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Investigating the Benefits of Enactment and Imagery at Encoding on Prospective Memory Performance Following Traumatic Brain Injury and Ageing

Thesis submitted for the degree of Doctor of Philosophy

School of Psychology and Clinical Language Sciences

Emmanuel K Sarku

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DECLARATION OF ORIGINAL AUTHORSHIP

I confirm that this is my own work and the use of all material from other sources has been properly and fully acknowledged.

Emmanuel K Sarku

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ABSTRACT

The primary aim of my research programme was to identify and explore the efficacy of some of the factors (e.g. enactment, imagery) that could potentially enhance prospective memory performance in traumatic brain injury patients and healthy older adults. The beneficial effects of these factors were explored in the Virtual Week task with the expectation that manipulations that improve prospective memory performance on this task will enhance prospective memory performance in everyday life. In Study 1, the Virtual Week prospective memory task was administered to 30 traumatic brain injury participants and 30 demographically matched controls who either enacted or verbally encoded prospective memory tasks. All participants also completed neuropsychological, executive function and quality of life tests. The findings revealed that we are better at remembering future intentions (prospective memory) after miming the intention than after saying it aloud – for both traumatic brain injury patients and healthy matched controls. However, miming only helps when we need to carry out the action when a particular event occurs. In contrast, miming did not improve prospective remembering for time-based tasks. Also, an indirect measure of sustained attention was related to traumatic brain injury patients' event-based prospective memory performance. In Study 2, the role of sustained attention in prospective memory functioning was explored further. The effect of two types of imagery on prospective memory performance was also examined. The Virtual Week prospective memory task was administered to 30 healthy older-old and 30 younger-old adults who either imagined (via 1st person perspective and 3rd person perspective) or verbally encoded prospective memory tasks. All participants also completed cognitive and executive function tests. The findings revealed that imagining tasks to be performed in future through a 3rd person perspective enhanced prospective memory performance for all participants. This suggests that the use of 3rd person imagery might be a powerful strategy to improve prospective memory. Results further revealed that short-term visuospatial working memory and reaction time plays a role in prospective memory performance for older-old adults but not younger-old adults. Potentially, sustained attention enhances event-based prospective memory performance in younger-old adults. The implications

of these findings in relation to theories and rehabilitation strategies in both traumatic brain injury patients and older adults are discussed.

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CHAPTER ONE

LITERATURE REVIEW

1.1 Introduction

"*A father agrees to drop his infant at daycare on the way to work, normally his wife's task. Recent safety legislation requires that infant carriers be strapped in a rear seat for greater safety in case of collision. The infant falls asleep, and the father is preoccupied with heavy traffic. Forgetting to swing by the daycare centre, he follows his habitual route directly to work and goes inside, forgetting the child sleeping quietly in the back seat*" (Dismukes, 2010, p. 3)

This is an example of a prospective memory failure and the consequences could be fatal, especially in the summer (when the weather is very hot) or in severe winter (with frost).

As we go about our daily activities, remembering to perform future intentions is critical for our survival. This type of memory has been termed as prospective memory (PM). Previous studies mostly define PM as remembering to perform an intended action at an appropriate moment in the future (Einstein & McDaniel, 1990). Examples of PM include give a message to Joe when you see him, pay a telephone bill when you pass the bank, buy groceries when you pass the shop on the way home, and attend an appointment (Shum, Fleming, Gill, Gullo, & Strong, 2011). The first three tasks are examples of event-based PM (EBPM) tasks because the retrieval of the intended action is triggered by an external cue, and the final one is an example of a time-based PM (TBPM) task because the intended action is cued by a specific time or time period (Maujean, Shum, & McQueen, 2003; McDaniel & Einstein, 2007). Research in PM is relatively recent (McDaniel & Einstein, 2007) and has been identified as essential for the successful completion of multiple activities of daily life (Graf & Uttl, 2001) such as remembering to return a book to the library on the way to the shop, or attend appointments on time (Ellis, 1996). Traumatic brain injury (TBI) patients and older adults frequently report difficulties with PM (Fish, Wilson, & Manly, 2010; Scullin, Bugg, McDaniel, & Einstein, 2011) and these difficulties can have a significant effect on independent living (Raskin & Sohlberg, 2009). This calls for research on how best to enrich our theoretical and practical understanding of PM deficits in order to enhance PM function in these populations through better assessment and rehabilitation. Before we continue, let us review a brief history of the emergence of research interest in PM.

1.2. Historical Overview of Memory of PM

Historically, PM recently emerged as a construct of memory research in the early 1970s. The first study on PM was by Loftus (1971). The term was however not in use until 1975 following the work of Meacham and Leiman (1972). A more concerted body of work on PM started with Einstein and McDaniel’s (1990) article on normal ageing and PM. Memory has been defined as the process of encoding, storing, retaining and recalling information (Atkinson & Shiffrin, 1968; Mastin, 2010). Memory, the “sum total of human experience” (Schultz & Schultz, 2015, p. 94) has undergone many stages of development and enhancement. Initially, during the Behaviourist approach in Psychology, memory was thought of as a single system based on a series of stimuli-responses (Baddeley, Eysenck, & Anderson, 2015). Most of this research on memory was limited to laboratory settings, based on research with non-human animals without any clear information on how people interact with the world. Memory was interpreted in a way that made little contact with everyday experience. As a result most of the findings were difficult to apply to everyday life (Atkinson & Shiffrin, 1968; Deutsch &

Deutsch, 1963) . There was therefore a need for a revolution to overcome the challenges posed by the behaviourist approach. Several authors (e.g., Broadbent, 1957; Chomsky, 1959; Miller, 1956) were more concerned with how information was processed in memory under different conditions (e.g., perception, attention, behaviour, and language). The publication of Neissers' (1967) book "Cognitive Psychology" provided the paradigm needed to understand information processing.

