Individual differences in prospective memory: the roles of handedness and interhemispheric interaction

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Individual Differences in Prospective Memory: The Roles of Handedness and Interhemispheric Interaction

by

Aparna A. Sahu

Submitted to the Graduate Faculty as partial fulfillment of the requirements for the Master of Arts Degree in Psychology

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The role of interhemispheric interaction is confirmed by past studies on handedness that have shown a mixed handed advantage in recalling episodic memories. The current study aimed to investigate whether a similar pattern exists for prospective memory (memory for future intentions). The study was performed on undergraduate participants of the University of Toledo (N = 143) and incorporated cognitive tests to measure prospective memory (Memory for Intentions Screening Test), working memory (Digit span) and executive function performance (Pair Cancellation Task) and a meta memory questionnaire on one’s assessment of everyday memory (Everyday Memory Questionnaire). Handedness differences were not observed for prospective memory, although mean scores were nominally higher for mixed-handers. However, a significant female advantage was present. Further analyses showed a) positive associations between working and prospective memories and b) executive functioning was a significant predictor for prospective memory, both of these findings which were specific to females only. Finally, a concordance between meta memory and objective prospective memory scores was observed in females only. Results are discussed in the light of past research.
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List of Abbreviations

AIM……………. Assessment of Intentional Memory
ANOVA…………Analysis of Variance Test
CC…………….Corpus Callosum
EHI……………. Edinburgh Handedness Inventory
EMQ…………… Everyday Memory Questionnaire
HERA………….. Hemispheric Episodic Retrieval Asymmetry
LOC……………. Loss of Content
LOT……………. Loss of Time
MCI……………. Mild Cognitive Impairment
MIST…………... Memory for Intentions Screening Test
PET…………….. Positron Emission Tomography
PL……………… Place Losing
ProM…………… Prospective Memory
RBMT………….. Rivermead Behavioral Memory Test
RetM…………… Retrospective Memory
TS……………… Task Substitution
TWTE…………... Test Wait Test Exit
WAIS-IV………..Wechsler Adult Intelligence Scale- 4th edition
Preface

The concept of interhemispheric interaction is emerging as an important factor in successful episodic memory recall. This is supported by the Hemispheric Encoding and Retrieval Model (HERA) proposed by Tulving, Kapur, Craik, Moscovitch and Houle (1994) that demonstrated that the prefrontal areas show a distinct asymmetry wherein encoding of information takes place in the left hemisphere, and retrieval of the same information is performed by the right hemisphere. This finding implies that the transference of information between the hemispheres is carried out by the corpus callosum- a white matter band consisting of millions of nerve fibers that connect the two brain hemispheres.

Past research (e.g.: Witelson, 1985) has shown a connection between corpus callosum volume and strength of handedness- a behavioral measure for a person’s consistent ability to use one or both hands for gross motor activities. Thus, individuals are categorized as strong handers (consistently using one hand over the other for all activities) or mixed handers (use of the nondominant hand for at least a few activities). It has been observed that mixed handers have larger volumes of the corpus callosum and therefore tend to have increased interhemispheric communication between brain hemispheres than strong handers. In terms of memory processes, a mixed handed advantage is seen for episodic information retrieval (e.g.: Propper & Christman, 2004; Propper, Christman, & Phaneuf, 2005; Lyle, McCabe & Roediger, 2008).

These robust findings are reported for episodic memories which are retrospective in nature. Prospective memory, which is also categorized under episodic memory is a novel area in the memory field and remains yet unexplored from the interhemispheric
interaction context. Prospective memory deals with one’s ability to hold on to intentions or actions that need to be performed (e.g.: visiting the grocery store on the way home) in the near future. Imaging studies have shown that prospective memory processing requires the involvement of both brain hemispheres (Simons, Scholvinck, Gilbert, Frith & Burgess, 2006), with cerebral asymmetries seen for monitoring cues in the environment, checking-rechecking mentally about performing a task in the future at the required time, holding intentions (e.g.: Burgess, Quayle & Frith, 2001) while also being involved in other ongoing activities. This evidence further strengthens the possible role of interhemispheric communication. The current research was therefore undertaken to explore the neurological underpinnings using a behavioral measure for prospective memory.

The thesis also incorporated other variables such as working memory, executive functioning, metamemory and gender to check for similar evidence and to check for their contribution in prospective memory. Data was collected from the undergraduate students of the University of Toledo (N = 143), in exchange of research credits. Mixed factorial analysis of variance tests, correlations, and a regression analysis were conducted for statistical verification.

Results revealed that interhemispheric interaction as measured by handedness was not a significant factor in prospective memory processing. However, the non-significant findings could be attributed to other factors that need to be addressed in future studies. These include methodological issues, measurement instruments for prospective memory, and the sample demographic variable such as age. Age appears to play a key role as research suggests that the developmental pattern for both interhemispheric interaction
(specifically, the corpus callosum changes over a life span) and prospective memory follow the inverted “U” curve of development. With the current study sample controlled for age, perhaps re-performing the study with the middle and the older age groups might shed light on the interhemispheric processing patterns and its impact on prospective memory.

Besides this finding, the study also highlighted gender asymmetries in prospective memory processes. The few studies that have addressed gender asymmetries in prospective memory have shown a female advantage (e.g.: Penningroth, 2005; Tan & Ksivilashvili, 2003). The results could be supported by the intention superiority effect which suggests that females tend to hold intentions at higher activation levels and therefore recall easily the “to be” executed intentions than males. In addition to this, females showed positive associations between working memory, executive functioning and prospective memory thus confirming the roles of the other cognitive processes that aid in better recall of prospective memory processes.

Finally, females mixed handers showed a significant positive association between self-report daily monitoring abilities and performance on the prospective memory task. This could imply that females who show the interhemispheric interaction pattern tend to be aware about the cognitive functioning and therefore appear to make realistic judgments about their current prospective memory functioning. In addition, it could also be proposed that this group is more sensitive to changes in cognitive processing, and therefore in daily lives tend to resort to memory aids for optimal functioning.
Chapter One

Laterality- A Brief Introduction to Brain Asymmetry

The neurological organization of the human brain is characterized by lateral asymmetry (Banich, 1995) and each hemisphere performs specialized functions (Witelson, 1995). Besides possessing language abilities (speech production and comprehension), the left hemisphere is considered analytical, and while processing information, as evidenced in spreading activation paradigms, semantic networks are activated focally (Binder, Frost, Hammeke, Cox, Rao & Prieto, 1997). The right hemisphere, on the other hand is proficient in nonverbal aspects of cognition such as visuo-spatial functioning, manipulating and perceiving complex two and three objects in space (Hellige, 1993). It uses a holistic approach to process information, and according to priming experiments, a widespread activation in semantic networks is present (Strange, Henson, Friston & Dolan, 2000). However, this does not necessarily mean that cognitive processes are strictly compartmentalized and categorized within a single hemisphere of the brain.

Hellige (1993) highlights that, despite the existence of hemispheric asymmetries, both hemispheres have the ability to perform the same task. However, one of them might do better than the other because each hemisphere might be approaching a task in a different manner. This is evident when one of the hemispheres is damaged or when information to one hemisphere is received before the other. Every task consists of various components or sub processes and hemispheric asymmetry for one component need not be the same as that for another. Thus, it is not easy to state which hemisphere is superior for a multi-component task.
**Interhemispheric Interaction**

Interhemispheric interaction also referred to as the interaction between the two cerebral hemispheres (Harris, 1995) could account for the optimal processing capacity of the brain (Hellige, 1993). Such enhancement is viewed as being most apparent when tasks are cognitively challenging. Thus, there is a requirement for co-ordination between cerebral hemispheres or the specialized processing systems. The main advantage of having specialized processors is that performance can be enhanced by allowing several tasks to be performed and by allowing for parallel processing of different aspects of information (Hellige, 1993).

Interhemispheric communication takes place via the corpus callosum- a major white matter tract that connects the cerebral hemispheres. Evidence for this is obtained from case studies of missing or incomplete formation of the corpus callosum (agenesis), cases of callosotomy (severing of the corpus callosum to curb the spread of epileptic seizures) and unilateral brain damage (cf. Harris, 1995).

The corpus callosum is broadly divided into rostrum, genu, truncus, isthmus and splenium with varying number of callosal fibers that pass through them (Aboitiz, Scheibel, Fisher & Zaidel, 1992). Research shows that the corpus callosum areas connect homologous cortical areas (De Lacoste, Kirkpatrick, & Ross, 1985; Hellige, 1993; Witelson, 1989). Thus, anterior areas (the prefrontal areas) of the two hemispheres are connected at the genu. The middle portion that includes the truncus connects the motor and sensory regions. The posterior end that is the splenium and the isthmus connects the temporoparietal- occipital areas. The splenium is also known to connect the dorsal parietal and occipital regions (Banich, 1995; Hellige, 1993).
Handedness - A Behavioral Representation of Interhemispheric Interaction

Preference for the left or right side of sensory organs (such as ears and eyes) and extremities (upper and lower limbs) is associated with the corresponding involvement of the contralateral hemisphere. Handedness, a preference for using one hand over the other for gross or fine motor tasks, is considered the easiest and most reliable behavioral index for functional asymmetry. For example, when we write, the preference is usually to use one hand over the other. It is a common observation that the two hands differ in their efficiency in performing different activities. This shows that carrying out activities with one or the other hand reflects that one hemisphere’s hand control is better than or preferred over the other (Hellige, 1993). About 90% or more of the general population shows the right hand preference for a variety of tasks (irrespective of cross cultural differences, see Springer & Deutsch, 1997). In view of the contra-laterality evidence, the excess use and preference for the right hand indicates that the left hemisphere is dominant for hand control in these individuals.

Hand preference is used for measuring behavioral asymmetries in humans, although its inadequacy in measurement cannot be denied (Witelson, 1985). Issues related to measurement continue to resurface (Habib, Gayraud, Oliva, Regis, Salamon, & Khalil, 1991) with the most predominant one being on whether direction or degree (also referred to as strength) of handedness or both aspects should be considered as the primary measure of laterality. Direction of handedness (left versus right) has received most attention because of its relation to language lateralization, with right handers showing language in the left hemisphere and left handers having a right lateralized or bilateral representation of language. However, classification of patients and participants based on
strength or degree (consistent versus inconsistent) of handedness has played a role in categorizing more people in the handedness groups (specifically non right handers) with some amount of stability in the proportion of the data in a sample all of which affect statistical significance (Annett, 1970; Bryden & Steenhuis, 1991).

Witelson’s (1985) study on post mortem brains of non-neurologically diseased patients, showed an association between the degree of handedness and the corpus callosum size. Those individuals with consistent right hand preference had smaller corpus callosum size whereas non-consistent right handed individuals showed large posterior regions (the isthmus, differed by 11% as compared to the consistent right handed individuals) of the corpus callosum. Importantly, the sample in this study was males only. The key features of this study were:

a) studying handedness from an unconventional dimension (i.e. strength of handedness rather than direction of handedness);

b) associating this dimension of laterality to the corpus callosum, a brain structure that was not known to have an obvious link to handedness prior to this study.

Subsequent studies confirmed the presence of significant relations between the callosal size and degree of handedness (Denenberg, Kertesz & Cowell, 1991; Habib, et al., 1991; Witelson, 1989). However, inconsistent findings between hand preference and callosal size have also been reported to date (e.g.: Kertesz, Polk, Howell, & Black, 1987; Preuss, Meisenzahl, Frodl, Zetzsche, Holder, Leisinger, et al., 2002). Witelson (1992) suggested that the discrepancy in research findings could be a result of methodological differences such as: use of a high powered imaging machine (that have a high image resolution to facilitate better outlines of the corpus callosum using pixel counts) or digitized graphics.
to measure the corpus callosum, inclusion or exclusion of pure left handers from the sample, the method of determining handedness groups and the range of hand preference in participants. Denenberg et al. (1991) further included age and health differences amongst samples as possible reasons for the discordance in the research findings. They on the other hand, used stereology program and a statistical procedure to scientifically separate parts of the corpus callosum and were able to replicate Witelson’s findings about non-consistent male handers having larger isthmal areas than females and consistent male handers.

A metaanalysis of 43 studies by Dreisan and Raz (1995) aimed to check for differences in the corpus callosum morphology in respect to gender, age and handedness. The findings revealed that in appearance, the corpus callosum area and the splenium were found to be larger in males; Younger subjects were seen to have greater callosal volumes than older subjects, implying a degeneration of the white matter band of fibers with age. Finally, with respect to handedness, they found that left handed people had larger callosal areas as compared to right handed people. However, since the findings were based on only seven studies that had included handedness (as compared to 21 studies for age and 36 studies for gender) the authors expressed less confidence for this finding. Besides, the handedness groups were based on direction and not degree of handedness; thus the results of this study need to be interpreted with caution.

**Measuring and Classifying Handedness**

The Edinburgh Handedness Inventory (EHI, Oldfield, 1971), Annett’s handedness questionnaire (Annett, 1970), the Crovitz-Zener inventory (Crovitz & Zener, 1962) are
some questionnaires that assess handedness. The EHI is a widely used handedness measure in research studies.

This short scale asks about hand preference for ten common activities: writing, throwing, drawing, using a spoon, combing the hair, cutting with scissors, brushing teeth, cutting with a knife, opening jars, and holding a match while striking. When Oldfield (1971) administered the inventory in his study of over thousand students, it was found that only 5 - 10% of the scores constituted the left side of the distribution curve (laterality quotient scores ranged from -100 to +100) and the rest of the scores were seen clustered at the right end. It was also noticed that scores of the left handed people (at the negative end) was evenly distributed over the range of the negative values unlike the right handed participants. If degree of handedness were to be plotted on a graph in the form of continuous raw scores, the result would be a J curve frequency distribution of hand preferences (Annett, 1970; Peters, 1992). In this sense, some researchers thus prefer using a handedness classification based on this sort of distribution, and therefore divide the group of people into strong right handed and non strong right (a.k.a. mixed) handed (Springer & Deutsch, 1998).

