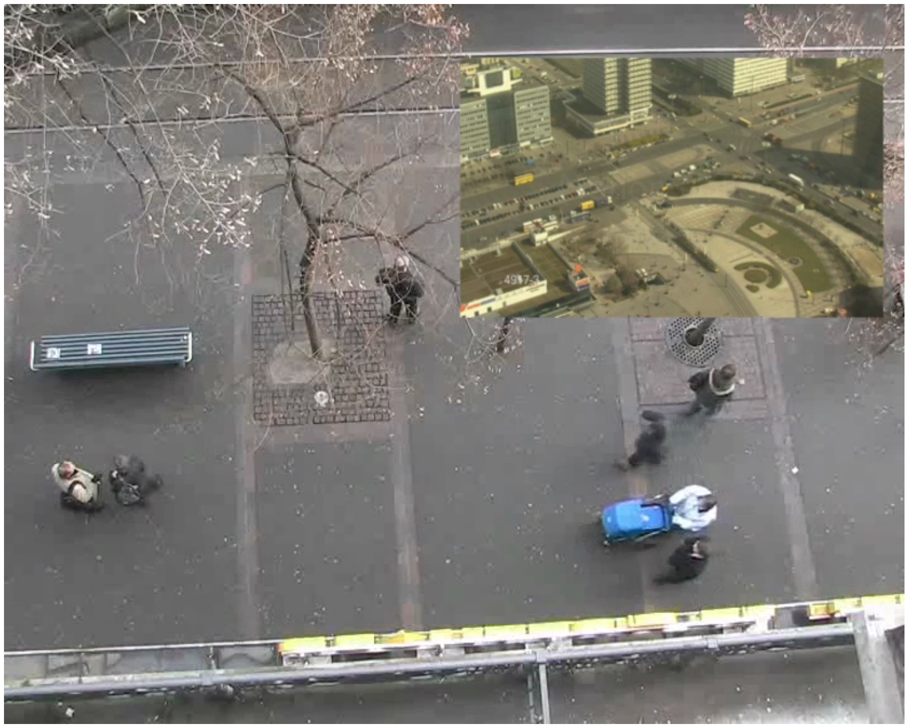
REMINDERS

Research points to a few methods that have potential for improving prospective remembering. Although decision aids are domain and task specific, explicit memory aids have been shown to improve appointment adherence (Macharia, Leon, Rowe, Stephenson, & Haynes, 1992; Morrow, Menard, Ridolfo, & Leirer, 2003), nurses (Grundgeiger et al., 2010), airline pilot aids (Loukopoulos et al., 2009), taking medication (Park, Morrell, Frieske, Blackburn, & Birchmore, 1991), air traffic controllers use of flight strips (Vortac, Edwards, & Manning, 1995), and used in everyday prospective memory tasks (Maylor, 1990). External reminders may improve delayed intentions, especially during interruptions—by spreading cognition over time and effetely reducing the memory demands of the task. Real-time feedback systems have been shown to predict operator errors (Ratwani et al., 2010) and may be adapted to improve prospective memory performance. Practical and effective prospective memory aids requires careful analysis of memory and ongoing task demands for specific operational situational requirements.