Neisser (1967) built on an information processing approach that proposed that memory was not uni-dimensional but rather, information flowed from the environment through various cognitive processes that lead to perceptions, memories, thoughts, and behaviours. For instance, information is received from the environment to the sensory memory, processed in a short-term memory store and then stored in a long-term memory store (Baddeley et al., 2015). An influential version of this model, the modal model, was proposed by Atkinson and Shiffrin (1968). This model was believed to represent all other models at the time (Baddeley et al., 2015).

Neisser's (1967) book induced a change in memory studies during the 1970s that has become known to us as the 'cognitive' revolution. Neisser (1967) defined cognition as processes by which sensory input is transformed, reduced, rehearsed, stored, recovered, and used. His work provided the foundation for the creation of the multi-store model of memory process, in which memory is seen as a sequence of three stages, from sensory to short-term to long-term memory, rather than as a unitary 'store' (e.g., Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Craik & Lockhart, 1972).

Since the time of Neisser (1967), models of memory have identified many different sub-divisions especially in long-term memory; for instance, explicit vs. implicit memory, declarative vs. procedural memory, and episodic vs. semantic memory (Baddeley et al., 2015). The work of Endel Tulving (1973), in particular, has been very influential in identifying encoding specificities associated with episodic and semantic memory. Tulving's (1973) encoding specificity hypothesis suggests that "that memory is improved when information available at encoding is also available at retrieval" (Tulving & Thomson, 1973, p. 359).

Tulving (1993) suggested that "semantic memory registers and stores knowledge about the world in the broadest sense and makes it available for retrieval" (p.67). In contrast, episodic memory "makes it possible for a person to be consciously aware of an earlier experience in a certain situation at a certain time" (Tulving, 1993, p. 67). An illustration of this scenario is, for instance, when we are in the lounge and decide to go to the bedroom to pick up something but forget what we wanted to take when we arrive in the bedroom; often we go back to the lounge, to remember what we originally intended to take from the bedroom. Tulving (1993) argued that unlike other types of memory, episodic memory enables an individual to engage in mental time travel to view personal past experience as well as project into the future. Episodic memory therefore enables individuals to remember past events and plan for the future (Tulving, 1993). This led to an extension of the encoding specificity principle. The principle suggests that in order to remember to perform intended intentions in the future, the nature of the cue at encoding must be the same as the nature of the cue at retrieval and the ongoing activity should encourage matching processing between the cue and the intended intention (McDaniel & Einstein, 2000; Mouza, 2016). For instance, the intention to return a book while passing by the library, must be encoded such that the presence of the library triggers memory for the need to return that book. Also, other activities for the day must be planned such that the individual would have the opportunity to pass by the library (see, for example, Ellis, 1996). The individual must also have knowledge of the location of the library. This extension of the encoding specificity hypothesis indicates the potential importance of episodic memory in remembering future actions.

In spite of the benefit of episodic memory, Loftus and Palmer (1974) research indicated that human memory for past events is subject to distortion thereby affecting accurate retrieval. Loftus (1975) focused on the effect of misinformation, the biases associated with memory, and the characteristics of false memories. She argued that human memory is malleable and subject to distortion and misinformation which can affect retrieval. Harris (1984) delved more into retrieval with emphasis on the importance of "remembering to remember". Harris (1984) was the first to classify long-term memory into Retrospective Memory (RM) and PM (which is the main focus of the current studies).

1.3. Retrospective Memory

The term Retrospective memory (RM) refers to memory for people, words, events and so on, experienced in the past (Baddeley, Eysenck, & Anderson, 2009). Examples include names of familiar faces or places, and past events (Leplow et al., 1997; Levin et al., 1997). It includes declarative, semantic, episodic and autobiographical memory, which can be either implicit or explicit (Baddeley et al., 2009; Mastin, 2010). A clear distinction between PM and RM has been identified and is discussed below.

1.4. RM vs. PM

Although it is believed that RM and PM are independent of each other, some aspects of RM are thought to be required for PM performance (e.g., retaining and recalling the content of the to-be-remembered intention; Mastin, 2010). For instance, studies have demonstrated that impaired RM has a negative impact on PM (e.g., amnesic patients;

Alderman & Burgess, 1994). Other studies have reported impaired PM with an intact RM, suggesting that the two types of memory to some extent involve separate processes (Mastin, 2010). For instance, Kvavilashvili's (1987) study suggests' that performance on a PM task is not connected with performance on a RM task. This indicates that these two types of memories involve distinct processes (Ellis, 1996). Similarly, Burgess and Shallice (1997) in a study with patients with temporal lobe (involved in RM) and frontal lobe (involved in PM) damage reported a non-significant correlation between PM and RM. This confirms Ellis and Milne's (1996) suggestion that PM and RM involve separate processes although there seems to be some overlap between both in cognitive processes (Burgess, 2000).

Einstein and McDaniel (1990) have suggested that PM differs from RM in several ways. For instance, in PM one must first 'remember to remember' (i.e., remember that you have to do something), whereas in RM the experimenter requests one to remember what action to take (Einstein & McDaniel, 1990). For instance, in an RM experiment, participants are required to learn and remember given materials, such as a list of words. Prompts from the experimenter or the presentation of an instruction served as an external cue to encourage participants to remember these materials at the appropriate moment (Gonen-Yaacovi & Burgess, 2012). In contrast, in PM tasks participants are expected to remember the intentions to be carried out in the future without any prompt from the environment (Gonen-Yaacovi & Burgess, 2012).