Dividing the handedness group into strong and mixed handed dichotomy based on a cut-off is not yet standardized, although some researchers have attempted to classify the group based on performance of some of the questionnaire items. For example, Annett (2004) has introduced 8 sub-classifications based on consistency of responses for the items and cluster of items on the handedness questionnaire created by her. According to her, writing is considered as a single item and constitutes one of the classifications, whereas the writing hand preference, throwing, using a tennis racket, striking a match,
using a hammer and toothbrush are considered together as “primary” actions and constitutes another classification group. In the current study however, the median split method will be applied on the EHI group data in order to classify strong and mixed handed groups. This method has been used in prior studies that have focused on the magnitude of handedness (e.g., Christman, Propper, & Dion, 2004). According to Schacter (1994), the inclusion of strong and mixed handed people in the right handed group can mislead the results as there is a compromise on the statistical power. Thus it is suggested that handedness should have a trichotomous division (consisting of strong left handed, strong right handed and mixed handed). However, the incidence of strong left handed people in the population is only about 1-2% (Lansky, Feinstein & Peterson, 1988) and therefore to have an adequate sample for comparison purposes is difficult to obtain. In addition, most studies seek to understand the construct of handedness in terms of strong versus mixed (or also referred to as consistent right versus non consistent right handers). In the current study, the absolute values of the EHI will be considered (this implies that participants who obtain -100 are the strong left handers will also be categorized as the strong right handers) for the median split method.

**Interhemispheric Interaction Effects and Memory Processes**

A well-researched area in the sphere of memory is retrospective memory (hereafter referred to as RetM), which refers to the ability to remember information about past events, for example, recalling last night’s dinner menu, memory of previous conversations, (these are classified under episodic memory), the first President of the United States of America, some details of World War II and Hitler (these are classified
under semantic/declarative memory). Essentially, RetM answers the question “what is remembered?”

Studies with patients who have undergone disconnection of the corpus callosum provide evidence for interhemispheric interaction and the role of the corpus callosum in episodic retrieval. For instance, Cronin-Golomb, Gabrieli, and Keane (1996) performed two experiments to investigate explicit and implicit memory processes in two patients who had undergone forebrain commisurotomy for intractable epilepsy. In their first experiment, explicit memory measured by tests of recall and recognition was tested by presenting half of their word list interhemispherically (words are presented to the left visual field during encoding and are tested for recognition by presenting words in the right visual field; likewise words presented in the right visual field are tested for recognition by presenting words in the left visual field). The other half of the word list was presented intrahemispherically (words that are presented in the left visual field during encoding are tested for recognition in the same field; a similar procedure is carried out for the right visual field). After a delay period, the participants had to recall and then recognize the words shown to them. Results revealed impairment in explicitly recalling and recognizing words for both participants in both the hemispheric conditions. In their second experiment, they tested for implicit memory by presenting word stem completion task. This task typically consists of presenting three letters that could be the beginning of a variety of words, e.g.: a word stem STA could elicit words such as stand/ stanza/stake. Participants demonstrated within-hemisphere priming on the stem completion task, indicating that implicit memory can be accessed both intrahemispherically and interhemispherically as opposed to explicit memories. Based on these findings, Cronin-
Golomb et al. (1996) suggested that implicit memories can be shared between the hemispheres via subcortical structures. Their performances on the explicit memory task on the other hand, were impaired indicating that episodic memory cannot be performed intrahemispherically or interhemispherically in the absence of a certain set of commissures.

Metcalfe, Funnell and Gazzaniga (1995) demonstrated the independent ways in which hemispheres process information by performing memory based recognition experiments on a patient who had undergone severing of the corpus callosum. The findings suggested that the right hemisphere is better at discriminating between previously presented items and is also able to correctly reject new items that were not presented in the earlier list of items. The left hemisphere on the other hand, tended to falsely recognize the similar items. These findings suggested that the right hemisphere is specialized in veridical processing and the left hemisphere processes information in a more semantically elaborative manner thus leading to false recognition of items.

While clinical data clearly demonstrates difficulties in memory retrieval due to the absence of hemispheric co-ordination, studies with normal population using imaging techniques further confirm the crucial role of the corpus callosum in the interhemispheric exchange of information. Positron emission tomography (PET) studies have shown a distinct asymmetry in brain activation for episodic memories. During the encoding of episodic (explicit) information (which is novel in its first presentation and deeply encoded) there is increased activation of the left prefrontal areas (Kapur, Craik, Tulving, Wilson, Houle & Brown, 1994), whereas during the retrieval of the same information, the right prefrontal areas show a significantly higher activation (Tulving, Kapur, Craik,
Moscovitch, & Houle, 1994). Tulving et al. (1994) have named this model the Hemispheric Encoding and Retrieval Asymmetry (HERA) model of prefrontal activation. The model presents evidence on bilateral activity for episodic memories and also implies the role of the corpus callosum that transfers the information from the left hemisphere to the right hemisphere during retrieval. Researchers have studied asymmetry in terms of both process (encoding, retrieval) and material (verbal, nonverbal) specificity. Habib, Nyberg and Tulving (2003) have opined, the HERA is true for both verbal and nonverbal material and encoding and retrieval of episodic information regardless of the type of material gets lateralized to the left and right prefrontal brain areas respectively.

**Handedness and Episodic Memory**: Studies with neurologically intact individuals have shown a robust association between interhemispheric interaction measured by handedness (strong and mixed handed groups) and episodic memory processes. One of the earlier studies dealt with the recognition ability in a memory task measured by ‘remember’ versus ‘know’ judgments (Propper & Christman, 2004). Participants were shown words in the encoding phase whereas in the recognition phase they were asked one of the three choices; a) state whether the word was remembered (that is, based on being able to consciously recollect the word’s original presentation) or b) whether they knew that the word was presented to them before (in other words, whether the word was familiar) or c) whether they had guessed their responses about the word being presented in the study phase. Mixed handers had more “remember” judgments suggesting that they were encoding the information as episodic events, which were better recalled whereas strong handers were confident on “know” judgments suggesting that they were better at recognizing based on familiarity. A follow up study by Propper, Christman, and Phaneuf
(2005) was conducted to provide evidence for the presence of handedness differences in episodic retrieval. A list learning test was administered and the number of words correctly recalled and false alarms were measured. Mixed handers had significantly higher number of words recalled and fewer false alarms than strong handers.

Propper et al. (2005) performed another study to check if episodic memory findings in a laboratory set up can be generalized to the “real world” making this an ecologically valid study. Subjects were asked to write ten unusual events in their respective journals, which were defined as occurrences that differed from a participant’s normal routine, and the events could range from mundane to highly significant. Recall was measured in terms of the number of items they could recall from their journal after a week’s time. Mixed handers had a significantly higher recall than the strong handed group. Marginal differences were seen with the false alarm data, which showed that mixed handers had fewer false alarms than strong handers. In order to confirm if false alarms in memory paradigms differ by the handedness groups, another experiment was performed that made use of the Deese-Roediger-McDermott paradigm (Deese, 1959). The paradigm consists of semantically associated words that are read out to a participant, and more often than not, participants tend to false remember a word that was not presented in the list. This word is elicited because of the category that was mentally formed for the associated words (Deese, 1959). This study showed that mixed handers had fewer false memories than strong handers, thus confirming that the source memory was better in the mixed handed group where as information triggering off other clues in the memory related to the list of words was more apparent with the strong handed group (Christman, Propper, & Dion, 2004).
Further research was carried out by Lyle, McCabe and Roediger (2008) who sought to check for the role of interhemispheric interaction in verbal memory using neuropsychological tests such as verbal paired associates recall, face memory, and list learning presented on a computer screen and in the form of anagrams. A significant mixed handedness advantage was observed for source and verbal paired associates’ memory tasks however this was not the case for the face memory tasks.

Autobiographical memory another facet of episodic memory measured in terms of self reports about one’s earliest memories, was researched with the handedness groups (Christman, Propper & Brown, 2006). The study showed that mixed handers had a significantly high recall for earlier childhood memories than the strong handed group. This indicated that mixed handers had a shorter period for childhood amnesia and were quick to encode and be aware of personal memories. The researchers speculate that mixed handers tend to have better autobiographical memories as a result of better callosal volumes that aid in increased interhemispheric communication for better recall of memories from the distant past.

To summarize, interhemispheric interaction (as measured by handedness) is another crucial dimension that accounts for episodic memory processes. Individual differences persist in cognitive performances and these could be attributed to possible differences in the manner in which information is being processed in terms of the amount of interaction between hemispheres. Greater hemispheric interaction would be advantageous for carrying out several important cognitive tasks thus ensuring division of cognitive labor between hemispheres. Thus, mixed handers possess an increased interhemispheric interaction that facilitates better recall of episodic memories, than the
strong handers. These findings are consistent with brain imaging studies indicating that episodic and non-explicit memories are associated with bi-hemispheric and uni-hemispheric activity, respectively (Cabeza & Nyberg, 2000).

Other studies have also sought to understand the application of the interhemispheric communication to daily memory difficulties. Christman and Propper (2008) administered the Everyday Memory Questionnaire (EMQ- the scale is reviewed in the later section that covers the scales and tests used in prospective memory) and found that mixed handers were better at task monitoring and conversation monitoring than strong handers. An earlier report studied handedness effects using the Cognitive Failures Questionnaire (Christman & Ammann, 1995). However this study did not reveal significant handedness influences.

In view of the dearth in literature about the application of the interhemispheric interaction and daily memory difficulties that tap monitoring abilities, the current study was undertaken. The study aimed at objectively measuring everyday memory- called Prospective memory (or memory for future intentions) and relate it to the interhemispheric theory. Prospective memory is also considered a type of episodic memory. Due to its complexity in its processing, it may be speculated that such a memory process would also require interhemispheric interaction for better management. Thus, the current study is an exploratory one, to further provide support for the interhemispheric model and its role in memory processes.
Chapter Two

Prospective Memory

“Sometimes I can't recall; As I stand at the foot of the stairs, 
If I'm going up for something; Or I've just come down from there.

I intend to make a bowl of soup; I intend to speak to a friend 
I intend to do the laundry; after quarter past hour... I just cannot recollect.

Here I stand beside the mailbox; with my face so very red 
Instead of mailing you my letter; I have opened it instead.”

- Folksy poem

Prospective memory (hereafter referred to as ProM), a term introduced by Meachem and Leiman (1982) concerns with the ‘when’ or ‘if’ something is remembered. It is the ability to carry out future acts and intentions that are predetermined by a person and lays importance on planning, updating information when it changes and at times can even involve multi-tasking. Everyday life examples of ProM include putting a letter in the mailbox on the way home, remembering to turn off the oven, and calling someone at a scheduled time. It is suggested that other important cognitive functions such as memory and attention dominate ProM (Ellis, 1996). Groot, Wilson, Evans, and Watson (2002) explain the construct that not only encompasses all areas that concern ProM but also emphasizes on the complexity of this memory process:

“Prospective memory involves remembering to perform previously planned actions at the right time or within the right time interval or after a certain event takes place while being involved in other activities.” (p. 645)
ProM is also called ‘delayed intentions’ (Ellis, 1996) as intentions need to be remembered and acted upon at a later point in time when the need arises. Kliegel, McDaniel and Einstein (2008) state “… it is one in which the prior representation of an action leaves the focus of attention for some amount of time prior to the eventual execution of the action” (p. 36) e.g.: Remembering to pick up certain grocery items on the way back home from work.

Ellis (1996) theorized the following stages for a ProM task.

*Formation and encoding of intention and action:* This stage is characterized by i) *nature of an action* (what you want to do), ii) *intent* (what you have decided upon doing) and iii) a *retrieval context* that requires some recall (when the intent must be retrieved and the related action and when both should be initiated). Planning and motivation would most likely influence the encoding and the eventual representation of the delayed intention.

*Retention interval:* It is the delay between the encoding of the intention and the beginning of a potential performance interval.

*Performance interval:* It is the period when the intended action should be retrieved. The duration of retention and performance intervals will vary considerably and a delayed intention may be remembered at any point during either of the two phases.

*Initiation and execution of intended action:* After the above three stages are realized and are in place, and at the right time and context, the intended action would be initiated and executed.
**Evaluation of outcome:** Evaluating whether the intended action was carried out or not is an important task in itself. This helps either to avoid an unnecessary repetition of a previously satisfied delayed intention and ensures the future success of a postponed or failed delayed intention.

The successful realization of an intention requires that the intention be retrieved on at least one occasion during a performance interval and on the occurrence of the initiation and execution of intended action and evaluation of the outcome. Thus, first an appropriate situation must be recognized as an occasion that is 1) a retrieval context and 2) associated with a particular intention to do something. Second, the action that was encoded with these elements must be retrieved.

**Past Controversies and Issues Related to ProM**

As far as the inclusion of prospective memory is concerned, researchers failed to conceptualize the construct until the 1970s merely because ProM did not technically fit the Associationist models (these models studied the strength of association between the various levels of mental representation) that were common at that time. After the 1970s, with the growing interest in cognitive psychology and the broadening of the field, ProM studies began gaining some attention.

In the 1990s, when ProM studies had just begun evolving, two researchers, Crowder and Roediger questioned the construct of ProM and its relation with episodic memory. They accepted that memory has a prospective function of carrying out planned activities, such as taking medication at bedtime or remembering to convey a message on the next encounter with a colleague. However, the question raised by Crowder (1996)
was whether ProM was justified in incorporating the term “memory” because it would actually redefine or create some issue with an already well-constituted cognitive process of “memory”. Memory by definition is the ability to store, retain, and recall information. RetM reflects the core nature of memory; however there were contentions about the ability of ProM to meet a similar characteristic.