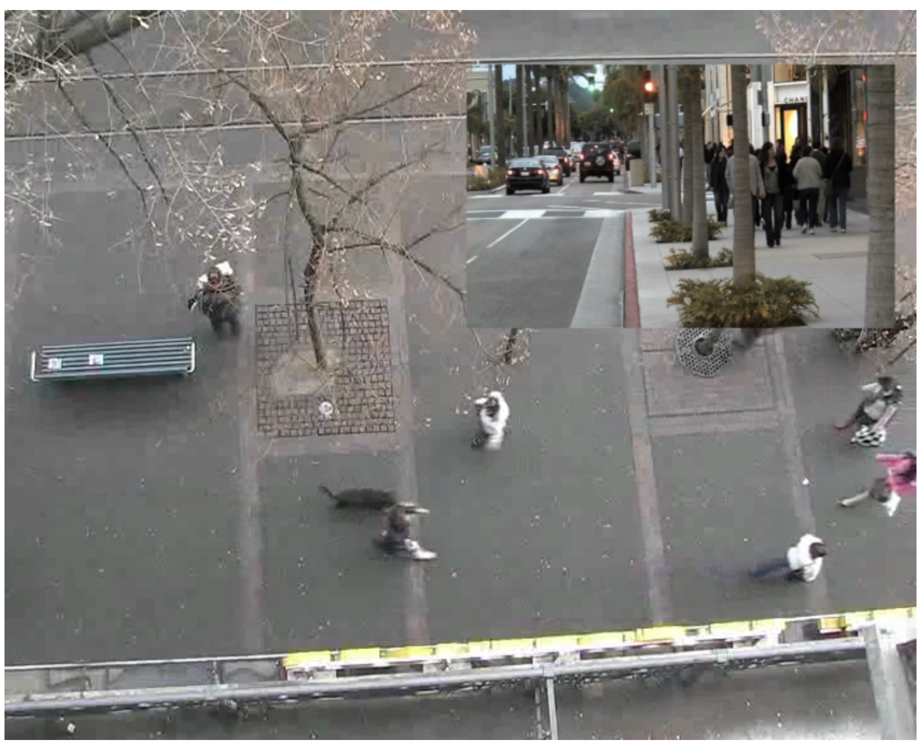
APPENDIX A: SAMPLE IMAGES OF TASK VIDEOS WITH INTERRUPTION TASK VIDEOS

Video 1:

Video 2:



Video 3:



Video 4:

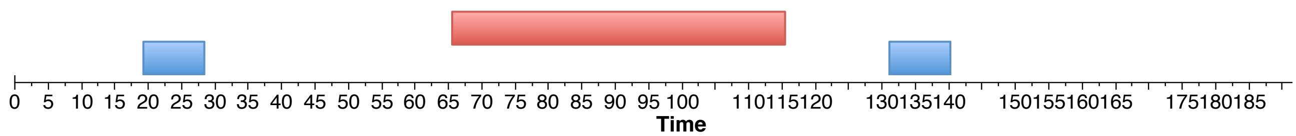
Prospective memory target and interruption task timelines:

Prospective memory target
Interruption task

Video 1

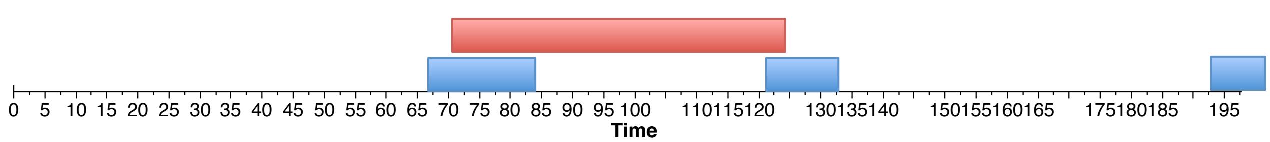
Instructions separate: The primary task will be to keep count of the number of groups of individuals (two or more) in the video, feel free to make tick marks on the paper in front of you, I just ask that you simply do not write down any instructions on it, just tick marks. (pause for 10-15 seconds) There are two prospective memory targets you'll be on the lookout for in the primary task video, when you see one of these enter the screen, press the I key on the keyboard, and when you see the target exit the screen, press the o key. (pause for 10-15 seconds) The first target is an individual pulling rolling luggage (pause for 10-15 seconds) and the second is an individual pushing a stroller. (pause for

10-15 seconds) There will be an interruption task that will appear on the screen, I ask that you give priority to the interruption task until completion. For the interruption task, you should keep a second count (feel free to make tick marks on the paper as well) of the number of red vehicles going straight through the intersection from any direction.