Traditionally, memory rehabilitation has concentrated on improving RM (Berg, Koning-Haanstra, & Deelman, 1991; Shum, Fleming, et al., 2011) using common techniques such as environmental adaptation where the environment is arranged to reduce patients' reliance on memory to complete important tasks (e.g., labelling materials to accommodate a patient's needs). Other techniques include Errorless Learning (preventing people from making errors while learning new tasks), expanding rehearsal, the use of mnemonics, paired associate learning, and external aids such as diaries, notebooks, or lists (Baddeley, Kopelman, & Wilson, 2003). In contrast, little attention has been accorded to the commonly reported deficits in PM (Cockburn, 1996; Henry, Phillips, et al., 2007; Kinsella et al., 1996; Shum, Fleming, & Neulinger, 2002). Such deficits can have a significant negative impact on the clients' responsiveness to rehabilitation, for example, failure to attend appointments. Intact PM is also important for successful everyday functioning and sustaining independence (Rendell & Thomson, 1999). Moreover, successful participation in a rehabilitation programme is critically dependent on PM skills. There is, therefore, an important need to further explore PM deficits and to identify strategies that might help improve PM functioning.

1.5. Trends in PM

The term PM has been a topic of intense debate and various labels have been given to PM depending on the researcher (Foley, 2007). For example, remembering a plan of action (Cohen, 1996); realising delayed intentions (Ellis, 1996), and remembering intentions (Einstein, McDaniel, Smith, & Shaw, 1998; Kvavilashvili, 1998). The various ways of describing PM signifies the relative infancy of PM research. However, the term realizing delayed intentions has been accepted as the most probable description of PM (Kliegel, Martin, McDaniel, Einstein, & Moor, 2007; McDaniel & Einstein, 2007; Smith, 2008).

1.6. Types of PM

As stated earlier, PM tasks have been classified as either event-based (EBPM), where an action is cued by an environment or time-based (TBPM) where an action must be performed after a certain time/period or at a specific time (Einstein & McDaniel, 1990). Einstein and McDaniel (1990) identified EBPM as a situation where an external event or environment signals the opportunity to perform an intended action. For example, the sight of John might bring to mind the intention to give him a message (Ellis, 1996). Einstein and McDaniel (1990) proposed that TBPM tasks require strategic monitoring and a higher level of self-initiated retrieval in order to perform an action after a period of time (e.g., toast the bread after 45 minutes; Smith, Hunt, McVay, & McConnell, 2007) or at a specific time (e.g. take your medication at 12 pm). This indicates that TBPM tasks are more difficult to perform than EBPM tasks which are environmentally cued (Block & Zakay, 2006).

A body of previous research has supported Einstein and McDaniel's (1990) assumption that TBPM tasks are more difficult compared to EBPM tasks. Difficulty remembering TBPM tasks has been reported in schizophrenic patients (Wang et al., 2009), patients with Parkinson's disease (Costa, Peppe, Caltagirone, & Carlesimo, 2008; Raskin et al., 2011), thalamic stroke patients (Cheng, Tian, Hu, Wang, & Wang, 2010), and TBI patients (Kinch & McDonald, 2001; Kinsella et al., 1996). Most published work, however, has focused on the cognitive processes associated with storing and realising EBPM and TBPM tasks (Cook, Marsh, & Hicks, 2005). This has helped in the development of theories and various laboratory techniques for studying EBPM and TBPM (Gonen-Yaacovi & Burgess, 2012). Activity-based PM (Kvavilashvili & Ellis, 1996) has received less attention. It involves the retrieval of an intended action after the completion of a task; for example, remembering to shut the office door after completing one's work (Gonen-Yaacovi & Burgess, 2012). According to Kvavilashvili and Ellis (1996), activity-based PM and EBPM rely on some form of external cue, while TBPM relies on self-initiation without the presence of an external cue (Kvavilashvili & Ellis, 1996; McDaniel & Einstein, 2007). TBPM and EBPM tasks also tend to require the interruption of an ongoing activity, whereas activity-based PM tasks are executed before or following the completion of an activity (Kvavilashvili & Ellis, 1996).

According to Kvavilashvili and Ellis (1996), EBPM and activity-based PM are similar to each other in that both have an external cue. For instance taking medication after a meal might be regarded as an external cue in the same way as giving a message when you see John. Activity-based PM is also easier to remember since it must be performed when an activity has been completed thereby requiring less or no monitoring (Kvavilashvili & Ellis, 1996). Because activity-based PM uses the completion of an ongoing task as a cue it is easier to remember compared to EBPM and TBPM (Kvavilashvili & Ellis, 1996; Yang, Wang, Lin, Zheng, & Chan, 2013). Similarly, difficulties with activity-based PM are reported less often than EBPM and TBPM tasks (Kvavilashvili, Kornbrot, Mash, Cockburn, & Milne, 2009; Shum, Valentine, & Cutmore, 1999; Yang et al., 2013).

1.7. Phases of PM

Ellis (1996) proposed a framework model of PM that involves intention formation and encoding, intention retention, intention initiation, intention execution and possible evaluation of outcomes. Details are outlined below.

1.7.1. Intention formation and encoding. This phase involves forming an intention to carry out an action (Burgess, Scott, & Frith, 2003; Kliegel, McDaniel, & Einstein, 2000) in the future (e.g. post a letter). The to-be performed action (delayed intention) is then encoded. The intended intention cannot be performed instantly but at a predefined period in the future (Burgess et al., 2003). The extent to which an intention is encoded might be influenced by the level of motivation associated with the intention (Mioni, McClintock, & Stablum, 2014). The potential benefit and cost of realising the delayed intention can also influence the importance that individuals attach to intentions to be encoded (Ellis, 1996; Mioni, McClintock, & Stablum, 2014). Difficulty in encoding intentions has been identified as one of the main reason for deficits in PM performance (Altgassen, Kretschmer, & Schnitzspahn, 2016; Altgassen, Kretschmer, & Schnitzspahn, 2017; Altgassen et al., 2015; Mioni, Rendell, Terrett, & Stablum, 2015; Mioni, Stablum, Biernacki, & Rendell, 2017). The key focus of the current thesis is to improve the encoding of a PM intention in order to enhance PM task performance.