Roediger (1996) on the other hand was curious about the distinct structures and processes of ProM and whether they differ from the ones required for RetM tasks. He attempted to answer the question “what is ProM?” by searching for empirical evidence based on experimental manipulations, and developmental and neuropsychological variables. He found that findings from such studies showed a huge overlap between ProM and RetM tasks and thus, his aim to find pure measures for ProM tasks became stronger.

Over the last 10 years, there has been a huge body of research that studied ProM processes in depth and increased interest has arisen about its neurological and neuropsychological underpinnings. The accumulated research evidence has strong implications of this cognitive process in neurological (particularly head injuries, stroke) and psychiatric conditions (such as schizophrenia and depression).

According to Einstein and McDaniel (1990), ProM differs from RetM in that ProM requires people to remember intentions as initiated by themselves, whereas in RetM tasks, the experimenter initiates or requests remembering. Despite this fine distinction, they are still intertwined with each other. For successful completion of a ProM task, an intact RetM that constitutes recall of knowledge and information about that task activity is required. Besides the contributions of RetM, ProM also depends on the
frontal based cognitive functions such as executive function that facilitate successful completion of the intention.

Since ProM is considered a part of the episodic memory system, researchers were curious to learn if it also followed the characteristic ‘forgetting curve’ similar to RetM. Hicks, Marsh and Russell (2000) conducted a series of experiments to answer this question. The manipulation factor in these experiments was either the retention interval time (which is the duration of interval from the time the intention was mentioned till the time it was completed. The time decided for the recall of the ProM task was either 2.5 minutes or 15 minutes) or varying number of distracter tasks given during a constant retention interval of 15 minutes (either a single task, or switching between five tasks or having a single task with breaks in between) or a combination of the interval time and the number of distracter tasks. Contrary to the anticipation of Hicks et al., the findings suggested that with longer duration of the retention interval, the possibility of the ProM task being carried out was higher. In addition, when there were several distracting tasks during a retention interval, the intention was better recalled and executed. And with the combination of retention time and distracter tasks (with more distracters and longer retention interval), higher chances of carrying out a ProM task were present. These findings showed that ProM follows a different pattern of forgetting unlike RetM. Additionally, Hicks et al. (2000) explained that ProM requires a level of awareness because people are aware that in the near future an event is bound to occur and a corresponding reaction will be required, which is not necessarily the case with RetM. They also proposed that perhaps there are three distinct cognitive mechanisms contributing to better ProM performance associated with changes in the retention interval.
First, longer retention interval would consequently provoke the intention to occur several times; this would be independent of the number of intervening activities. Therefore, increasing the interval period could improve ProM performance over longer delays. Second, with an increase in the number of intervening activities, thoughts concerning the prospective task may occur with greater frequency during breaks, as one would be aware of a pending activity and perhaps be more cautious because of the presence of many interfering tasks in between. Third, retention intervals with breaks in between would often be perceived as psychologically longer than intervals filled with fewer or less densely occurring events.

Types of ProM

1) Habitual and Episodic ProM

Meacham and Leiman (1975) introduced this type of ProM. Habitual as the word suggests, refers to remembering the intended action, which is engaged in frequently and consistently, e.g.: brushing of teeth every morning upon entering the bathroom. Episodic on the other hand requires a person to carry out a specific task on a less frequent or an irregular basis or in different contexts, e.g.: calling a dentist to schedule an appointment, or going to the car mechanic for an overhauling of the car before the snow season. Meacham and Leiman (1975) argued that remembering habitual tasks was easier than episodic ProM tasks because of the potential role of the external cues of the environment (in continuation of the above example, entering a bathroom would be the environmental cue) that facilitated the execution of the task (brushing the teeth as an activity triggered
upon entering the bathroom every morning). Thus, the presence of preceding activities would help in carrying out a related pending activity.

2) Time based ProM and Event based ProM

Einstein and McDaniel (1990) distinguished between two kinds of prospective memory on the basis of the cues that trigger retrieval; whether they rely on self-initiated cues or on external cues. Thus, based on this, retrieval may be time-based or event-based.

**Time based prospective memory** requires performance of a task at a certain time or after a certain period of time has elapsed. It is akin to an “appointment keeping” process (Sellen, Louie, Harris & Wilkins, 1997). An example would be turning up at a meeting at 10:00 a.m. tomorrow. Time based ProM tasks are more difficult to assess and to carry out as there are no obvious cues, the environment does not usually provide retrieval cues (perhaps with the exception of clocks), and therefore, people must rely mainly on their own self-initiated monitoring of the perceived passage of time (Einstein, McDaniel, Richardson, Gyunn & Cunfer, 1995). However, time based ProM has higher ecological validity because many real-world situations involve retrieved intentions which often cannot be performed immediately but must be delayed or maintained in memory until there is an appropriate opportunity to perform them.

**Event-based prospective memory** requires an activity to be carried out in response to a certain external event or physical stimulus. An everyday example would be giving a message to a colleague in the next encounter. Studying event based ProM is easier to achieve since control on cues is based on the environment; it is external in nature and this helps in triggering a recollection (Einstein, Holland & McDaniel, 1992).
Einstein et al. (1992) propose that event based ProM is based on two components, cue identification and intention retrieval. Cue identification involves the detection of a cue event that signals the performance of an intended action; intention retrieval on the other hand, involves the retrieval of an intention from memory in order to execute the action. Based on these properties, Einstein and McDaniel (1990) draw structural similarities between a typical retrospective memory (particularly cued recall) task and the event based ProM. Yet, the key difference between the two is that the individual has to spontaneously recognize the cue in the environment than being reminded about it.

It is important to know that some events can be converted from a time based ProM to an event based ProM, e.g.: calling a friend at 6:00pm (time based); this can also remembered by encoding it by associating the call to the friend when a particular television series begins at 6:00pm and therefore remembering to call when the television serial starts takes the status of an event based task. However, it is important to acknowledge that time based ProM task considers an action appropriate when it specifically depends on the passage of time (Einstein & McDaniel, 1990).

The Roles of Ongoing Tasks and Target Cues in ProM

A ProM process is incomplete without ongoing tasks that occur between the moment the ProM task is encoded and executed. Ongoing tasks are analogous to activities that keep an individual busy in daily life while holding on to intentions and waiting to execute them at the right time. Several studies have emphasized on the characteristics of ongoing tasks that could either facilitate or delay ProM execution.
When two demanding tasks such as a ProM task and an ongoing task are being supervised and/or executed simultaneously, there exists a huge cognitive load and at times a certain compromise occurs for either one. For instance, in one of the experiments by Smith (2003), results indicated that performing an event-based ProM task concurrently with an ongoing task considerably slowed the processing on the ongoing task because of divided allocation of attention. However, the nature of the ongoing task would affect ProM performance. In order to test this, Marsh and Hicks (1998) carried out experiments where the difficulty level of the ongoing activities was manipulated while performing event based ProM tasks. In addition, if ongoing tasks and ProM tasks are embedded within one another and thus share similar characteristics (e.g.: memorizing a list of words and circling only those words which are specified by the experimenter) ProM task performances are not significantly affected. However, if an experimental paradigm demands a shift in the level of analysis (e.g.: where the ongoing task is about word association [ink- pen] the ProM task requires the participant to be alert that the cue word belongs to a specific category of liquids) ProM task is most likely going to suffer (Mäntylä, 1996). This finding is more apparent with the older than with the younger adults (Maylor, 1996). The findings of the Marsh and Hicks (1998) experiments are inconsistent with Hicks et al. (2000) wherein the latter had showed that demanding ongoing tasks in fact facilitate better ProM performance. However, to support their findings, they speculated based on the introspective reports that participants might have indulged in self reminders either during the distractor task performance or during the gap that existed when switching between distractor tasks.
Cues, on the other hand, are not necessarily reminders of an explicit ProM task. However they bring to awareness that an impending ProM task exists. Some studies have categorized cues in terms of their properties such as salience, complexity, and relatedness (Mäntylä, 1996). Other properties of cues such as familiarity and cue distinctiveness have also been studied in ProM tasks. In one study, McDaniel and Einstein (1993) found that unfamiliar target events and highly distinctive cues in the backdrop of a relevant context facilitate successful ProM retrieval. Marsh, Hicks and Hancock (2000) incorporated an experiment wherein participants were divided into two groups. One group received a match between the event based ProM task and the ongoing tasks; the ongoing task also played the role of cue identification. Thus, the ProM task was to press a key when palindromes appeared in a list of words; the ongoing task was to identify words with repeated letters. The other group received a mismatch between the event based ProM task (pressing a key when an animal name appeared in the list of words) and the ongoing task (rating each word for pleasantness). The results demonstrated that when a person is made to remember the intention, certain ongoing activities are instrumental in making the ProM cue more salient which in turn, brings the intention to mind more readily than when there is a mismatch between the intention and the ongoing task.

**Cerebral Asymmetries in ProM**

Several imaging studies reveal a bilateral frontal involvement (e.g.: Simons, Scholvinck, Gilbert, Frith, & Burgess, 2006) while performing a ProM task. This therefore could have an implication for the role of interhemispheric interaction. PET imaging studies have found that the left frontal pole and right ventrolateral prefrontal
areas are important for holding an intention (Burgess, Quayle & Frith, 2001; Okuda, Fujii, Yamadori, Kawashima, Tsukiura, & Fukatsu, 1998). When an additional load is placed on the working memory for a ProM task, there is an increase in the right middle frontal activation (Okuda et al., 1998). Interestingly, this area is also activated when there is an expectation that a ProM task needs to be executed. In addition, when an intention is realized and a ProM target is recognized than just being maintained, greater activation of the right thalamus and a decreased activation of the right dorsolateral prefrontal cortex are observed (Burgess et al., 2001). In a subsequent study by Burgess, Scott and Frith (2003), hemodynamic changes were observed in several other areas of the frontal lobe for ProM tasks. For instance, a double dissociation was found in the rostral regions with an increase in blood flow in the rostrolateral and a simultaneous decrease in the rostromedial regions at the time of executing a delayed intentions task. Simons et al. (2006) replicated this finding during cue detection and intention retrieval functions for event based ProM tasks. In addition, they found the extra frontal areas, that is the lateral prefrontal cortex and the parietal cortex activated; these areas project the role of sustained attention and vigilance for visual stimuli. Specifically, for cue detection, they found the anterior cingulated cortex whereas for the intention retrieval, the posterior cingulate cortex and the precuneus were activated. Electrophysiologically speaking, similar regions are also reported as active or having slow wave discharges during event related potential analysis of ProM activity (West, Jakubek, & Wymbs, 2002).
ProM and the Contribution of Other Cognitive Processes

**Working memory.** Research has also raised questions about the involvement of working memory in ProM tasks. Working memory, a theoretical concept introduced by Baddeley and Hitch (1974), refers to holding of information in the online present activity with a limited-capacity “workplace” that can be divided between storage and control processing. It consists of three components: a) The central executive that directs the flow of information, the type of information that needs to be processed, how and when the information would be processed; b) The phonological loop which carries out the subvocal rehearsal to maintain verbal information; c) The visuo spatial sketchpad that is used to maintain visual material through visualization. Park and Payer (2006) further clarify that working memory integrates not only storage of information but also an active processing and evaluating of this information.

However, several working memory studies revealed that the model had lacked in terms of the integration of information from all modalities to form a temporary representation. Researchers were becoming convinced that the central executive was not a sufficient component for dealing with complex information. Thus, a fourth component was added to the model called the *episodic buffer*. According to Baddeley (2000), “… the buffer serves as an interface between range of systems, each involving different sets of codes” (p.421). The buffer accommodates the role of conscious awareness, ensures the participation of the other working memory systems, and also assimilates information from the long term memory for a rich cognitive representation (Baddeley, 2000).

Ellis (1996) points out that in the fourth stage of the ProM task, (the initiation and execution phase) there might be a possible role of the working memory. In the prior
phase of monitoring for executing the task at the appropriate time, there is a requirement for holding the information in the online processor. In addition, in daily lives, a ProM task is not necessarily performed immediately (this is also referred to as the delay execute ProM task) and therefore the delay calls for the role of working memory to hold on to the task information until the right time arrives for the execution (Einstein et al., 2005).

When a retrieval of a task is due to happen sometime soon, and the working memory is already preoccupied with another activity, or other online processing of information, a ProM task execution is likely to suffer (Kliegel & Jáger, 2006).

Marsh and Hicks (1998) demonstrated that occupying the articulatory loop of working memory during the ongoing activity had little effect on the accuracy of ProM. However, occupying the central executive of working memory or dividing attention with a demanding ongoing task that required monitoring potentially disrupted the efficiency of event based ProM (Einstein, Smith, McDaniel, & Shaw, 1997; Marsh, Hancock, & Hick, 2002; Marsh & Hicks, 1998). Similar findings were reported in another study that had participants in either low or high demanding working memory conditions embedded within time or event based ProM (Kidder, Hertzog & Morrell, 1997; Logie, Maylor, Della Salla, & Smith, 2004; Parente, De Taussik, Ferreira, & Kristensen, 2005). These results together suggest that when the working memory is already processing demanding activity, a concurrent ProM task execution is compromised. Based on the evidence, it can be stated that the working memory has a potential role in the execution of a ProM task.
**Metamemory.** Meta memory is a term that represents one’s knowledge, perceptions and beliefs about the functioning, development and capacities of one’s own memory and the human memory system (Dixon, 1989). There are four dimensions that are associated with metamemory:

a) *Memory knowledge*: factual knowledge about memory tasks and memory processes,

b) *Memory monitoring*: self knowledge about how one uses and knows the current state of one’s memory,

c) *Memory self efficacy*: refers to one’s sense of mastery within the memory domains. It also refers to one’s attitude and affect related to memory abilities and

d) *Memory related affect*: involves a variety of states that may be related to or generated by situations where optimal memory processing is required. Such a demand could elicit affective states such as anxiety, depression, fatigue etc.