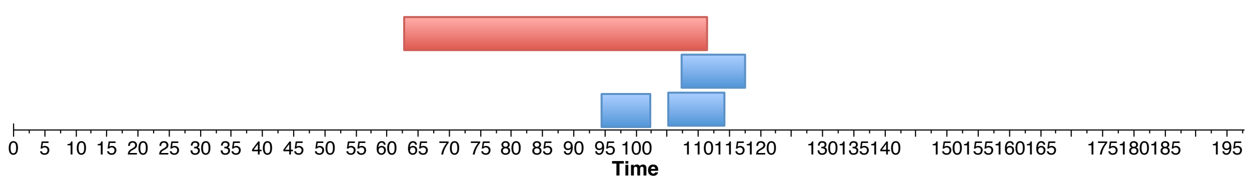
Video 2

Instructions separate: The primary task will be to keep count of the number of groups of individuals (two or more) in the video, feel free to make tick marks on the paper in front of you, I just ask that you simply do not write down any instructions on it, just tick marks. (pause for 10-15 seconds) There are three prospective memory targets you'll be on the lookout for in the primary task video, when you see one of these enter the screen, press the I key on the keyboard, and when you see the target exit the screen, press the o key. (pause for 10-15 seconds) The first target is an individual pushing a stroller (pause for 10-15 seconds) the second is a different individual pushing a stroller (pause for 10-15 seconds) and the third is an individual with an orange coat coming off a train (pause for 10-15 seconds). There will be an interruption task that will appear on the screen, I ask that you give priority to the interruption task until completion. For the interruption task, you should keep a second count (feel free to make tick marks on the paper as well) of the number of white vehicles going straight through the intersection from any direction.



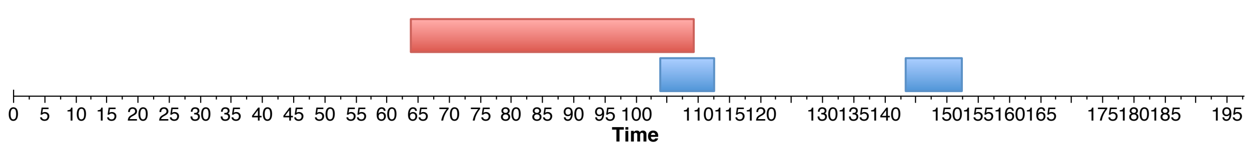
Video 3

Instructions at once: The primary task will be to keep count of the number of groups of individuals (two or more) in the video, feel free to make tick marks on the paper in front of you, I just ask that you simply do not write down any instructions on it, just tick marks. There are three prospective memory targets you'll be on the lookout for in the primary task video, when you see one of these enter the screen, press the I key on the keyboard, and when you see the target exit the screen, press the o key. The first target is an individual walking a dog, the second target is a individual pulling rolling luggage, and the third is an individual with a red coat and hat. There will be an interruption task that will appear on the screen, I ask that you give priority to the interruption task until completion. For the interruption task, you should keep a second count (feel free to make tick marks on the paper as well) of the number of white vehicles going straight through the intersection from any direction.



Video 4

Instructions at once: The primary task will be to keep count of the number of groups of individuals (two or more) in the video, feel free to make tick marks on the paper in front of you, I just ask that you simply do not write down any instructions on it, just tick marks. There are two prospective memory targets you'll be on the lookout for in the primary task video, when you see one of these enter the screen, press the I key on the keyboard, and when you see the target exit the screen, press the o key. The first target is an individual pushing a stroller and the second is an individual walking a dog. There will be an interruption task that will appear on the screen, I ask that you give priority to the interruption task until completion. For the interruption task, you should keep a second count (feel free to make tick marks on the paper as well) of the number of vehicles going straight through the intersection that are upcoming and pass the camera in the closest lane.



APPENDIX B: NUMBER OF TARGETS AND TARGET ENCODING STATISTICAL TEST RESULTS

The tables below shows the ANOVAs performed for the following dependent variables.