1.7.2. Intention retention. This phase involves retaining the intention while performing other tasks (Henry, Phillips, et al., 2007). During the period of retaining the intention (i.e., the delay interval between intention encoding and the appropriate moment to act), the individual engages in an activity called the ongoing activity/or task (Burgess et al., 2003). The intention might need to be retained for a few minutes, hours, days or longer depending on an individual's expectations on when they will have an opportunity to perform the intended action. According to Burgess, Gonen-Yaacovi, and Volle (2011), the aim of the ongoing activity is to "prevent a continuous, conscious rehearsal of the intention during the delayed interval/ or period" (p. 2247). It has been suggested that the characteristics of a delay period could affect the recall and execution of intentions. For instance, previous research using young adults has reported poorer intention performance after a long compared to a short delay interval (Meacham & Leiman, 1982). In contrast, other studies neither observed any relationship between the length of delay and PM decline in young and older adults (Einstein, Holland, McDaniel, & Guynn, 1992), nor improvement in performance in patients with closed head injury (Carlesimo, Casadio, & Caltagirone, 2004). Additional studies have observed the benefit of increased intention delay interval (with variable ongoing tasks) on PM performance in young adults (e.g., Hicks, Marsh, & Russell, 2000). In a typical experiment, Hicks et al. (2000) explored the effect of different properties of retention interval on EBPM performance and observed that longer intention interval with increasing number of distracter task enhances EBPM performance. Cognitive load associated with the delay interval (e.g. performing an ongoing activity or not performing an ongoing activity) might also influence performance (Einstein et al., 1992; Henry, Phillips, et al., 2007).

1.7.3. Intention initiation. This involves the inhibition of an ongoing task in order to carry out the intention to be performed (Ellis, 1996). Successful retrieval depends on the ability to recognise an event as a cue for an intended action while performing the ongoing task. Ellis (1996) argued that successful PM performance does not only involve accurately encoding and maintaining the PM task during the delay period, but also recognising an event as a cue that should trigger remembering, retrieving the action to be performed, and performing the PM task. Individuals might fail to execute the PM task if the process involved in monitoring for the occurrence of a cue required considerable cognitive resources (McDaniel, Einstein, & Jacoby, 2008; McDaniel, Einstein, & Rendell, 2008).

1.7.4. Intention execution. This phase involves carrying out intended actions after a delay. Ellis (1996) considered intention execution to be the final stage. However, errors might occur at the previous stages which might affect the execution phase. For instance, an individual might mistake a telephone booth for a letterbox if the colour and shapes appear similar. Unforeseen circumstances or distraction might also affect the execution process. For instance, the intention to go shopping might fail because of bad news. Ellis (1996) suggested that in a situation where one failed to execute the intended action, it is necessary to revise the plan and re-establish the intended intention. Burgess et al. (2003) indicated that immediate feedback on failure is usually lacking in many situations involving PM execution and that this might account for many deficits observed in PM performance since participants are not made aware of errors or failures in experimental settings.

1.7.5. Evaluation of outcomes. This involves the determination of whether or not a delayed intended action has been carried out correctly (Ellis, 1996). A sixth factor namely *output monitoring* has also been identified (Marsh, Hicks, Hancock, & Munsayac, 2002).

1.7.6. Output Monitoring. This is the process of evaluating one's memory for past actions in order to determine if the action was successfully executed or not (Gardiner & Klee, 1976; Klee & Gardiner, 1976). The term emanated from the work of Koriat and colleagues (Koriat, Ben-Zur, & Nussbaum, 1990; Koriat, Ben-Zur, & Sheffer, 1988; Koriat, Pearlman-Avnion, & Ben-Zur, 1998). According to Koriat et al. (1998), two errors can occur in the performance of PM tasks: repetition errors and omission errors. Repetition errors occur when one thinks one has not performed an intended action when in actual fact the action has already be performed (Marsh et al., 2002). Errors of omission occur when one believes that an intended action has been performed when this is not the case (Einstein et al., 1998; Marsh et al., 2002). Einstein et al. (1998) suggested that these errors are a result of failure to engage in correct output monitoring process (e.g., Koriat, Ben-Zur, & Sheffer, 1988).

If the evaluation of outcome indicated that PM intention was carried out correctly and successfully, then it is cancelled. Sometimes, in the case of multiple retrievals, the intentions are maintained until they have all been performed. In some situations, if the PM intention was not successfully carried out fully or correctly, the intention would need to be re-encoded and the process repeated (Ellis, 1996).

1.8. Theories of PM

Two key theories have attempted to explain the processes underlying PM task retrieval: the preparatory attentional and memory (PAM) theory (Smith, 2003; Smith, 2010; Smith & Bayen, 2004) and the multi-process theory (Einstein & McDaniel, 1996; Einstein & McDaniel, 2010; McDaniel & Einstein, 2000; McDaniel & Einstein, 2007).