Several documented studies on metamemory and ProM are conducted with the geriatric population because ProM failures are most unique to in old age.

As is already discussed in the previous sections of the thesis, ProM strongly depends on one’s ability to assess the strength of the ability to memorize about future events. This self analysis represents metamemory and based on one’s evaluation and awareness about ProM capacities, one tends to use compensatory devices such as external memory aids for prompt reminding, E.g.: use of PDAs, daily planners. Several studies have concentrated on the role of metamemory on RetM processes. Meeks, Hicks and Marsh (2007) carried out a study on college students to find out whether people are good
at predicting their performance on a ProM task. Their findings suggest that people are generally aware about their memory capacities, which helps in assessing their ProM performance. They also found that people judge their memories to be bad when in fact they perform better on memory tasks. The possible reason for this could be that they remembered memory failures more than memory successes. Zeintl, Kliegel, Rast, and Zimprich (2006) conducted a study with the aged population that was divided on the basis of high and low complainers and found a significant positive association between subjective complaints and objective ProM performance, further confirming the role of metamemory in assessing one’s ProM.

McDonald-Miszczak, Gould, and Tychynski (1999) in their study, had metamemory (memory for self efficacy) as a predictor for ProM processes (both time and event) and RetM processes in the older population. Significant predictors were metamemory and locus of control for time based ProM and event based ProM respectively. The authors speculated that time based ProM has increased demands on internal control (such as keeping track of time, recurrent checking et cetera) and therefore influences one’s awareness and the opinion about memory capacities. On the other hand, in event based ProM, since the cues are external to a person, such that, if the occurrence of the cue can trigger a memory, the increased importance for such realization lies within the individual, and therefore locus of control would have had a role to play.

**Measuring ProM**

Memory performance and accuracy are assessed subjectively by the administration of self report scales as well as objectively by using performance based
tests. Scales such as the Prospective Retrospective Memory Questionnaire (Crawford, Smith, Maylor, Della Salla & Logie, 2000), Cognitive Failure Questionnaire (Broadbent, Cooper, Fitzgerald, & Parkes, 1982), and Prospective Memory Questionnaire (Hannon, Gipson, Rebmann, Keneipp, Sattler, Lonero, Day & Bolter, 1990) measure ProM subjectively. Several tests such as the Rivermead Behavioral Memory Test (Wilson, Cockburn & Baddeley, 1985), the Cambridge Test of Prospective Memory (Wilson, Shiel, Foley, Emslie, Groot, Hawkins, & Watson, 2005) and the Memory for Intentions Screening Test (MIST, Raskin, 2009) have been used in the past to assess ProM. In the current study, the MIST will be used for the objective measurement of ProM particularly because of its short duration in administration.

The MIST was created by Raskin and Buckheit (Raskin, 2009) and is an extended version of the Assessment of Intentional Memory (AIM). The test is characterized by a) formation of a conscious intention, b) a delay period between encoding and execution of the intention, c) the presence of secondary ongoing tasks that play the role of distracters and, d) the person’s awareness of the cues and/or prompts in the environment. In addition, the MIST consists of i) a series of multiple choice recognition questions on the specific items that were presented during the test. These questions are asked at the end of the test and represent the retrieval memory index and, ii) it contains a 24 hour item to approximate the time span of actual memory for intentions in daily life (Raskin, 2009).

In addition, the MIST has a classification scheme for a ProM failure. These include

- ProM errors: Absence of response

- Task substitution (TS): Performing an action for a verbal response
- Loss of content (LOC): Recalled an incorrect task/inability to recall the task at the correct time

- Loss of time (LOT): Recall of a correct task at the incorrect time

- Place losing (PL): Performing only part of the task or repeating a previous task

- Random errors: When the error does not fit any of the above five categories.

The test takes about 30 minutes to complete and aims at being ecologically valid. The main ProM tasks are interspersed with word search puzzles that take the role of the ongoing distracter task.

The MIST was validated against the Rivermead Behavioral Memory Test (RBMT), a test to measure everyday memory abilities in people with acquired nonprogressive brain injury. The resulting correlation between the MIST and RBMT was 0.80. The MIST provides two forms, A and B, and the inter form reliability was found to be high ($r = 0.89$). Woods, Moran, Dawson, Carey and Grant (2007) have tested for split half reliability using the Spearman Brown coefficient and reported a high correlation ($r = 0.70$). A moderate inter item reliability is present (Cronbach’s alpha = 0.48).

To summarize, literature suggests that interhemispheric interaction dominates encoding and retrieval of episodic memories in the normal brain. This was further corroborated by an imaging study that demonstrated the bi-hemispheric involvement and the implicit role of the corpus callosum. Prospective memory, a memory process for future execution of tasks encoded episodically, is a complex cognitive process that requires the role of several other cognitive processes such as working memory, executive
functioning, meta memory to name a few for its optimal functioning. Imaging studies have shown the involvement of both brain hemispheres at various levels of its execution. In view of the already present evidence for its neurological underpinnings, the current thesis proposes to check for the role of interhemispheric communication via a behavioral measure- handedness.
Chapter Three

Rationale for the Study

The thesis presents evidence for interhemispheric interaction and its association to memory processes. Strength of handedness appears to be strongly associated with interhemispheric interaction. Brain imaging techniques further support the bilateral nature of functioning in memory.

The current study primarily aimed at gathering evidence for interhemispheric interaction for another episodic memory process – ProM. Following the literature that suggests a bilateral involvement for ProM as well, it was logically presumed that a similar trend might be present for ProM as well.

In addition to the primary goal, there are some farfetched implications for this study. The study indirectly aims at bridging the gap between lateral asymmetry framework and its practical applications to human cognitive processes.

A significant finding could have beneficial implications for the clinical neurological population such as, young adults who have sustained brain injuries (mild, moderate) and the elderly, who might meet criteria for specific neurological conditions such as Mild Cognitive Impairment (MCI) and Alzheimer’s disease. Research suggests that adults who have sustained brain injuries show significantly more ProM errors (no response during ProM tasks). Karantzoulis, Troyer, Murtha and Rich’s study (as cited in Raskin, 2009) showed that the MCI group had significantly more ProM and loss of content errors, more number of errors in time based than event based ProM tasks, and performed significantly worse on the 24-hour delay task and the recognition component.
of the MIST. Similar findings by Pearce and Raskin (as cited in Raskin, 2009) are reported for the Alzheimer’s disease group. Based on the evidence presented between handedness and episodic memory, mixed handers are often at an advantage for memory processing. Thus, it is possible that handedness, just like gender and age can play a potentially important role for evaluating the outcome of a disease condition.

Besides playing a role in prognosticating a neurological condition, handedness research for ProM can also contribute to rehabilitation of individuals with cognitive impairments. In particular, past studies have shown that left-right horizontal eye movements facilitates access to information across hemispheres and therefore elicits better explicit memory performances for the strong handed group (Christman, Garvey, Propper & Phaneuf, 2003; Christman, et al., 2004). Thus, if the current study produces significant results or emerging trends with handedness as a potential variable, performing the ProM study along with bilateral eye movements could play a potential role in improving cognitive performance for such individuals.

The current study aimed at administering a battery of cognitive tests. It included the MIST (with 6 subscales- time, event, 2 minutes delay, 15 minutes delay, verbal based and action based) to measure performance based ProM, digit span (forward and backward spans) for working memory, and pair cancellation task for executive functioning. In addition, two scales were administered- the handedness inventory and the everyday memory questionnaire.
Chapter Four

Research Hypotheses

I) Primary Hypotheses

1) It was hypothesized that a significant interaction between handedness and ProM would be present, with mixed handers showing better performance than strong handers on both time and event ProM of the MIST. In other words, increased interhemispheric communication would facilitate collaboration between several processes that function independently in various parts of the brain and therefore aid mixed handers to retrieve an intention better than strong handers. In the context of ProM, the multi-process framework could support the hypothesis further. The theory is a combination of attentional and memory processes in addition to monitoring and spontaneous retrieval mechanisms that would aid in better ProM recall. Increased monitoring would require intentionally keeping a track of events/time, and spontaneous retrieval mode would be facilitated by the external cues presented by the environment that would trigger certain memory for events.

Within time based ProM, it was hypothesized that mixed handers would perform better than strong handers on the 15 minute delay condition of the time based ProM. As proposed earlier, bi-hemispheric involvement, and exchange of information, would ensure increased monitoring; however, with long retention intervals, there might be a probable involvement of a sub vocal reminder (thus referring to the metacognitive component). Therefore, mixed handers would be at an advantage to perform a longer delayed time based ProM task than strong handers. In relation to ProM, this hypothesis could be explored further with the test-wait-test-exit (TWTE) mechanism that was
originally proposed for monitoring behavior and has been applied to time based ProM (Harris & Wilkins, 1982). According to this process, situations would be monitored recurrently till it is time to execute a task because a delay in responding could result in a loss.

2) It was hypothesized that mixed handers would perform better for both verbal and action based ProM tasks than strong handers. This ProM task is characterized by response modality. Instructions for both verbal and action based ProM are administered verbally for future recall. Based on past studies on retrospective memory, there exists a mixed handed advantage for recalling information and therefore it is expected that the same shall be the case for ProM.

3) In order to rule out the effects of gender on ProM, it is hypothesized that both males and females would perform similarly in the six types of ProM measured by the MIST.

II) Correlational Hypotheses

Other variables of interest such as working memory, executive functioning and a self report measure about daily memory were incorporated in the study. These were put through statistical analyses along with ProM to check for possible associations. In addition, secondary analyses were undertaken whereby the sample was further divided based on the strength of handedness and gender to find the source of significant findings, if any. The following are the proposed hypotheses:
1) Based on past literature, working memory has been considered to be an important cognitive process for the execution of a ProM task. In view of its role, the current research also aimed to find associations between the working memory capacity and performance on the ProM tasks.

2) A correlational analysis was performed between ProM and executive functioning. In order to monitor the intention while carrying out an ongoing activity, executive functioning is considered to be an important component for effective ProM execution.

3) A correlational analysis was attempted between the performance on ProM and the one’s impression about everyday memory as assessed by a questionnaire. This was done in order to check if there exists a concordance between subjective and objective measurements of ProM.

III) Regression Analysis

A regression analysis was performed by incorporating gender, handedness, working memory and executive function as potential predictors for performance on ProM (total score on the MIST). This was attempted for exploratory purpose in order to ascertain if the other variables can successfully predict ProM performance.
Chapter Five

Methods

Participants

A total of 159 participants from the undergraduate subject pool of the University of Toledo were recruited for the study in exchange for research credits. Prior to data collection, a Power analysis revealed a requirement for 136 participants for the study based on a large effect size of 0.80 and an alpha level of 0.05. Participants were screened for the presence of any psychiatric or neurological disorders. There were ten participants with a probable medical history of benign epilepsy, mild brain injury, benign cerebral tumors or dyslexia. The presence of these data did not affect the main parametric statistical analyses and therefore were considered as part of the sample.

Procedure

Each participant was tested on the cognitive battery on an individual basis. At the outset of the study, the participant was given the informed consent form. Following that, he/she participated in a one hour battery of cognitive tests that included (in the order mentioned): the Digit Span Test (of the Wechsler Adult Intelligence Scale- fourth edition), Pair Cancellation Task (it is a task that was created and closely resembles the original Pair Cancellation Test of the Woodcock-Johnson-III Test of cognitive abilities battery), the MIST, and the self report questionnaires (Edinburgh Handedness Inventory, and the Everyday Memory Questionnaire). After the completion of the questionnaires, the participant was debriefed about the study, thanked for participating, and escorted out of the testing room.
**Materials & Scoring**

The MIST: This half hour test required the participant to follow instructions given by the experimenter while being engaged in an ongoing task (word search puzzles). A digital clock was provided on the table for the participant to keep track of time (for time based tasks). Objects such as a red pen, a postcard, and a tape recorder were presented during the testing scene for event-based ProM tasks. In case participants made a note of the task or the time, the experimenter requested them to erase the information and refrain from doing so during the study. Seating arrangements and administration was followed as per the instructions provided by the author of this test. The MIST measures variables (hereafter will be referred to as subscales) such as type of cue (time, event), type of response (verbal, action) and the effect of the length of delay period (2 minutes delay, 15 minutes delay). Thus each instruction is characterized by the above sub scale attributes, e.g.: a time based ProM task that requires a verbal response to be executed after 15 minutes. A total of 8 trials or tasks represent the MIST and each subscale (time/event/verbal/action/2 min/15 min) comprises of 4 trials.