Primary task performance:

Response Primary Task Performance (%)

Summary of Fit

RSquare	-0.43773
RSquare Adj	-0.49449
Root Mean Square Error	16.88811
Mean of Response	72.03625
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	0.5268226	150.25408	51.574457	49.170002	251.33816	34.505
Subject*Num Targets	-0.373671	-106.5741	47.720761	-200.1051	-13.04316	0.000
Subject*Instruction	-0.229474	-65.44776	52.604796	-168.5513	37.655742	0.000
Subject*Num Targets*Instruction		285.20813	92.533735	164.94888	608.4258	65.495
Total		435.4622	124.5137	266.5923	836.62348	100.000

-2 LogLikelihood = 637.24738801
Note: Total is the sum of the positive variance components.
Total including negative estimates = 263.44031

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	30.0923	<.0001*
Num Targets	1	1	19	12.8432	0.0020*
Num Targets*Instruction	1	1	19	7.1711	0.0149*

Target in latency:

Response Target in avg

Summary of Fit

RSquare	0.691996
RSquare Adj	0.679837
Root Mean Square Error	1.052155
Mean of Response	2.72405
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject*Num Targets	0.0160154	0.0177295	0.2580697	-0.488078	0.5235368	0.910
Subject*Instruction	0.3852928	0.4265308	0.3651776	-0.289204	1.1422658	21.885
Subject	0.3592087	0.397655	0.3557182	-0.29954	1.0948498	20.404
Subject*Instruction*Num Targets		1.1070305	0.3591681	0.6402463	2.3615944	56.802
Total		1.9489458	0.3557182	1.4039711	2.888246	100.000

-2 LogLikelihood = 274.72114439
Note: Total is the sum of the positive variance components.
Total including negative estimates = 1.9489458

Residual is confounded with Subject*Instruction*Num Targets and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Num Targets	1	1	19	28.5447	<.0001*
Instruction	1	1	19	2.0595	0.1675
Num Targets*Instruction	1	1	19	8.4381	0.0091*

Target out latency

Response Target out avg

Summary of Fit

RSquare	0.03199
RSquare Adj	-0.00622
Root Mean Square Error	1.89239
Mean of Response	1.25334
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	0.0344882	0.1235071	0.5577193	-0.969603	1.2166169	3.334
Subject*Num Targets	-0.052586	-0.188319	0.779565	-1.716238	1.3396004	0.000
Subject*Instruction	-0.022732	-0.081405	0.8031117	-1.655475	1.4926646	0.000
Subject*Num Targets*Instruction		3.5811415	1.1618757	2.0711376	7.6395399	96.666
Total		3.7046486	1.5283925	1.8939083	10.229721	100.000

-2 LogLikelihood = 326.92062539

Note: Total is the sum of the positive variance components.

Total including negative estimates = 3.4349243

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	3.1614	0.0914
Num Targets	1	1	19	3.1460	0.0921
Num Targets*Instruction	1	1	19	3.2758	0.0862

Interruption Task Performance

Response Interruption Task Performance (%)

Summary of Fit

RSquare	0.313001
RSquare Adj	0.285882
Root Mean Square Error	35.25276
Mean of Response	83.79875
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	0.0818788	101.75545	218.01998	-325.5559	529.06675	7.282
Subject*Num Targets	0.0424913	52.806421	297.46942	-530.2229	635.83576	3.779
Subject*Instruction	-0.053605	-66.61797	270.25727	-596.3125	463.07655	0.000
Subject*Num Targets*Instruction		1242.757	403.2036	718.74307	2651.1355	88.939
Total		1397.3188	358.91403	894.14305	2487.9862	100.000

-2 LogLikelihood = 779.17051005

Note: Total is the sum of the positive variance components.

Total including negative estimates = 1330.7009

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	0.4046	0.5323
Num Targets	1	1	19	21.6360	0.0002*
Num Targets*Instruction	1	1	19	0.0984	0.7572

Interruption lag duration

Response Interruption lag

Summary of Fit

RSquare	0.318156
RSquare Adj	0.291241
Root Mean Square Error	0.501987
Mean of Response	0.673875
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	-0.058985	-0.014864	0.0419312	-0.097047	0.06732	0.000
Subject*Num Targets	0.0190901	0.0048105	0.0589246	-0.11068	0.1203006	1.764
Subject*Instruction	0.0631696	0.0159182	0.0615709	-0.104759	0.1365949	5.837
Subject*Num Targets*Instruction		0.2519907	0.0817566	0.1457377	0.5375641	92.399
Total		0.2727194	0.062618	0.1820921	0.4531882	100.000

-2 LogLikelihood = 130.01568405

Note: Total is the sum of the positive variance components.