1.8.1. The PAM Theory

The PAM theory (Smith, 2003; Smith & Bayen, 2004) proposes that "PM always requires attentional processes that are resource demanding due to explicit monitoring or the need to maintain the intention" (Smith et al., 2007, p. 734). It postulates that after forming a PM intention, individuals engage in continuous monitoring of the environment for the occurrence of the cue needed to trigger the PM intention (Smith, 2003; Smith & Bayen, 2004; Smith, Bayen, & Martin, 2010; Smith et al., 2007). This would mean that limited cognitive resources are diverted from an ongoing activity towards the monitoring and preparation for the occurrence of a cue needed to initiate PM tasks (Gonen-Yaacovi & Burgess, 2012). This suggests that the preparatory attentional processes are not automatic (McDaniel & Einstein, 2007). The timely recall of the intention is assumed to be the PM aspect of the task whereas the retention of what one was supposed to do is thought to be based on RM (Smith, 2003; Smith & Bayen, 2004). This presupposes that the PAM processes are essential for successful PM functioning as otherwise the individual will miss the PM task at the appropriate moment during the delay period in which they are not monitoring the environment. Likewise, PM failures might also occur when the individual monitors for the occurrence of a retrieval cue but fails to identify the PM target (Einstein & McDaniel, 2007; Smith et al., 2010). This assumption was based on previous findings suggesting that increasing the cognitive load of the ongoing activity influences the performance on PM tasks (e.g., Kvavilashvili, 1987).

Smith and Bayen's (2004) theory was based on findings from studies comparing performance on an ongoing activity without a PM task with performance during an ongoing task with a PM task in undergraduate students. The original theory was that preparatory attentional processes are attentionally-demanding (Smith, 2003). Smith (2003) asked participants to perform a lexical decision task as the ongoing activity. She presented a string of letters to her participants and asked them to indicate whether or not the string represented a word. In the second part, a PM task was embedded in the ongoing activity. Smith (2003) then instructed participants to respond differently to several PM cues. She discovered that the speed in making the lexical decision in the ongoing activity trials was significantly slower when the PM task was embedded, compared with similar trials in the first part, before the PM task was added. The reduction in performance of the ongoing task whilst maintaining an intention has variously been termed 'attentional cost', 'task interference' or 'intention cost' (Burgess, Quayle, & Frith, 2001). Other studies using a variety of ongoing tasks and PM cues on different populations have yielded similar findings, providing further support for the role of preparatory attention in PM (e.g. Adda, Castro, e Silva, de Manreza, & Kashiara, 2008; Block & Zakay, 2006; Brooks et al., 2002; Cheng et al., 2010; Costa et al., 2008; Einstein et al., 2005; Graf & Grondin, 2006; Marsh, Hicks, Cook, Hansen, & Pallos, 2003; McCauley & Levin, 2004; Smith, 2008; Smith et al., 2010; Smith et al., 2007; Wang et al., 2009). Furthermore, the intention cost on the ongoing activity has been found to be positively associated with PM performance

(Smith, 2003; Smith & Bayen, 2004), and has also been found on tasks preceding PM hits compared with tasks preceding PM misses (Bravin, Kinsella, Ong, & Vowels, 2000; West, Krompinger, & Bowry, 2005). This suggests that a working relationship exists between PAM processes and PM functioning.

Opponents of PAM theory, however, argue that the constant use of cognitive attentional resources in PM performance would be too costly to allow competent functioning in daily life (McDaniel & Einstein, 2007). Accordingly, they suggest that the PAM theory might relate to PM in specific situations where the predictability of the appearance of the PM cue is low (Marsh, Hicks et al., 2006) or where retention intervals are relatively short (Einstein et al., 2005). McDaniel and Einstein's (2007) Multiprocess theory of PM, for example, proposed that PM performance can be supported by both attention-demanding monitoring and also by more automatic processes.

1.8.2. Multi-Process Theory

The multi-process theory proposes that people can remember and perform PM intentions by monitoring the environment for the occurrence of the PM cue, or by responding spontaneously in the presence of a cue (Einstein & McDaniel, 2007; Einstein & McDaniel, 2010; McDaniel & Einstein, 2000). It suggests that whether PM performance is spontaneous or relies on strategic monitoring depends on the nature of the task (Einstein & McDaniel, 2007). Spontaneous retrieval implies that "retrieval can occur without mental resources devoted to the PM intention (i.e., without preparatory attentional processes) at the time that the target event first occurs" and that "no resources need to be devoted to evaluating the target event as a PM cue at the moment that it is first processed" (Einstein et al., 2005, p. 328; McDaniel & Einstein, 2007). The

PAM theory, in contrast, emphasises that "capacity must be devoted to the PM task in the form of monitoring before a target event occurs if the target is to be recognized as a signal or an opportunity to perform the PM action" (Smith, 2003, p. 359). According to Einstein and McDaniel (2007), spontaneous retrieval processes depends on variations, not only in the type of task but also in type of cue, nature of the ongoing task, and the individual. Thus, for example, tasks that must be remembered at a particular time require more strategic monitoring than those that must occur in response to an external cue (Einstein, McDaniel, Richardson, Guynn, & Cunfer, 1995).

The above theories suggest that PM processes demand a lot of resources (Smith, 2003; Smith, 2008), at least in some circumstances (McDaniel & Einstein, 2007). The multi-process and PAM theories indicate the complex cognitive processes that are involved in PM remembering and execution (Barr, 2011). For instance, in a meta-analysis, Henry, MacLeod, Phillips, and Crawford (2004) reported that age-related deficits were greater in EBPM tasks that made high demands on cognitive resources. This suggests that it is important to consider the nature of an EBPM task and thus the level of task monitoring that is likely to be required for success on that task (Henry et al., 2004). Similarly, it is argued that TBPM tasks require constant monitoring rather than spontaneous processes as they require self-initiated monitoring of clock time. TBPM tasks are therefore thought to impose a higher demand on cognitive processes and should be more susceptible to performance deficits, particularly in older adults and participants with impaired executive processing (McDaniel & Einstein, 2000).