A few instructions in the MIST were replaced in the original scale (trials d, e, and f) in keeping with the request made by the Institutional Review Board at the University of Toledo. The items specifically asked for the participant’s address, name of the doctor, and names of one’s current medications that were thought to violate one’s personal information. These items were replaced by relevant items (note: The task items that were modified have an asterisk sign). The tasks are as follows (in the order of presentation along with the corresponding cue, response modality and the delay period):

a) In 15 minutes tell me it is time to take a break *(time, verbal, 15 minute delay)*
b) When I show you the red pen, sign your name on the paper (the Experimenter points to the word search puzzle sheet) *(event, action, 15 minute delay)*

c) In 2 minutes, ask me what time the session ends today *(time, verbal, 2 minute delay)*

d) When I hand you a postcard, write down the classroom in which you have your discussion/lecture for Psychology 1010 *(event, action, 15 minute delay)* *

e) When I hand you a course request form, write the name of your TA/psychology professor who holds the discussion section/psychology lectures for the 1010 course *(event, action, 2 minute delay)* *

f) In 15 minutes, use the paper (the experimenter points to the word search puzzle sheet) to write the number of courses you are currently taking *(time, action, 15 minute delay)* *

g) When I show you my tape recorder, tell me to rewind the tape *(event, verbal, 2 minute delay)*

h) In 2 minutes please tell me two things you forgot to do this past week *(time, verbal, 2 minute delay)*

The MIST was scored according to the guidelines provided by the author. Time based ProM tasks have a scoring system of 0 (no response), 1 (partial credit) and 2 (full credit if the task was correctly executed). Event based ProM tasks have an all or none scoring system of 0 (no response/incorrect response) and 2 (full credit for the correct response). The range of scores that can be obtained for each subscale is 0 to 8. A summary score, which is the cumulative of all 6 subscales, ranges from 0 to 48 (Woods, Moran, Dawson, Carey, & Grant, 2007).
Responses by the participants are predominantly based on their alertness for the
cues (either internal as required for time based or external which are characteristic of
event based). Thus, if the participant forgot to respond to a cue (time or event) the
experimenter did not remind him/her about it. Following the eight trials of the MIST, a
recognition test consisting of eight questions, each with three response choices was
provided. Each correctly recognized answer weighed one point, thus, total recognition
scores ranged between 0 and 8. The recognition scores are independent of the main tasks
and were not meant to influence the scoring of the main ProM tasks. Thus, for instance, if
the participant correctly identified the item during recognition trial however had forgotten
to give that response during the main task (in other words, the participant did not respond
to the cue and therefore has missed the point) he or she was not assigned a
corrected/prorated score.

At the end of the test, each participant was given a slip of paper with an email
address on it. The participant was requested to email after 24 hours (an interval of +/- 1
hour was permitted) and report the numbers of hours of sleep obtained that night (note:
the modality of the contact was modified from calling a specific phone number as is in
the original test to emailing the information to a specific web address for logistic
purposes.)

**Digit Span**: is a measure for assessing working memory capacity. This verbal subtest of
the Wechsler Adult Intelligence Scale- fourth edition (WAIS-IV) consists of forward and
backward immediate recall. There are two trials for each string of numbers. The
maximum possible raw score on the forward is 9 (minimum = 2) whereas on the
backward is 8 (minimum = 2). A combined score of digit span forward and backward
forms the total digit span raw score (minimum = 4, maximum = 17). Immediate recall was obtained once the entire string was read out at a rate of one number per second. If the participant successfully completed the two trials for each string of numbers, then the experimenter proceeded to the subsequent longer trial.

**Pair cancellation task** (adapted from the Woodcock-Johnson-III-Test of cognitive abilities battery): consists of an 11.7 x 8.3 inch sheet of paper with three stimuli (dog, cup and soccer ball) presented in a random order across 21 rows. In all, there are a total of 483 stimuli. The participant is instructed to circle the pair that consists of the soccer ball immediately followed by the dog. There are 71 pairs on the sheet. Before the administration of the cancellation sheet, a practice trial with three rows of stimuli is presented to the participant. Any error during the practice trial is brought to the participant’s attention. A correct identification of the pair is considered a ‘hit’; if the participant circled an incorrect pair (e.g.: the cup first then the soccer ball) or an incorrect order (dog followed by the soccer ball), then it was considered a false alarm. If the participant failed to notice the pair, then that was considered a ‘miss’. The main task is timed and the total number of seconds taken to complete the task is recorded.

**Edinburgh’s Handedness Inventory (EHI):** The inventory asks questions on hand preference for activities such as writing, throwing, drawing, using a spoon, combing the hair, cutting with scissors, brushing teeth, cutting with a knife, opening jars, and holding a match while striking. Subjects are asked to indicate the strength of preference on a Likert scale: ‘always left’ is scored as -10, ‘sometimes left’ scored as -5, ‘no preference’ scored as 0, ‘sometimes right’ scored as +5 and ‘always right’ scored as +10. Thus, scores range from –100 (perfectly left-handed) to +100 (perfectly right-handed).
Everyday Memory Questionnaire (EMQ): The questionnaire consists of 28 items that assesses the subjective opinion about one’s memory and also taps into the metacognitive aspects of memory abilities. Five factors constitute this questionnaire. They are retrieval (6 items), task monitoring (8 items), conversational monitoring (5 items), spatial memory (4 items) and memory for activities (5 items). Each item describes an everyday activity, which most possibly has the characteristic of being forgotten. The item scores are added for each factor. Thus, six scores are obtained that comprise of the five factor scores and the total of the five factor scores (total scores can range between 28 and 252). The participant had to rate the frequency of the forgetting experience on a 9 point likert scale that ranges from not at all in the last six months (score of 1) to more than once a day (score of 9) (Cornish, 2000). Therefore, higher the score on any of the factors constituted increased trouble in that area of everyday memory.
Chapter Six

Statistical Analyses

2 x 2 x 2 mixed factorial analyses were conducted with two between subjects factor with two levels; they were strength of handedness (mixed handers versus strong handers) and gender (males versus females). Three different within subjects factors with two levels were examined for each mixed factorial analysis. They were time based versus event based scores, 2 minutes versus 15 minutes scores and verbal versus action scores. Thus a total of three mixed analysis of variance tests (ANOVA) were conducted to test the hypotheses proposed in this study. In the presence of significant interactions, tests of simple main effects were performed to explore the nature of the interaction.

In addition, correlational analyses between ProM and working memory and the self report measure using the EMQ were carried out for the entire group and after dividing the group based on handedness and gender. Finally, a regression analysis was performed with gender, handedness, and working memory as predictors for ProM.
Chapter Seven

Results

Demographics: Data from 16 participants were excluded from the sample \((N = 159)\). Three participants had missing data on the EHI and therefore the data were treated as incomplete. Three participants had minor issues in comprehending the instructions and therefore several MIST instructions had to be repeated several times thus defeating the purpose of the test. Therefore, on the discretion of the experimenter, these data were excluded. Seven participants whose age was three standard deviations (SD) above the mean were counted as outliers as the study specifically sought to control for age in view of evidence that suggests age influence on ProM performance. Three participants were considered as outliers based on their low MIST scores, which were beyond three SD from the mean. Thus the total sample used for the analysis was 143 (males = 63, females = 80) and the mean age of the sample was 19.06 years \((SD = 1.14)\).

In order to classify and differentiate between the strong and the mixed handers, a median split was performed on the absolute EHI total scores of the participants. (Scores on the EHI range from -100 to +100. For categorization purposes, negative values were treated as absolute values). The median for the sample was 85, and participants who scored 85 or above were categorized as strong handers \((n = 73)\), and those who scored 80 and below were mixed handers \((n = 70)\).

MIST analysis:

Scores on all six subscales of the MIST and the recognition score were considered for the analyses. However, the 24 hour delay data was not considered for the current
Several responses via email were received later than expected either due to server problems, or unavailability of a computer or other logistical issues (not being in town, illness et cetera) as reported by several participants. In view of the unevenness of responses, the data was not considered for further analysis.

Table 1

Mean scores (SD) of the six sub scales and the total score of ProM (MIST) across handedness and gender groups

<table>
<thead>
<tr>
<th></th>
<th>Strong Handers</th>
<th></th>
<th>Mixed Handers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 27)</td>
<td>Females (n = 46)</td>
<td>Males (n = 36)</td>
<td>Females (n = 34)</td>
</tr>
<tr>
<td>Time</td>
<td>6.85 (1.10)</td>
<td>7.02 (1.04)</td>
<td>6.92 (1.05)</td>
<td>7.24 (0.92)</td>
</tr>
<tr>
<td>Event</td>
<td>6.81 (1.39)</td>
<td>7.35 (1.20)</td>
<td>7.17 (1.30)</td>
<td>7.59 (0.96)</td>
</tr>
<tr>
<td>2 minutes</td>
<td>7.81 (0.55)</td>
<td>7.91 (0.41)</td>
<td>7.83 (0.51)</td>
<td>7.94 (0.34)</td>
</tr>
<tr>
<td>15 minutes</td>
<td>5.85 (1.46)</td>
<td>6.46 (1.60)</td>
<td>6.25 (1.75)</td>
<td>6.88 (1.32)</td>
</tr>
<tr>
<td>Verbal</td>
<td>7.78 (0.58)</td>
<td>7.67 (0.63)</td>
<td>7.67 (0.53)</td>
<td>7.76 (0.55)</td>
</tr>
<tr>
<td>Action</td>
<td>5.89 (1.55)</td>
<td>6.70 (1.41)</td>
<td>6.42 (1.70)</td>
<td>7.06 (1.13)</td>
</tr>
<tr>
<td>Total Score</td>
<td>41.00 (4.99)</td>
<td>43.11 (5.27)</td>
<td>42.25 (5.84)</td>
<td>44.47 (4.21)</td>
</tr>
</tbody>
</table>

Table 1 displays the mean scores (and the standard deviation) for the six subscales across gender and handedness groups. Results revealed better performance by females ($M = 43.69$) than males ($M = 41.71$) on the MIST. A similar finding was evident with mixed handers ($M = 43.33$) displaying higher means than strong handers ($M = 42.33$) across almost all scales. The data is graphically represented in figure 1.

Three Mixed ANOVAs were performed with two between subject’s factors (handedness and gender) each with two levels and one within subjects factor (ProM) with two levels. (Note: Mauchley’s test of sphericity was not reported because the within subject’s factor consisted of only two levels). Levene’s test for homogeneity of error variances was violated for event ProM ($F(3, 139) = 4.163, p = 0.007$) and action ProM


\(F(3,139) = 3.622, p = 0.015\). Although transforming the data was an option in view of the violation, the raw scores were used because of the robust characteristic of the ANOVA. In addition the ratios of the largest to the smallest group sizes and variances are not grossly wide for the consideration of transformed data.

\[F(1,139) = 2.225, p = 0.138, \eta^2_p = 0.016\]. A significant between subjects’ main effect of gender was present for time and event ProM, \(F(1,139) = 6.112, p = 0.015, \eta^2_p = 0.04\) with females performing better \((M = 7.28)\) than males \((M = 6.95)\). There was an emerging trend for the within subject main effect for ProM, \(F(1,139) = 3.248, p = 0.07, \eta^2_p = 0.02\) with overall better performance for event ProM \((M = 7.26)\) than for time ProM \((M = 7.01)\). No significant two way interactions between ProM and gender \((F(1,139) = 0.887, p = 0.348, \eta^2_p = 0.006)\), ProM and handedness \((F(1,139) = 0.402, p = 0.527, \eta^2_p = 0.003)\) and for the three way interaction between ProM, gender and handedness \((F(1,139) = 0.276, p =\)

Figure 1. Mean MIST total scores for the gender and handedness groups.

In the first mixed ANOVA, time and event ProM were considered as the within subject factor. No main effect for handedness was present \((F(1, 139) = 2.225, p = 0.138, \eta^2_p = 0.016)\). A significant between subjects’ main effect of gender was present for time and event ProM, \(F(1,139) = 6.112, p = 0.015, \eta^2_p = 0.04\) with females performing better \((M = 7.28)\) than males \((M = 6.95)\). There was an emerging trend for the within subject main effect for ProM, \(F(1,139) = 3.248, p = 0.07, \eta^2_p = 0.02\) with overall better performance for event ProM \((M = 7.26)\) than for time ProM \((M = 7.01)\). No significant two way interactions between ProM and gender \((F(1,139) = 0.887, p = 0.348, \eta^2_p = 0.006)\), ProM and handedness \((F(1,139) = 0.402, p = 0.527, \eta^2_p = 0.003)\) and for the three way interaction between ProM, gender and handedness \((F(1,139) = 0.276, p =\)
0.60, $\eta_{p}^2 = 0.002$) were present implying no group differences in the performance of the MIST-time and event ProM.

The second mixed ANOVA had 2 minutes and 15 minutes delay of time ProM as the within subject factor. A significant main effect for gender was present on ProM, $(F (1,139) = 6.112, p = 0.015, \eta_{p}^2 = 0.04)$ with an overall better performance seen for females ($M = 7.28$) than for males ($M = 6.95$). No main effect was found for handedness on ProM $(F (1, 139) = 2.225, p = 0.138, \eta_{p}^2 = 0.016)$. A significant main effect for the within subject factor was present, $(F (1,139) = 138.059, p = 0.001, \eta_{p}^2 = 0.50)$ with better recall and execution of 2 minute delay ProM ($M = 7.88$) than of the 15 minute delay ProM ($M = 6.39$). As illustrated in figure 2, a significant interaction effect between gender and ProM was present, $(F (1,139) = 3.994, p = 0.05, \eta_{p}^2 = 0.03)$. In view of the significant interaction, further analyses were performed. In this analysis, delay of 2 minutes and 15 minutes performances were compared for each of the gender groups. Tests of simple main effects revealed a significant difference between 2 minutes ($M = 7.83$) and 15 minutes ($M = 6.08$) performance for males $(F (1,141) = 83.50, p = 0.001)$. Similar patterns were revealed between 2 minutes ($M = 7.92$) and 15 minutes ($M = 6.64$) for females $(F (1,141) = 57.65, p = 0.001)$. In the next analysis, gender groups were compared within the 2 minute delay and the 15 minutes delay ProM. Tests of simple main effects revealed no significant difference between the genders in the 2 minute delay ProM performance $(F (1,141) = 1.72, p = 0.192)$ however a significant difference was present between males ($M = 6.08$) and females ($M = 6.64$) for the 15 minute delay ProM performance $(F (1,141) = 4.54, p = 0.035)$. These results showed that females predominantly drove the interaction as seen in the 15 minute delay condition. No other
significant interactions were present for ProM and handedness \( F(1,139) = 2.270, p = 0.134, \eta_{p}^{2} = 0.016 \) and for ProM, handedness, and gender \( F(1,139) = 0.001, p = 0.972, \eta_{p}^{2} = 0.00 \).