Total including negative estimates = 0.2578557

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	0.2391	0.6305
Num Targets	1	1	19	1.5578	0.2271
Num Targets*Instruction	1	1	19	29.7997	<.0001*

Resumption lag duration

Response Resumption lag

Summary of Fit

RSquare	0.758378
RSquare Adj	0.74884
Root Mean Square Error	2.274717
Mean of Response	4.8046
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	0.1145932	0.5929439	2.0462207	-3.417575	4.6034628	5.130
Subject*Num Targets	0.4371332	2.2618738	1.7831564	-1.233049	5.7567962	19.568
Subject*Instruction	0.6821667	3.5297596	2.1548047	-0.69358	7.7530992	30.537
Subject*Num Targets*Instruction		5.174336	1.6787763	2.9925547	11.038253	44.765
Total		11.5589913	2.0462207	8.4026348	16.908914	100.000

-2 LogLikelihood = 411.2571268

Note: Total is the sum of the positive variance components.

Total including negative estimates = 11.558913

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	0.2332	0.6347
Num Targets	1	1	19	0.3686	0.5510
Num Targets*Instruction	1	1	19	4.1014	0.0571

Mental Workload:

Response TLX Score

Summary of Fit

RSquare	0.779188
RSquare Adj	0.770472
Root Mean Square Error	6.423438
Mean of Response	48.67338
Observations (or Sum Wgts)	80

REML Variance Component Estimates

Random Effect	Var Ratio	Var Component	Std Error	95% Lower	95% Upper	Pct of Total
Subject	3.8962572	160.76175	53.781561	55.351826	266.17167	79.576
Subject*Num Targets	-0.248303	-10.24512	7.4935764	-24.93226	4.4420236	0.000
Subject*Instruction	-0.041765	-1.723252	9.0790916	-19.51794	16.07144	0.000
Subject*Num Targets*Instruction		41.260559	13.386693	23.862864	88.019891	20.424
Total		202.02231	56.225098	125.10853	380.37667	100.000

-2 LogLikelihood = 553.90614336

Note: Total is the sum of the positive variance components.

Total including negative estimates = 190.05394

Residual is confounded with Subject*Num Targets*Instruction and has been removed.

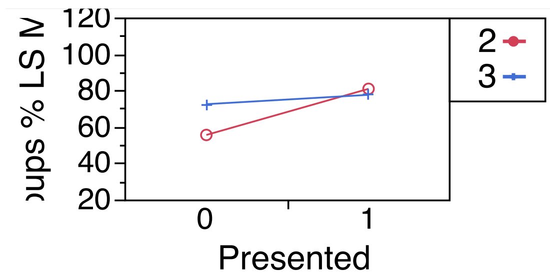
Fixed Effect Tests

Source	Nparm	DF	DFDen	F Ratio	Prob > F
Instruction	1	1	19	0.2859	0.5990
Num Targets	1	1	19	11.4860	0.0031*
Num Targets*Instruction	1	1	19	0.1282	0.7243

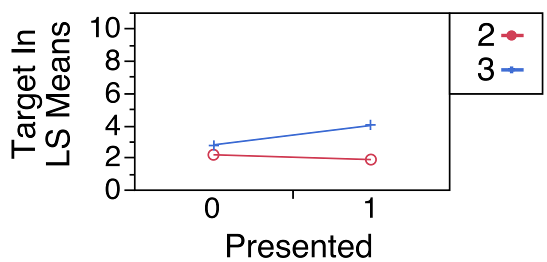
APPENDIX C: NUMBER OF TARGETS AND TARGET ENCODING LEAST-SQUARES MEAN PLOTS

The table below shows the Least-squares mean plots performed on number of targets and target encoding format (0 = *separate*ly, 1 = *at once*) for the following dependent variables.