1.9. Neurological Basis of PM

PM processes involve multiple memory components (Burgess & Shallice, 1997; Dobbs & Reeves, 1996; Graf & Uttl, 2001) which are possibly located at different neuroanatomical areas (Foley, 2007). The prefrontal cortex (PFC), for example, is thought to play a major role in PM functioning, given its role in supporting executive (attentionally-demanding) processes such as planning (Burgess et al., 2007; Burgess et al., 2011; Burgess et al., 2001; Burgess et al., 2003; Den Ouden, Frith, Frith, & Blakemore, 2005; Glisky, 1996; Kesner, 1989; McDaniel, Glisky, Guynn, & Routhieaux, 1999; Okuda et al., 1998; Simons, Schölvinck, Gilbert, Frith, & Burgess, 2006). The definition of PM implies that it involves executive processes such as planning, interruption of an ongoing task and switching from that task to initiate a PM action (Shum et al., 2002). Consistent with these assumptions PM has been found to be sensitive to frontal lobe damage (Demakis, 2004). The performance of PM tasks has been associated also with the activation of the medial and lateral prefrontal cortices (Burgess et al., 2007; Burgess et al., 2003; Kesner, 1989). For instance, Burgess et al's. (2007) Positron Emission Tomography (PET) study of PM found, with the help of a PET scan, that the rostral frontal cortex (Brodmann's area 10 i.e., BA10) plays a major role in PM performance. Importantly, they discovered that the lateral and medial regions of BA10 play a role in the maintenance and remembrance of an intention while performing ongoing tasks. This finding provided support for previous work in the area (e.g., Burgess et al., 2001; Okuda et al., 1998). Further studies have consistently confirmed the role of the frontal lobes in PM performance, particularly BA10 (Burgess et al., 2007; Burgess, Gonen-Yaacovi, & Volle, 2011; Okuda et al., 2007; Simons et al., 2006).

Okuda et al. (2007) conducted two PET studies in order to determine the areas of the brain associated with EBPM and TBPM performance. Using young healthy adults, they discovered that an area of the left superior frontal gyrus was more active in the TBPM condition when participants were asked to perform a PM task based on self-estimation on the passage of time without a clock, while performing a demanding ongoing task. When a clock was present, the authors discovered that right superior frontal gyrus, anterior medial frontal lobe, and anterior cingulate gyrus which are part of BA10, were more active during the TBPM task. In contrast, the left superior frontal gyrus was more active during the EBPM task (Okuda et al., 2007). These findings further strengthen the role of the frontal lobe in both EBPM and TBPM performance. The hippocampus has also been suggested to be involved in PM performance (Cohen & O'Reilly, 1996; Ferbinteanu & Shapiro, 2003), specifically in remembering the content of the PM task (McDaniel et al., 1999; Mioni, Rendell, Henry, Cantagallo, & Stablum, 2013).

A considerable body of research indicates that PM is more sensitive to deficits in executive processes compared to RM (Kliegel, Martin, McDaniel, & Einstein, 2004; Kopp & Thöne-Otto, 2003). Findings suggest that PM might be supported primarily by prefrontal mediated (executive control) processes rather than temporally mediated (RM) processes (Brunfaut, Vanoverberghe, & d'Ydewalle, 2000; McDaniel et al., 1999). PM processes such as intention planning and formation, intention initiation, and intention execution require EF processes supported by the prefrontal cortex, while intention retrieval is supported by the medial temporal lobe (Cohen & O'Reilly, 1996; Guynn, McDaniel, & Einstein, 2001).

Specific findings have also been reported in patients with localised lesions. For instance, Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, and Burgess (2011) compared the performance of 45 patients with focal brain lesions with that of 107 control participants in EBPM and TBPM tasks, in order to examine the role of the PFC in PM functioning. They found that the performance of people with lesions in the right polar prefrontal region (right rostral PFC), approximating BA10 was specifically associated with poor performance on the TBPM task. Volle et al. (2011, p. 2193) speculated that the role of the rostral PFC in TBPM performance suggests that “TBPM and EBPM might be supported at least in part by distinct brain regions”. Simons et al. (2006) also reported significant BA 10 activation bilaterally in both EBPM and TBPM. Neuropsychological investigations have also implicated other brain regions in PM performance. For instance, Palmer and McDonald (2000) examined the involvement of temporal lobe structures in PM in 13 patients with lesions in the left temporal lobe plus a matched control group on TBPM tasks. They found significant impairments in the patient group compared with the control participants in all of the TBPM tasks (e.g., “every 15 minutes tell the experimenter what you are working on”, “at a pre-specified time tell the experimenter that the testing should almost be finished”; Gonen-Yaacovi & Burgess, 2012, p. 185).

Taken together, the neuroscience of PM suggests that the PFC is involved in PM phases, showing greater activation during performance of the ongoing tasks and PM monitoring (Burgess, Simons, Coates, & Channon, 2005; Burgess et al., 2007; Burgess et al., 2011; Burgess et al., 2011; Simons et al., 2006). This appears to support the PAM model, which suggests that PM involve resource demanding processes needed to maintain PM intentions while performing an ongoing task (especially TBPM).