![Graphical illustration of the interaction between ProM scores (2 & 15 minutes delay) and gender](image)

Figure 2. Graphical illustration of the interaction between ProM scores (2 & 15 minutes delay) and gender

In the third mixed ANOVA, verbal and action based ProM were considered as the within subject factor. A significant main effect for gender was present on ProM, \( F(1,139) = 6.112, p = 0.015, \eta_{p}^{2} = 0.04 \) with overall better performance reported by females \( M = 7.28 \) than for males \( M = 6.95 \). No main effect was found with handedness on ProM \( F(1,139) = 2.225, p = 0.138, \eta_{p}^{2} = 0.016 \). A significant main effect for the within subject factor is present, \( F(1,139) = 101.22, p = 0.001, \eta_{p}^{2} = 0.42 \), with better overall performance for verbal based ProM \( M = 7.71 \) than for action based ProM \( M = 6.56 \). Figure 3 displays the significant interaction between ProM and gender, \( F(1,139) = 9.209, p = 0.003, \eta_{p}^{2} = 0.06 \). Test of simple main effects revealed a significant difference between verbal \( M = 7.71 \) and action ProM \( M = 6.19 \) for males \( F(1,141) = 72.83, p = 0.001 \). Similarly, a significant difference between verbal \( M = 7.71 \) and
action ProM ($M = 6.85$) for females was present, ($F(1,141) = 29.63, p = 0.001$). In order to compare the gender groups at each level of ProM, tests of simple main effects were performed however no significant gender difference was found for verbal ProM ($F(1,141) = 0.00, p = 0.98$). Instead, a significant difference existed for action ProM ($F(1,141) = 7.16, p = 0.01$) with females ($M = 6.85$) performing better than males ($M = 6.19$). A marginal significance was seen for the interaction between ProM and handedness, ($F(1,139) = 3.614, p = 0.059, \eta_p^2 = 0.03$) with mixed handers performing better ($M = 7.22$) than strong handers ($M = 7.055$). The three way interaction, with ProM, handedness and gender did not show significance ($F(1,139) = 0.585, p = 0.446, \eta_p^2 = 0.004$).

![Graphical representation of the interaction between Prospective memory mean scores (verbal and action based) and gender.](image)

*Figure 3.* Graphical representation of the interaction between Prospective memory mean scores (verbal and action based) and gender.

A two way analysis of variance was performed on the recognition scores with handedness and gender as the between subjects factors. There were no significant main effects for handedness ($F(1,139) = 0.004, p = 0.949, \eta_p^2 = 0.00$) and gender ($F(1,139) =$...
0.08, \( p = 0.76, \eta_p^2 = 0.001 \) and no interaction between handedness and gender \( (F(1,139) = 0.22, p = 0.64, \eta_p^2 = 0.002) \) was present.

MIST errors

Table 2

*Number of participants in the handedness and gender groups who made MIST errors (\( N = 143 \))*

<table>
<thead>
<tr>
<th>Number of errors</th>
<th>Strong Handers</th>
<th>Mixed Handers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males ((n = 27))</td>
<td>Females ((n = 46))</td>
</tr>
<tr>
<td>0</td>
<td>5</td>
<td>15</td>
</tr>
<tr>
<td>1</td>
<td>9</td>
<td>19</td>
</tr>
<tr>
<td>2</td>
<td>11</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 3

*Frequency distribution of the number of participants and the type of MIST errors in the handedness and gender groups*

<table>
<thead>
<tr>
<th>Trial</th>
<th>Error</th>
<th>Strong Handers</th>
<th>Mixed Handers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Males ((n = 27))</td>
<td>Females ((n = 46))</td>
</tr>
<tr>
<td>1</td>
<td>LOC</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>LOC</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>ProM</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>LOC</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>LOT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ProM</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Trial</td>
<td>Error</td>
<td>Males (n = 27)</td>
<td>Females (n = 46)</td>
</tr>
<tr>
<td>-------</td>
<td>-------</td>
<td>---------------</td>
<td>-----------------</td>
</tr>
<tr>
<td>5</td>
<td>LOC</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>LOT</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>ProM</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>LOC</td>
<td>12</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>ProM</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>-</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>RE</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>LOC</td>
<td>5</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>LOT</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td>ProM</td>
<td>8</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>TS</td>
<td>-</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>PL</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>RE</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>38</td>
<td>39</td>
</tr>
</tbody>
</table>

Note: LOC = loss of content; LOT = loss of time; ProM error = absence of response; TS = task substitution; PL = place losing; RE = random error

Data was checked for the number of participants who made MIST errors. Table 2 displays the information for the handedness and gender groups. This was further partitioned based on the number of people in each of the handedness and gender groups across each trial of the MIST. As presented in table 3, fewer mixed handed females committed the MIST errors (28) followed by strong handed males (38) and strong handed females (39). Mixed handed males had the highest number of errors (47).

*Descriptive data of the other variables in the study*

Besides the MIST, digit span (forward and backward span), pair cancellation task (total number of hits and time taken to complete the test as both these parameters
represent characteristics for executive functioning), and scores on the Everyday Memory Questionnaire (EMQ) were also considered for exploratory purposes.

Table 4

*Mean (SD) working memory and executive function scores across handedness and gender groups*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Strong Handers Males (n = 27)</th>
<th>Strong Handers Females (n = 46)</th>
<th>Mixed Handers Males (n = 36)</th>
<th>Mixed Handers Females (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit span (Total)</td>
<td>11.08 (2.19)</td>
<td>10.60 (1.76)</td>
<td>11.81 (1.82)</td>
<td>11.62 (2.30)</td>
</tr>
<tr>
<td>Digit span (Forward)</td>
<td>6.27 (1.31)</td>
<td>6.04 (1.04)</td>
<td>6.94 (0.98)</td>
<td>6.66 (1.18)</td>
</tr>
<tr>
<td>Digit span (Backward)</td>
<td>4.81 (1.27)</td>
<td>4.56 (1.11)</td>
<td>4.86 (1.18)</td>
<td>4.97 (1.43)</td>
</tr>
<tr>
<td>Pair cancellation (Hits)</td>
<td>64.15 (4.71)</td>
<td>64.49 (4.28)</td>
<td>65.75 (3.74)</td>
<td>64.59 (5.35)</td>
</tr>
<tr>
<td>Pair cancellation (Time)</td>
<td>146.23 (34.2)</td>
<td>135.51 (26.5)</td>
<td>130.06 (19.4)</td>
<td>136.53 (29.4)</td>
</tr>
</tbody>
</table>

Note: Pair cancellation hits – out of 71, time taken for the test is measured in seconds

Table 5

*Mean (SD) scores on the five factors and the total score on the EMQ across handedness and gender*

<table>
<thead>
<tr>
<th>EMQ</th>
<th>Strong Handers Males (n = 27)</th>
<th>Strong Handers Females (n = 46)</th>
<th>Mixed Handers Males (n = 36)</th>
<th>Mixed Handers Females (n = 34)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retrieval</td>
<td>24.23 (10.86)</td>
<td>24.13 (8.56)</td>
<td>23.94 (8.92)</td>
<td>23.28 (7.53)</td>
</tr>
<tr>
<td>Task monitoring</td>
<td>19.58 (11.95)</td>
<td>15.58 (7.03)</td>
<td>14.22 (5.64)</td>
<td>15.09 (4.90)</td>
</tr>
<tr>
<td>Conversational monitoring</td>
<td>19.04 (10.12)</td>
<td>17.22 (6.63)</td>
<td>16.31 (7.10)</td>
<td>19.06 (6.94)</td>
</tr>
<tr>
<td>Spatial memory</td>
<td>13.35 (6.54)</td>
<td>9.93 (3.99)</td>
<td>10.47 (4.23)</td>
<td>10.63 (4.53)</td>
</tr>
<tr>
<td>Memory for activities</td>
<td>21.46 (8.18)</td>
<td>18.00 (6.89)</td>
<td>18.31 (5.77)</td>
<td>16.59 (5.67)</td>
</tr>
<tr>
<td>Total EMQ</td>
<td>97.65 (42.26)</td>
<td>84.87 (28.03)</td>
<td>83.25 (25.91)</td>
<td>84.66 (23.50)</td>
</tr>
</tbody>
</table>

The mean scores and SD for digit span and pair cancellation test across handedness and gender groups are shown in table 4. Mixed handers have nominally performed better on both the working memory and executive functioning measures than the strong handers. A
similar trend was present for the EMQ data with mixed handers reporting nominally lesser everyday memory problems than strong handers. Mean scores on the EMQ factors and total score are presented in table 5.

Correlation Analyses (using two tailed tests)

Table 6 shows group correlations between the six subscales of the MIST and working memory, executive function, and the self report measure about everyday memory abilities. Time ProM positively correlated with executive function, \( r = +0.18, p = 0.05 \).

Table 6

Correlation analyses between the six subscales of ProM and Working memory and executive function (\( N = 143 \))

<table>
<thead>
<tr>
<th>Measures</th>
<th>Working memory</th>
<th>Executive function</th>
<th>Self report</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time</td>
<td>0.15</td>
<td>0.18*</td>
<td>-0.13</td>
</tr>
<tr>
<td>Event</td>
<td>-0.01</td>
<td>0.04</td>
<td>0.03</td>
</tr>
<tr>
<td>2 minutes</td>
<td>-0.05</td>
<td>0.08</td>
<td>0.000</td>
</tr>
<tr>
<td>15 minutes</td>
<td>0.10</td>
<td>0.12</td>
<td>-0.07</td>
</tr>
<tr>
<td>Verbal</td>
<td>0.14</td>
<td>0.12</td>
<td>-0.02</td>
</tr>
<tr>
<td>Action</td>
<td>0.04</td>
<td>0.11</td>
<td>-0.06</td>
</tr>
</tbody>
</table>

Working memory: Digit span total; executive function = pair cancellation hits; self-report = EMQ total; * = significant at 0.05 level.

The data was further split based on handedness and gender to check for intra group correlations between ProM and the other measures incorporated in the study. Tables 7, 8 and 9 depict separate correlations for the between subject factors.
Table 7

Correlation between the six subscales of the MIST and working memory for handedness and gender groups separately

<table>
<thead>
<tr>
<th>Variables</th>
<th>Strong Handers</th>
<th></th>
<th>Mixed Handers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 27)</td>
<td>Females (n = 46)</td>
<td>Males (n = 36)</td>
<td>Females (n = 34)</td>
</tr>
<tr>
<td>Time &amp; working memory</td>
<td>0.30</td>
<td>0.23</td>
<td>-0.17</td>
<td>0.26</td>
</tr>
<tr>
<td>Event &amp; working memory</td>
<td>-0.33</td>
<td>0.32*</td>
<td>-0.531**</td>
<td>0.51**</td>
</tr>
<tr>
<td>2 minute &amp; working memory</td>
<td>-0.50*</td>
<td>0.13</td>
<td>-0.04</td>
<td>0.27</td>
</tr>
<tr>
<td>15 minute &amp; working memory</td>
<td>0.10</td>
<td>0.35*</td>
<td>-0.49**</td>
<td>0.48**</td>
</tr>
<tr>
<td>Verbal &amp; working memory</td>
<td>0.26</td>
<td>0.22</td>
<td>-0.16</td>
<td>0.21</td>
</tr>
<tr>
<td>Action &amp; working memory</td>
<td>-0.18</td>
<td>0.34*</td>
<td>-0.46**</td>
<td>0.54**</td>
</tr>
</tbody>
</table>

*p = 0.01, *p = 0.05

Table 7 shows a gender difference regardless of membership to a specific handedness group. Males showed a negative correlation between ProM and working memory, whereas females showed a positive correlation between these factors. Table 8 displays the significant positive correlations between time, 15 minute delay and action ProM and executive function specifically in the female group regardless of handedness, implying that performance on the executive function is associated with performance on some of the ProM types.

According to table 9, female mixed handers showed a positive correlation between time ProM and self evaluation of daily memory as measured by the EMQ. (The scoring for the two measures is in opposite directions. Thus, better the performance on the MIST, higher the scores; whereas in the EMQ, lower scores implied better everyday memory abilities). This finding implied that female mixed handers show a concordance in their objective performance and subjective understanding of their ProM abilities.
Table 8

*Correlation between the six subscales of the MIST and executive function for handedness and gender groups separately*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Strong Handers</th>
<th></th>
<th>Mixed Handers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 27)</td>
<td>Females (n = 46)</td>
<td>Males (n = 36)</td>
<td>Females (n = 34)</td>
</tr>
<tr>
<td>Time &amp; executive function</td>
<td>-0.17</td>
<td>0.39**</td>
<td>0.02</td>
<td>0.36*</td>
</tr>
<tr>
<td>Event &amp; executive function</td>
<td>-0.17</td>
<td>0.28</td>
<td>-0.10</td>
<td>0.06</td>
</tr>
<tr>
<td>2 minute &amp; executive function</td>
<td>0.21</td>
<td>0.12</td>
<td>0.20</td>
<td>-0.18</td>
</tr>
<tr>
<td>15 minute &amp; executive function</td>
<td>-0.35</td>
<td>0.43**</td>
<td>-0.13</td>
<td>0.35*</td>
</tr>
<tr>
<td>Verbal &amp; executive function</td>
<td>-0.12</td>
<td>0.23</td>
<td>0.16</td>
<td>0.16</td>
</tr>
<tr>
<td>Action &amp; executive function</td>
<td>-0.21</td>
<td>0.42**</td>
<td>-0.12</td>
<td>0.28</td>
</tr>
</tbody>
</table>

*p = 0.01, *p = 0.05

Table 9

*Correlation between the six subscales of the MIST and self report (EMQ total score) for handedness and gender groups separately*

<table>
<thead>
<tr>
<th>Variables</th>
<th>Strong Handers</th>
<th></th>
<th>Mixed Handers</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Males (n = 27)</td>
<td>Females (n = 46)</td>
<td>Males (n = 36)</td>
<td>Females (n = 34)</td>
</tr>
<tr>
<td>Time &amp; self report</td>
<td>-0.09</td>
<td>-0.08</td>
<td>-0.07</td>
<td>-0.37*</td>
</tr>
<tr>
<td>Event &amp; self report</td>
<td>0.07</td>
<td>0.05</td>
<td>0.11</td>
<td>-0.01</td>
</tr>
<tr>
<td>2 minute &amp; self report</td>
<td>-0.20</td>
<td>0.18</td>
<td>0.02</td>
<td>0.16</td>
</tr>
<tr>
<td>15 minute &amp; self report</td>
<td>0.07</td>
<td>-0.06</td>
<td>0.03</td>
<td>-0.30</td>
</tr>
<tr>
<td>Verbal &amp; self report</td>
<td>0.07</td>
<td>-0.18</td>
<td>0.16</td>
<td>-0.15</td>
</tr>
<tr>
<td>Action &amp; self report</td>
<td>-0.03</td>
<td>0.07</td>
<td>-0.01</td>
<td>-0.23</td>
</tr>
</tbody>
</table>

*p = 0.05
Regression Analysis

In view of the significant correlations, and for exploratory purposes, a multiple regression analysis was conducted. Gender, handedness, digit span forward and backward, and pair cancellation- hits and total time taken to complete the task were considered as potential predictors for ProM (total score on the MIST). The analysis indicated that the predictors accounted for 10.6% of the variance in ProM performance ($F(6,132) = 2.615, p = 0.02$). Table 10 presents the regression coefficients for the model. It was found that gender ($\beta = 0.233, p = 0.006$) and the number of hits on the pair cancellation ($\beta = 0.19, p = 0.035$), were significant predictors of ProM. The model suggested that females and the ones who performed optimally on the pair cancellation by correctly detecting the pairs on the test were more likely to perform well on ProM.