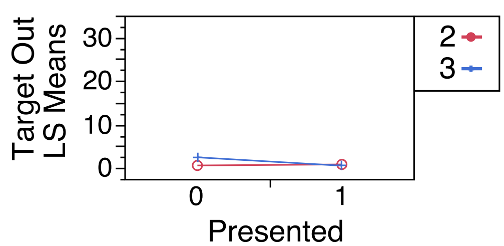
***Primary task performance*:**



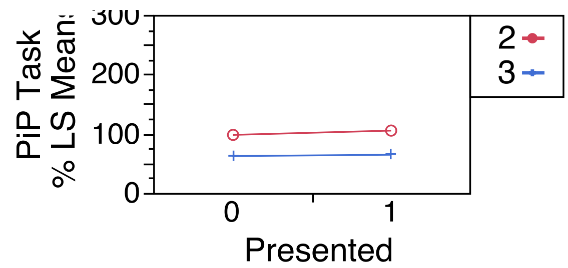
***Target in latency*:**



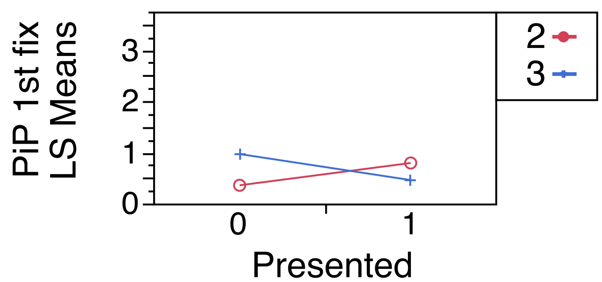
***Target out latency*:**



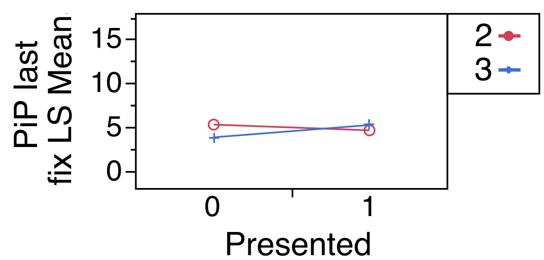
***Interruption Task Performance*:**



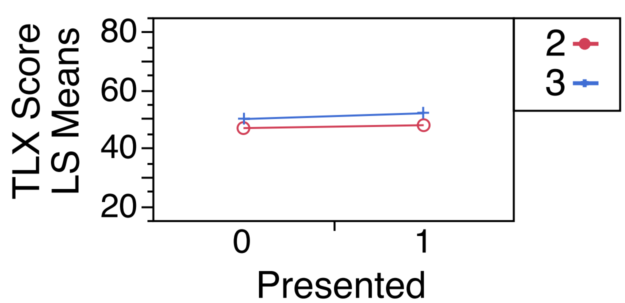
***Interruption lag duration*:**



***Resumption lag duration*:**



Mental Workload:



APPENDIX D: COMPARISON OF INTERRUPTION AND RESUMPTION LAGS BY AVERAGE CONFIDENCE AND NASA-TLX

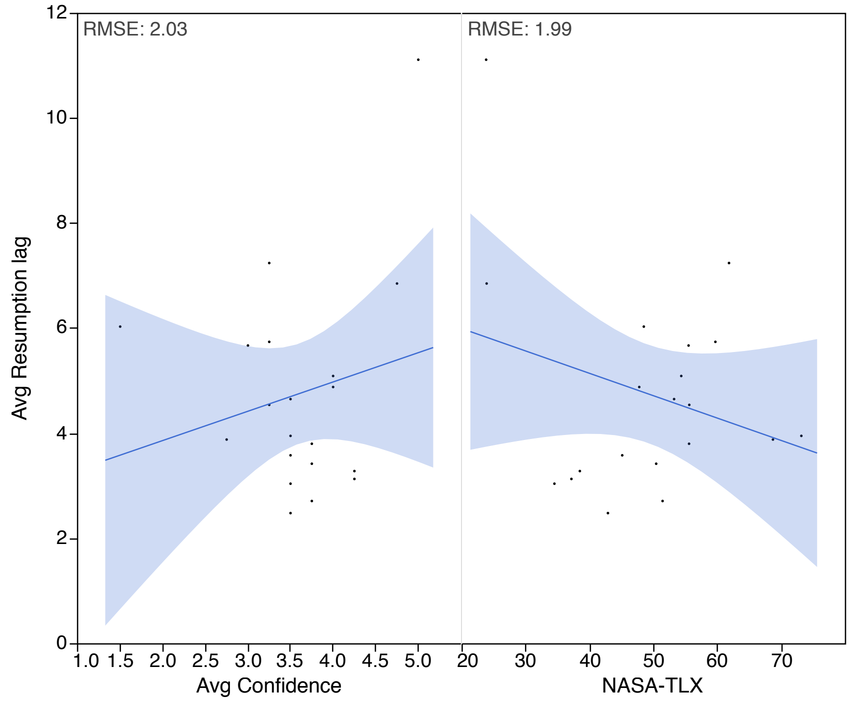


Figure 26. Average Resumption lag by average confidence and NASA-TLX

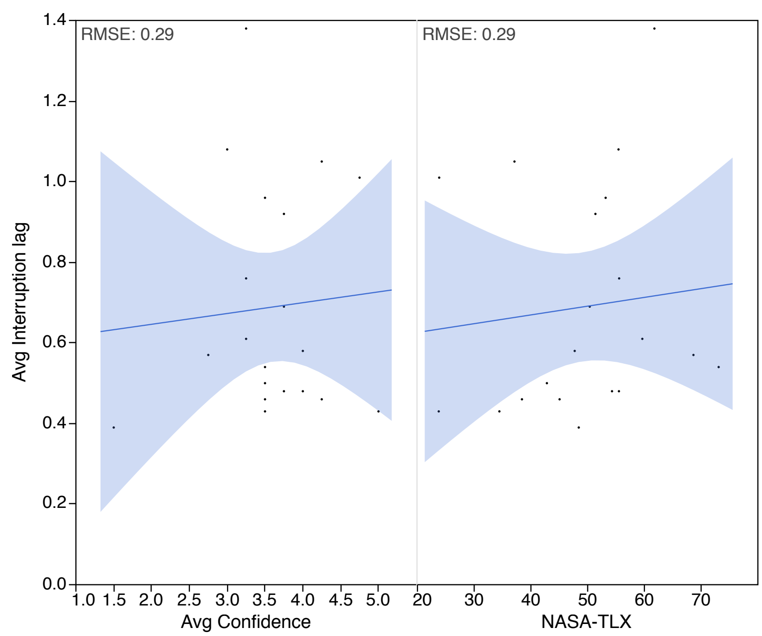


Figure 27. Average Interruption lag by average confidence and NASA-TLX

APPENDIX E: PERMISSION FOR VARIOUS TABLES AND FIGURES

Table 3 Representative examples of task conditions, assumed high and low in focal processing (Einstein & McDaniel, 2005)**:**

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Author: Gilles O. Einstein, Mark A. McDaniel

Publication: Current Directions in Psychological Science

Publisher: SAGE Publications

Date: 12/01/2005

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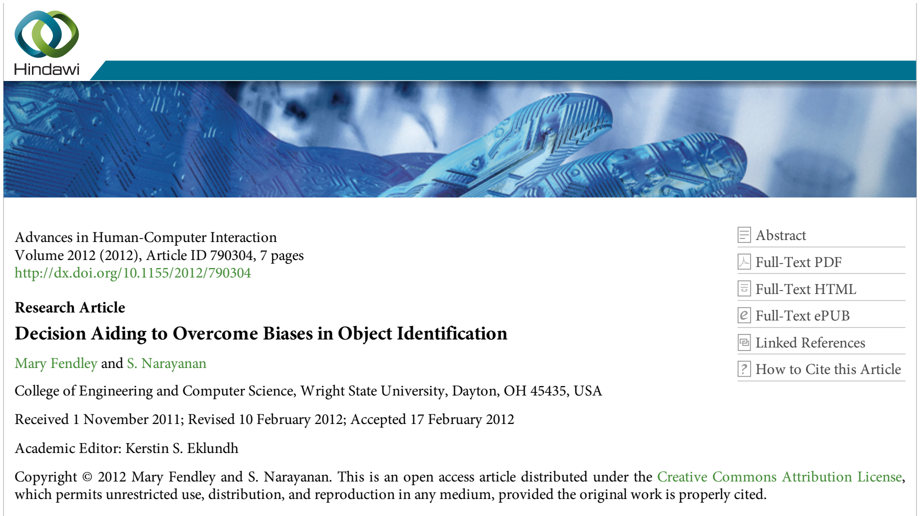
Table 4: Potential biases in object identification (Fendley & Narayanan, 2012)**:**