1.10. Factors Affecting PM

Several factors are believed to affect PM performance. These include the focality of a PM cue, working memory load of the ongoing task, self-or-experimenter generated target, number of PM targets, motivation, the distinctiveness or saliency of the cue, the semantic relationship between retrieval cue and PM and the length of the retention interval (Banville & Nolin, 2012; Graf, 2012; McDaniel & Einstein, 2000; Mioni et al., 2013; Raskin, Buckheit, & Waxman, 2012; Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010). Healthy individuals without any neurological impairment have decreased accuracy when attentional and/or working memory demands of the task are increased, with rapid stimuli presentation, and when the ongoing task is unfamiliar and requires multiple responses (McDaniel & Einstein, 2000; Rendell, McDaniel, Forbes, & Einstein, 2007). In complex PM tasks that impose greater attentional and effortful processing demands, older adults tend to perform significantly worse than young adults (Banville & Nolin, 2012; McDaniel & Einstein, 2000; Rendell, McDaniel, et al., 2007; Uttl, 2008). It has been suggested that as individuals age, they begin to experience deficits in attention, processing speed, and EFs, especially on tasks that involve controlled and effortful processing (Banville & Nolin, 2012; Lezak, Howieson, Bigler, & Tranel, 2012; Uttl, 2008). TBI patients also present with impairments related to working memory, EFs, attention, and processing speed, (Banville & Nolin, 2012). As a result, PM tasks with greater attentional and effortful processing demands are thought to have a more pronounced negative impact on TBI patients' performance (Maujean et al., 2003; Mioni et al., 2013; Raskin et al., 2012).

Maujean et al. (2003) asked TBI and healthy participants to perform EBPM tasks together with a low or high demand lexical decision (ongoing) task. They discovered that the patients group's performance on EBPM tasks was poor compared to the healthy control group when the ongoing task demands are high. Maujean et al. (2003) suggested that the high demand condition places more cognitive resources of the patients thereby affecting their performance.

Schmitter-Edgecombe and Wright (2004) investigated PM performance after severe closed-head injury (CHI) with a focus on EBPM. They examined the influence of the extent to which a PM cue is either integral (focal cue) or peripheral (non-focal) in relation to the processing requirements of the ongoing task. Prior research indicated that non-focal cues impact negatively on performance in an EBPM task (e.g., Marsh, Hicks & Hancock, 2000; McDaniel & Einstein, 2000). Twenty-four severe CHI participants (> 1-year post-injury) and 24 controls completed EBPM tasks while performing an ongoing verbal working memory task. PM cue focality was manipulated by embedding some event cues in the ongoing working memory task (i.e., focal cue) while other cues were defined as a change in the background pattern in which cue and non-cue words appeared (non-focal cue). The ongoing task was to keep track of the last 3 words presented on the screen. Participants were randomly assigned to one of two groups: focal cue and non-focal cue. In the focal cue condition, they were asked to press a particular key whenever the word "stone" appeared on the screen (6 times). In contrast, in the peripheral cue condition they were required to press a particular key whenever they observed a change in the background pattern (6 times). Consistent with other findings, the authors reported poorer PM remembering for patients in both the focal- and peripheral-cue conditions and there was no significant difference between the groups on the ongoing tasks. Moreover, there was no difference, in both CHI and control groups, between performance in the focal and non-focal PM cue conditions. Therefore, CHI patients appear to demonstrate poor PM performance even in the presence of a ‘salient’ PM cue (i.e., the focal cue).

Despite the influence of many factors in PM performance, difficulties are commonly reported in older adults and neuropsychological patients especially TBI (Kliegel, Eschen, & Thöne-Otto, 2004; Kliegel & Martin, 2003). Several studies suggest that PM performance declines with ageing (e.g.; Dobbs & Rule, 1987; Einstein, McDaniel, Manzi, Cochran, & Baker, 2000; Huppert, Johnson, & Nickson, 2000; Mantyla & Nilsson, 1997; Park, Hertzog, Kidder, Morrell, & Mayhorn, 1997). Similarly, TBI patients are more vulnerable to PM difficulties due to deficits in executive processes following injury (Azouvi, 2000). Also, many TBI patients tend to present with PM deficits as their main symptoms following injury and integration into the community (Martin, Kliegel, & McDaniel, 2003). This might have accounted for their everyday difficulties in life (Kinsella et al., 1996). It is therefore essential for us to enrich our theoretical understanding of PM deficits and identify strategies by which PM performance could be enhanced in this population thereby improving their quality of life. In this thesis, we focused on TBI (Chapter 2) and older adults (Chapter 3) since research on improving PM functioning in these populations is relatively limited (e.g., Altgassen et al., 2015; Mioni, Bertucci, et al., 2017; Mioni et al., 2015; Raskin, Smith, Mills, Pedro, & Zamroziewicz, 2017). The effects of ageing and TBI on PM performance are discussed further at a later point in this chapter (Sections 1.12 and 1.13).

1.11. The Measurements of PM

Several approaches have been used to assess PM especially in neuropsychological patients and older adults (Henry et al., 2004; Mioni, McClintock, et al., 2014; Shum, Levin, & Chan, 2011; Uttl, 2008). Studies used questionnaires and subjective ratings to document PM failures (Crawford, Smith, Maylor, Della Sala, & Logie, 2003; Hannon, Adams, Harrington, Fries-Dias, & Gipson, 1995; Heffernan, Ling, & Scholey, 2001; Ling et al., 2003; Raskin et al., 2012; Roche, Moody, Szabo, Fleming, & Shum, 2007; Rönnlund, Sundström, Adolfsson, & Nilsson, 2015; Shum, Levin, et al., 2011; Smith, Del Sala, Logie, & Maylor, 2000; Zeintl, Kliegel, Rast, & Zimprich, 2006). The most commonly used are the PM Questionnaire (PRMQ; Hannon et al., 1995), the Prospective and RM Questionnaire (PRMQ; Smith et al., 2000), and the Comprehensive Assessment of PM (CAPM; Roche et al., 2007). Although self-report measures have provided sound preliminary data which can be used to inform diagnostic and treatment decisions, they sometimes present with issues of ecological validity due to their subjective nature (Thompson, Henry, Rendell, Withall, & Brodaty, 2015; Uttl & Kibreab, 2011). Although subjective ratings do provide unique insights into the limitations TBI survivors face in the real world, several studies report that a subjective rating of prospective memory functioning does not correlate with performance on PM tasks for either healthy or clinical populations (Mateer, Sohlberg, & Crinean, 1987; Raskin et al., 2012; Uttl & Kibreab, 2011). In order to deal with the limitations of self-reported rating scales, several PM tasks have been developed and standardized to investigate PM functioning in both clinical and non-clinical settings (Raskin, 2009; Wilson, Cockburn, & Baddeley, 1985). The most commonly used tests are the Memory for Intentions Test (MIST; Raskin, 2009), the Cambridge PM Test (CAMPROMPT; Wilson, 2005; Wilson et al., 2005), and the Rivermead Behavioural Memory Test (RBMT; Wilson et al., 1985). Example of PM tasks includes remembering to ask a specified question when an alarm sounds or to switch puzzles at a particular time.