Table 10

Regression coefficients for the predictors of ProM

<table>
<thead>
<tr>
<th>Predictors</th>
<th>$b$</th>
<th>SE $b$</th>
<th>$\beta$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>25.915</td>
<td>7.117</td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>2.453</td>
<td>0.885</td>
<td>0.233**</td>
</tr>
<tr>
<td>Handedness</td>
<td>1.007</td>
<td>0.917</td>
<td>0.096</td>
</tr>
<tr>
<td>Digit span forward</td>
<td>0.236</td>
<td>0.439</td>
<td>0.052</td>
</tr>
<tr>
<td>Digit span backward</td>
<td>-0.062</td>
<td>0.409</td>
<td>-0.015</td>
</tr>
<tr>
<td>Pair cancellation (time)</td>
<td>-0.029</td>
<td>0.016</td>
<td>-0.151</td>
</tr>
<tr>
<td>Pair cancellation (hits)</td>
<td>0.222</td>
<td>0.105</td>
<td>0.190*</td>
</tr>
</tbody>
</table>

Note: $R^2 = 0.106, *p = 0.05, **p = 0.01$
Chapter Eight

Discussion

The study primarily aimed at examining interhemispheric interaction via a behavioral measure - handedness, in performing prospective memory tasks. Briefly, handedness did not come out as a significant factor. Interestingly, gender did. Besides this, several within group differences were also present with 2 minute delayed ProM performed better than 15 minute delay and, ProM based on verbal modality better recalled than action modality.

According to hypothesis 1, a significant interaction between handedness and type of ProM (time and event and the delayed 2 minutes/15 minutes for time ProM) were predicted. However, results did not support this hypothesis. The premise for handedness and interhemispheric interaction holds that for the successful completion of a demanding cognitive process, a bi-hemispheric involvement would result in a better output. Thus, if biologically one is a mixed hander and is challenged with a cognitive task, he or she is more likely to utilize both hemispheres for its successful completion. It was proposed that handedness would be an important factor because of past evidence obtained with RetM (e.g. Propper et al., 2004) that showed large effect size and because both RetM and ProM are assumed under the umbrella of episodic memory. However, the current study shows small effects for ProM and interhemispheric interaction. Besides, imaging studies suggest bilateral involvement of the brain for both the HERA model that accounts for episodic retrieval (Tulving et al., 1994) and ProM (e.g.: Burgess et al., 2001), thus strengthening the rationale for the applicability of handedness for ProM. Despite all evidence implying
the role of interhemispheric interaction, the current research does not show such an association due to the following probable reasons.

It is possible that the test used in the current study was not a challenging one to ensure interhemispheric exchange of information. The MIST is a standardized measure for ProM primarily developed for the clinical population. The distractor task involved in the MIST (word search puzzles) could have been less challenging for a normal population than for a clinical population. In addition, most experimental paradigms use demanding distractor tasks that challenge the working memory. This in turn could place higher expectations on a participant to be alert about when a ProM task needs to be executed. Perhaps, such experimental tasks would show a handedness effect.

Another possibility for both handedness groups to perform likewise could be the amount of deliberate thought process invested by strong handed participants. Mixed handed participants have shown nominally better mean performance in ProM compared to strong handed participants however, the latter group could have performed optimally because of their increased tendency to ruminate (Niebauer, 2004). This could be supported with the possible role of working memory for the strong handed group. As mentioned earlier, based on the digit span scores, mixed handers have performed significantly better than strong handers. This finding goes against the current argument of the working memory support for strong handers. However, if one takes into consideration the sub processes involved in ProM such as remembering a prospective task, being aware of cues in the environment, using self reminders during and/or between distractor tasks, then it can be assumed that rumination about the “to do” events would facilitate better
ProM recall; it could be speculated that the episodic buffer of the working memory might have a role to play, evidence for which continues to lack in the current literature.

A third possibility could be the sample demographic- age. Behavioral studies of ProM show the inverted U trend (Zimmermann & Meier, 2006; Zollig, West, Martin, Altgassen, Lemke & Kliegel, 2007), wherein ProM improves from childhood (e.g.: Guajardo & Best, 2000) to young adulthood, and declines when one approaches later adulthood (e.g.: West, Crook & Barron, 1992). Interestingly, imaging studies that have studied the developmental patterns of the interhemispheric communication channel- the CC, have found that it follows a similar inverted ‘U’ pattern of development and deterioration (McLaughlin, Paul, Grieve, Williams, Laidlaw, DiCarlo, et al., 2007). Studies show that the anterior parts of the CC negatively correlate with age implying that young adults have better volumes than older adults (Yoshi & Duara, 1989). These findings thus imply that perhaps these interhemispheric differences are not apparent in the young population, and it can be speculated that with the older age groups, there might be a possibility of delayed deterioration in the CC functioning of the mixed handers than the strong handers. Only further research can show if the speculation holds true.

Finally, it could be that the measurement tool for handedness that assesses interhemispheric communication has no relation with a frontal based cognitive task. Past research has shown robust relations between strength of handedness and retrospective memory, both of which have strong connections with the posterior regions of the corpus callosum. It could be that, interhemispheric communication measurement for cognitive processes that are predominantly frontal in nature, need a different measurement tool that
would represent excitatory/inhibitory mechanisms and such that have relevance for the mechanisms of alertness of cues, recurrent self reminders to execute tasks etc.

A main effect between 2 minute and 15 minute delay periods for the ProM task shows significance, with the 2 minute delay resulting in better ProM recall than the 15 minute delay period. Interestingly, this finding goes against the one that was found in the study performed by Hicks, Marsh and Russell (2000) in which they manipulated the delay periods and better ProM retrievals for the longer delay duration were reported. They also found that with more number of filler tasks during delayed durations, better was the task retrieval. This discrepancy between the experimental evidence and the current study could be attributed to different study designs incorporated in the two studies: 1) the Hicks et al. study used the delay duration for ProM as a between subject’s factor, whereas the current study incorporates the delay as a within subject’s factor and 2) the ProM tasks were different. Remediating these methodological differences could aid in clarifying the role of the variables.

According to hypothesis 2, it was speculated that there would be an interaction between the modality for ProM performance and handedness, with mixed handers showing superior performance over strong handers. According to the results, there are emerging trends for this hypothesis, with female mixed handers showing marginally better mean scores for action based ProM than males (regardless of the handedness groups). In addition, between verbal and action based ProM, performance for action based is significantly better than verbal based ProM. Koriat, Ben-Zur and Nussbaum (1990) carried out three experiments in which they tested for memory for future events in terms of modalities- participants were expected to either memorize commands verbally
for future recall (verbal based) or were asked to remember the tasks to be performed in the near future (performance based). They found that performance based memory for future events were better recalled than verbal based memory for future events. They supported their results by referring to the dual coding hypothesis, which proposes that participants code information in two modalities - a verbal encoding in view of a conscious recall and the imaginal coding when expected to perform a task. As Koriat et al. (1990) point out that beside the intention, the manner in which the content for a ProM recall is encoded is also an important aspect of ProM.

According to hypothesis 3, it was speculated that males and females would perform similarly on ProM tasks. On the contrary, gender was a significant main factor for ProM, therefore rejecting the hypothesis. Females have performed significantly better than males on almost all subscales of ProM. It is possible that females were accurate about the upcoming tasks that needed to be executed, were keeping track of the time, solving word search puzzles without getting too involved in it, and thus managed to perform better on the ProM tasks. Studies related to gender asymmetries in ProM are few. For instance, a study by Tan and Kvavilashvili (2003) that aimed to assess gender differences in event and time ProM found that females performed significantly better at event based ProM (for both distinctive and non distinctive embedded cues) than males. They supported this finding by proposing that females tended to depend more on metamemory processes and might have unconsciously processed for the presence of the environmental stimuli. However, within the same study, they did not find a gender difference for time based ProM task.
To further support the gender difference in ProM, an interesting child study by Ceci and Brofenbrenner (1985) had incorporated gender as one of the variables for those ProM tasks that could be categorized based on sex role expectations. The study found a significant interaction between gender and type of task for frequency of time monitoring. Another study by Huppert, Johnson and Nickson (2000) aimed at exploring the demographic variables that predicted ProM impairments in the elderly. The study showed that gender was a significant predictor, besides the other factors of socio-economic status and education, with males showing an early decline in ProM than females. Using this cross-sectional study as a reference point, the gender difference observed in the current study gains support as it could be speculated that females tend to be more alert about ProM type tasks compared to males. This explanation also supports the robust interaction effect between the 2 minute and 15 minutes delay of ProM and gender, with females outperforming males in the 15 minute delay condition. This finding could be explained by the test-wait-test-exit (TWTE) hypothesis (Harris & Wilkins, 1982), which proposes that for time cued tasks, an individual checks for the time to execute a task. If it is not, then there follows a wait period until the next check for the environment/time happens. This process stops or exits once a task is executed at the expected time. In relation to females driving the significant difference, the finding could be attributed to their increased awareness of pending tasks that need to be executed, and the ability to keep track of them over longer periods of time.

Another cognitive mechanism, the intention superiority effect and its connection with individual differences in ProM has been suggested (Penningroth, 2005). The intention superiority effect (introduced by Goschke & Kuhl, 1993) shares similarities
with the Adaptive control of thought (ACT*) model. The effect states that intentions about “to be performed” activities are stored as subthreshold source nodes in memory, which are sustained without rehearsal and are in a heightened state of activation.

Penningroth’s study showed an intention superiority effect in females whereas males showed an intention inferiority effect. Females tend to have higher activation levels for future intentions than past actions whereas the opposite appears to be the case for males.

However, not all studies show converging evidence for gender differences. For instance, Heffernan and Ling (2001) in their study on personality correlates for ProM did not find any specific gender related effects; though, it could be attributed to the methodology of the study as they incorporated a ProM scale to measure the construct than getting the participants to perform the ProM tasks. Likewise, a questionnaire based study that evaluated gender on the subjective assessment of ProM also did not find significant differences (Crawford, Smith, Maylor, Della Sala & Logie, 2003). There is insufficient literature in the adult area of ProM research that could entirely account for the gender difference, and only further gender studies can show if such an effect exists for monitoring.

Additional research questions were proposed to explore the relationship between ProM, working memory, executive function, and subjective measure of one’s everyday memory abilities. In the primary group analyses, except for a low positive correlation between executive function and time ProM, none of the others were significant. However, to understand the nature of the relationship between the variables in the study better, secondary group analyses were carried out, with the data being divided based on handedness and gender groups. Interestingly, significant findings began to emerge. There
were different trends that were present once again, dominated by gender asymmetries than laterality asymmetries. Females showed a positive correlation between ProM and working memory, however, males showed the opposite trend. This could be interpreted in three ways:

1) That there exists sex asymmetries in cognitive performances which could be attributed to differences in cerebral organization for the two genders (e.g.: Good, Johnsrude, Ashburner, Henson, Friston, & Frackowiak, 2001).

2) A farfetched reason could be the attitude of male participants in optimally performing a working memory task out of sheer excitement of competing with themselves on the increasing length of digit strings therefore accounting for the results. However, on the other hand, they might have found word search puzzles too competitive (as the instructions for the latter is as follows: “…your goal is to find all the words by the end of this test.”) such that there is a compromise in performing ProM tasks.

3) The opposite of #2 might have occurred, which would mean that despite having a poor working memory capacity, ProM did not suffer because of the nature of the ongoing task that was part of the ProM test (word search puzzles being an understimulating task – reported anecdotally by several male participants).

Thus, a possible reason for the results evolving in this manner could be the nature of the task in the study. Whereas one way to measure the relation between working memory and ProM is by assessing the two cognitive functions separately, another way of doing it would be to embed a working memory task by varying the task load while also keeping track of the environment for cues for executing ProM actions. The latter paradigm was
incorporated in a study by Logie, Maylor, Della Sala and Smith (2004) and they found that as a concurrent working memory task load increases, there are compromises in ProM execution.