Advances in Human-Computer Interaction
Volume 2012 (2012), Article ID 790304, 7 pages
http://dx.doi.org/10.1155/2012/790304

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Research Article

Decision Aiding to Overcome Biases in Object Identification

Mary Fendley and S. Narayanan

College of Engineering and Computer Science, Wright State University, Dayton, OH 45435, USA

Received 1 November 2011; Revised 10 February 2012; Accepted 17 February 2012

Academic Editor: Kerstin S. Eklundh

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Table 5. Summary of Event-based or Activity-Based PM Publications in Which Retention Interval Has Been Manipulated adapted from (Martin et al., 2011) reprinted with permission**:**

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American Psychological Association

Title: Ongoing task delays affect prospective memory more powerfully than filler task delays.

Author: Martin, Benjamin A.; Brown, Noelle L.; Hicks, Jason L.

Publication: Canadian Journal of Experimental Psychology

Publisher: American Psychological Association

Date: Mar 1, 2011

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Subject: referencing document

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I am a master's student and would like to reference table 3.2 variables that affect prospective memory performance in R. Key Dismukes' publication entitled "Remembrance of Things Future: Prospective Memory in Laboratory, Workplace, and Everyday Settings" for my thesis. How may I obtain copyright clearance?

Thank you,
Michael Nickels

Figure 14: Knowledge dependency cycle (Li & Laird, 2013), reprinted with permission:

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From: Justin (Ning Hui) Li
To: m n

Two version of the original diagram is attached.

Yes, please do send me a copy after you've defended. Good luck!

Justin

```
 ___ Justin (Ning Hui) Li
(o,o) Computer Science
/)  ) University of Michigan
-"-"- justinnhli@gmail.com
```

On Sat, Jul 26, 2014 at 4:49 PM, m n <michael.nickels3@gmail.com> wrote:

> Justin,
>
> I appreciate it and the original figure would be helpful. I am interested in multi-tasking, primarily caused by interruptions, with (nonfocal) embedded prospective memory targets . I am investigating working memory capacity correlation with prospective memory performance. My work is relating these topics to help intelligence analysts so the experiments are visual search tasks in a more applied setting. If you interested, I can send you a copy after I defend it in a couple weeks.
>
> Mike
>
> ---
>
> **From:** "Justin (Ning Hui) Li" <justinnhli@gmail.com>
> **Date:** Saturday, July 26, 2014 at 4:17 PM
> **To:** m n <Michael.nickels3@gmail.com>
> **Cc:** John Laird <laird@umich.edu>
> **Subject:** Re: referencing document
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>
> Justin
>
> ```
>  ___ Justin (Ning Hui) Li
> (o,o) Computer Science
> /)  ) University of Michigan
> -"-"- justinnhli@gmail.com
> ```
>
> On Fri, Jul 25, 2014 at 5:04 PM, m n <michael.nickels3@gmail.com> wrote:
>
> > Hi,
> >
> > I am a master's student and would like to reference a figure (knowledge dependency cycle) from your publication titled "The Computational Problem of Prospective Memory Retrieval" for my thesis. How may I

Page 1 of 2

Figure 16: Illustration of the automated operation span task. In the task, a math operation is presented. After it is solved, participants click the mouse and a digit is presented, which is judged to be either correct or incorrect. This is followed by a letter for 800 msec. For recall, the correct letters from the current set are selected in the correct order. After recall, feedback is presented for 2 seconds (Unsworth et al., 2005)**:**

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