A female advantage was observed for ProM and executive function. The role of executive function in ProM is discussed in some research studies. For example, Martin, Kliegel and McDaniel (2003) tested both young and old adults on ProM tasks and executive function tasks (WCST, Tower of London, stroop- together these were combined to form a Z score) separately and found a significant correlation of 0.32 for time ProM and executive function which is also reported in the current study specific to the female group (it is important to note that in the Martin et al. 2003 study, females outnumber males in both young and old age groups). Yet, it is not completely clear as to why females show the advantage. This finding could be linked to the significant gender and ProM task interaction and that perhaps females possess a different way of representing information for future intentions and this could be reflected in the correlation between ProM and executive function. Nevertheless, one could also attribute this trend in the current study to the sample itself, the interest levels of participants, the interaction between the experimenter and the participant, the individualized testing protocol that might have made the female group more conscious and therefore motivated them to perform better.

In view of the significant correlations, a regression analysis was attempted which showed that gender and executive function were significant predictors of ProM. A similar finding is also reported by the Martin et al. (2003) study that used a stepwise regression analysis and found executive function and age as their significant predictors. Though,
Martin et al. have used a group of neuropsychological tests to measure several characteristics of executive function, the pair cancellation task used in the current study could be considered a good measure of executive function as it involves monitoring, executive processing (interference control), attention/concentration, and processing speed abilities (Schrank, Flanagan, Woodcock, & Mascolo, 2002). The ability to correctly identify the pairs in the cancellation test in a time frame represents a good executive functioning ability. Interestingly when working memory scores were also put in the regression equation, it did not turn out to be significant therefore implying the role of executive function than working memory in ProM. The Preparatory attention and memory framework could explain this significant finding. The theory states that ProM involves a more conscious processing that triggers the awareness component, monitoring for cues in the environment than merely being on an automatic mode without much effort. Possessing an optimal executive function ensures smooth execution of ProM.

Finally, the study also sought to find if there was a concordance between a performance based task for ProM and one’s subjective opinion about everyday memory abilities. Results revealed a positive correlation between ProM performance (specifically, time and verbal) and self report ability on everyday memory for mixed handed females. It would be worthwhile to ask why time ProM but not event ProM has shown the relation with the self report (though there were emerging significant trends in this group for 15 minute and action related ProM). Interestingly, a study conducted by Kvavilavshvili, Erskine, and Tan (2003) showed the females tended to do better than males on event based ProM tasks. Using self report measures, the authors supported their finding by stating that females tend to have better metamemory awareness about their ability to
remember and execute event based ProM. However their findings could be attributed to their study design, which sought to find out the roles of categorical and distinctiveness of targets/tasks in the environment. The study however did not report significant findings with time based ProM tasks.

Meeks, Hicks and Marsh (2007) performed a study on college students to find out if people are good at predicting their performance on a ProM task. Their findings suggested that people are generally aware about their memory capacities and they use this awareness in predicting their ProM performance. They also found that people judge their memories to be bad when in fact they perform better on memory tasks. Meeks et al. (2007) suggested that metamemory would facilitate in choosing memory strategies. For example, individuals who possess metacognitive awareness about their ProM abilities would also resort to better strategies for remembering, however if there is a lack of this awareness would then lead to poor choice of strategies. Unfortunately, their study did not consider further intragroup differences such as gender as a possible between subject variable.

Similar kinds of studies have been undertaken in the area of geriatric work. For example, McDonald, Gould, and Tychynski (1999) used a metamemory scale to understand subjective performance and also incorporated performance based ProM tasks and found that self efficacy- the perception for better memory performance, capacity, stability were strong predictors of time based ProM tasks. It is possible that female mixed handers are alert about their performance and would be sensitive about subtle changes that might direct them to check for a possible deterioration in memory functioning.
Chapter Nine

Conclusions

The thesis highlights the following findings:

1) Handedness, a behavioral measure for interhemispheric interaction, has not been a significant factor for ProM. The primary reason for its modest contribution could be related to the age factor. Further research with longitudinal paradigms or cross sectional designs may clarify the inverted U trend of ProM in relation to handedness.

2) As per current evidence and past research studies despite methodological differences, executive function and working memory appear to aid the successful completion of ProM tasks.

3) Female participants have shown positive correlations between ProM and working memory, executive function. As shown in the research by Penningroth (2005), females tend to show the intention superiority effect wherein information remains intact without much rehearsal and in the heightened state of activation. This effect supports the important roles of working memory and executive function.

4) Mixed handed females have shown significant associations between objective measure of ProM and subjective measures of every day memory abilities. This can be supported by the study on handedness and rumination/reflection modes of metacognitive thinking by Niebauer (2004) who found that mixed handers indulged in self reflection whereas strong handers were more likely to be ruminators. If a female advantage already exists for ProM processes, there is reason to believe that handedness aides in creating more awareness through metacognitive processes. Females appear to be more accurate about
their metacognitive awareness and are able to objectively evaluate their ProM abilities. In addition, females would not only perform required ProM tasks based on their priorities, but also be more judicious in choosing better strategies to successfully perform the ProM tasks. This could have long term advantages as it implies that female mixed handers are going to be more aware about growing deficits in their memory systems and resort to external memory aids to help them continue function optimally.

5) Self reports versus objective performance on cognitive tests: The current study elucidates the discrepancy between one’s metamemory skills of assessing one’s everyday memory abilities and the actual performance on a ProM test. This finding then could be a caveat for future researchers and practitioners, that perhaps self reports may not sufficiently reflect the true cognitive state. In addition, taking into consideration both a self report measure and results of an objective cognitive test would help ascertain an individual’s ability to evaluate one’s cognitive status.

Although the study did not provide evidence for the presence of interhemispheric communication for ProM, the other exploratory section contributes in terms of reaffirming the important role of the working memory and executive functioning for the successful execution of the ProM task. Additionally, it appears that this significance is driven by gender, further adding to the literature that there are gender asymmetries to ProM.
Chapter Ten

Future Directions

In view of the current findings, it appears that certain limitations in the study if controlled for could bring about different results.

1) The MIST is a test that was specifically created for the clinical population. Perhaps using an experimental paradigm that involves carrying out ProM tasks with demanding ongoing tasks could ensure added involvement of the cognitive processes for successful performance. Alternatively, making the ongoing tasks during the MIST more challenging (instead of word search puzzles, including demanding math, spatial location type puzzles) might help elicit less ceiling effects and also meet criteria for ecological validity.

2) Although the study has shown a difference between objective and subjective measurements of ProM, the results may not be considered entirely reliable. The study has not followed a counterbalanced format of the order of the ProM task and the EMQ scale, and perhaps this might have influenced the participants’ subjective impressions based on their objective performance. However, the reason for not doing so was to maintain uniformity in data collection and control for the EMQ scale items’ influence on participants’ performance on the MIST task. Therefore, a repeat study using a counterbalanced design might ascertain if indeed such a discrepancy exists, further enhancing the importance of their relationship for assessing cognitive processes.
References


*Journal of Experimental Psychology: Learning, Memory and Cognition, 16*, 717-726. doi: 10.1037/0278-7393.16.4.717


Appendix A

Prospective Memory Theories

**Monitoring**

For a ProM task to be performed the environment needs to be constantly monitored; this in turn relies on the attentional sources and working memory capacity. Einstein, McDaniel, Thomas, Mayfield, Shank, and Morrisette, (2005) propose that retrieval during a ProM task requires a process that monitors the environment for the target cues. Einstein et al. refer to the supervisory system originally introduced by Norman and Shallice (1980). This theory suggests that an action/intention is a combination of processes. The processes begin to function once the correct cues get activated and interrupt an ongoing activity when a target event is identified, thereby facilitating the execution of a ProM task at hand. The supervisory system comes into play when actions are novel and there is a schematic plan for these actions to be performed at a later point.

Thus, the three components required for the supervisory system are: a) a marker (or a message that alerts an individual that a novel task needs to be executed), b) an intention and c) a plan. If something occurred in the environment that is a signal for the execution of a task, the marker would get activated and based on a plan the intention would be performed. McDaniel and Einstein (2007) reason that this executive system has a probable role in terms of keeping a check on the environment in order to carry out certain tasks. This monitoring behavior is further confirmed by Smith and Bayen’s (2004)
formal multinomial model (the multinomial model will be discussed in relation to the Preparatory Attentional and Memory theory).

Besides the supervisory system to explain monitoring, Harris and Wilkins (1982) refer to the test-wait-test-exit (TWTE) process that was originally introduced by Miller, Galanter, and Pribram (1960). The TWTE paradigm offers an explanation for time based ProM. The idea states that people will initially evaluate the situation (test period) early because the cost of responding late is high (e.g.: Taking the cookies out of the oven too late results in ruined cookies). Thus, when the ‘test’ reveals that it is too early to perform the intended activity, a ‘wait’ period follows, during which attention to other ongoing events continues in a normal fashion. After some period of waiting, another ‘test’ is initiated and this cycle continues until the test period confirms that it is appropriate to perform the intended action. At this point, the test-wait cycle is discontinued (exit).

In order to check for the TWTE process within a ProM experiment, Harris and Wilkins (1982) conducted a laboratory based experiment that required participants to respond at a particular time (either at 3 minutes or at 9 minutes depending on the stack of cards that had the times written. These cards were being held by each participant) while being engaged in an ongoing activity (watching a 2 hour movie). Besides testing for the TWTE paradigm, the study illustrated that there is a higher chance of carrying out a prospective memory task when it is being constantly monitored. An increased frequency of monitoring time (referring to a clock) is an important factor for time based ProM. Therefore monitoring frequency when nearing the time for executing a ProM task was directly associated with executing the task at the right time. With infrequent monitoring, the trade offs of not executing the task are most certain.
**Preparatory Attentional and Memory (PAM) Processes**

Proposed by Smith (2003), the Preparatory Attentional and Memory (PAM) processes theorize about event based ProM tasks. One of the key features is that the authors believe that ProM performance is not an automatic one. Instead, ProM requires a two component preparatory process that depends on cognitive resources. One of them constitutes the preparatory attentional process that is non automatic and is required to monitor for events during appropriate occasions for performing the ProM task.

The preparatory attentional processes are functionally related to successful ProM performance. In addition to the attentional component, a “memory” component exists that takes charge of two aspects: a) discriminating between the several target events and recognizing the target event as the one and b) recalling the intended action. To illustrate this in the context of PAM, Smith and Bayen (2004) discuss the example of buying a grocery store item and the decision to stop at the store (target event) on the way home from work. Until the time arrives when one stops at the grocery store, one continues to be busy with other works and errands that need to be carried out in the meanwhile. Even during the performance interval, the time during which the task could be accomplished, when one sees the store one continues to engage in driving, attending to traffic, perhaps listening to the radio, and so on. Thus, when this target event is encountered, one would stop by the store and execute the remembered task. ProM tasks occur in the midst of other activities and involve interrupting those activities.
Smith and Bayen (2006) further propose that for a ProM task to be accomplished successfully, the attentional and memory processes need to interact with each other. They applied a mathematical model called the Multinomial Process Tree (MPT) model in their PAM design. They manipulated several parameters such as task importance, distinctiveness of cues to discriminate between target and non-target events, demanding nature of ongoing tasks which are embedded in a ProM experiment, and the amount of time participants get to encode ProM tasks. With MPT models, researchers also have the freedom to manipulate the influence of ongoing activities on ProM tasks, or raise the importance of a ProM task and reduce demands of the ongoing activities on individual performances. Using MPT, they were able to tease out the separate functions of the preparatory modes of attention and memory in relation to the introduction of a target event. Thus, with this model, Smith and Bayen showed the validity of the PAM framework in the context of successful completion of an event-based ProM.

*Spontaneous Retrieval Theory*

This theory proposes that when ProM target event is encountered, people tend to depend on the spontaneous memory and/or attentional processes to facilitate intention retrieval (Einstein et al., 2005). The theory emphasizes that participants do not monitor or evaluate for the presence of cues in the environment for target events, instead, the presence of the target event provokes the memory for that event, and this initiates successful retrieval processes. Thus, retrieval can occur spontaneously and reflexively without the involvement of the executive resources to trigger the ProM intention at the
time that the target event first occurs. The strength of the association between the target event and the cue embedded within the environment will most often dominate the fulfillment of the ProM act. Some studies have shown support for this theory when participants during the experiment have reported the occurrence of the ProM thought during ongoing activity (Einstein and McDaniel, 1990; Reese & Cherry, 2002).

**The Multi Process Framework**

McDaniel and Einstein (2000) propose the multi-process framework in the context of event based ProM. Their theory’s key feature is the flexibility of the mechanisms in completing the ProM task. They propose that a ProM task can be carried out based on a plan, which can be strategic in nature, is voluntarily enforced and requires increased monitoring processes. Alternatively, it can be automatic in terms of a cue in the environment triggering a response. The automatic process can be classified into another two categories: attention based, which reacts to the salience feature of the cue in the environment that triggers a spontaneous appropriate reaction.

The second is memory based, which is characterized by the association between the target and the memory trace stored; or it is retrieval driven without the context playing any role whatsoever. In sum, the multiple process framework states that automatic processes that comprises of an attentional system and several memory systems working together lead to ProM retrieval. This framework gains support from the parameters that influence ProM retrieval. Distinct targets provoke involuntary ProM task execution; the association between target cue with the intended action calls for the
automatic memory system to function; the similarity between an ongoing task and a ProM task will decide whether the cue is retrieved automatically or deliberately; if the nature of the ongoing task is demanding and requires increased levels of involvement, there follows an inverse relation with thinking about the ProM retrieval; the type and degree of planning affects the choice of ProM retrieval (automatic or strategic); individual differences influence this framework— for instance, Goschke and Kuhl (1993) have delineated the relation between personality profiles and ProM retrieval, thus people who show a predisposition for “state orientation” are more likely to ruminate (in other words monitor the thought) about unfulfilled intentions regardless of the cue characteristics.