Other studies have made use of ‘conventional’ PM laboratory experiments, such as those described previously in this chapter (Fleming et al., 2008; Henry, Phillips, et al., 2007; Shum, Levin, & Chan, 2011; Shum, Valentine, & Cutmore, 1999; Umeda, Kurosaki, Terasawa, Kato, & Miyahara, 2011; Uttl, 2008). In a typical experimental paradigm, participants are usually asked to encode a PM intention to be executed later in the future in the presence of a cue (e.g., press a keyboard key when you see the word “DOG” on the screen; Shum et al., 1999). The delay period usually involves completing a filler task (e.g. Sudoku, lexical decision making). The aim is to distract participants so that they avoid rehearsing the PM task to be performed. When the PM cue ("DOG") appears, participants are expected to recognize the cue, inhibit performance of the ongoing task (filler task), and execute the PM intention (e.g., pressing the key). The above example describes a measure of EBPM (Henry, Phillips, et al., 2007). In the TBPM task, the cue could be a specific time or time interval (e.g., pressing the key every 15 minutes). The number of cues varies depending on research designs (Shum, Levin, et al., 2011). Some studies employed a single cue and measures are scored as correct or wrong as an index of PM performance (Hannon et al., 1995; Kondo et al., 2010; Mathias & Mansfield, 2005; Umeda et al., 2011). This scoring criterion was limited since it often leads to ceiling or floor effects, affecting the validity and reliability of the measure (Mioni, McClintock, et al., 2014; Uttl, 2008; Uttl & Kibreab, 2011). In order to overcome this methodological limitation, most studies use multiple cues to obtain an index of PM performance (Fleming et al., 2008; Groot, Wilson, Evans, & Watson, 2002; Henry, Phillips, et al., 2007; Kliegel, Eschen, et al., 2004; Pavawalla, Schmitter-Edgecombe, & Smith, 2012; Raskin et al., 2012; Tay, Ang, Lau, Meyyappan, & Collinson, 2010). For example, the PM cue could be presented 8 times during the course of the task, and the index of PM performance calculated as the proportion of correct PM responses (Banville & Nolin, 2012). One major limitation of laboratory-based research is that the findings are based on performance on tests that do not necessarily encapsulate all of the different types of PM tasks that individuals usually encounter in daily life (Barr, 2011; Mioni & Stablum, 2013).

Recent studies using a 'virtual week' or a 'virtual environment' have made an effort to improve ecological validity including PM intentions, cues and ongoing tasks that are intended to resemble daily activities (Barr, 2011; Canty et al., 2014; Kinsella, Ong, & Tucker, 2009; Mioni, Bertucci, et al., 2017; Mioni et al., 2013; Mioni et al., 2015; Mioni & Stablum, 2013; Potvin, Rouleau, Audy, Charbonneau, & Giguere, 2011). In one recent study of PM, Potvin et al. (2011) examined the validity and sensitivity of a virtual task, which they described as an ecological test of PM for use with patients with moderate and severe TBI. The test includes a 20-min video of various parts of a city as an ongoing task that simulates driving through the streets of the city. EBPM tasks and five TBPM tasks were embedded in the video and participants are instructed to perform these tasks in order to prepare for a birthday dinner (version A) or a holiday (version B). The authors found that the TBI patients experienced more pronounced difficulty in both EBPM and TBPM performance than the healthy matched controls.

Taken together, the literature review suggests that PM deficits in patients with TBI are robust across studies irrespective of the experimental task or measurement used (Shum, Levin, et al., 2011). PM deficits in older adults, however, may be dependent on the location or testing environment (Henry et al., 2004; Uttl, 2008). Details of location effect on PM performance in ageing are discussed later in this Chapter (Section 1.12). Some of the measures for testing PM performance in the TBI and healthy older adult population include; paper and pencil tasks (e.g., Dobbs & Rule, 1987; Kinch & McDonald, 2001; Kinsella et al., 1996; Smith et al., 2000; Uttl & Kibreab, 2011), computerized tasks (e.g., Einstein et al., 1995; Maujean et al., 2003; Rendell & Craik, 2000; Schmitter-Edgecombe & Wright, 2004; Shum et al., 1999), psychometric tests (e.g., Mathias & Mansfield, 2005; Raskin, 2009; Tay et al., 2010), and virtual week and virtual reality tasks (Kinsella et al., 2009; Knight, Harnett, & Titov, 2005; Knight & Titov, 2009; Knight, Titov, & Crawford, 2006; Mioni, Bertucci, et al., 2017; Mioni et al., 2013; Mioni et al., 2015; Paraskevaides et al., 2010; Potvin et al., 2011; Rendell &

Craik, 2000; Rendell & Henry, 2009; Rendell & Thomson, 1999; Rose et al., 2015; Rose et al., 2010; Rose, Rendell, McDaniel, Aberle, & Kliegel, 2010; Trawley, Law, & Logie, 2011). The findings from the above studies suggest that TBI patients' deficit in PM is consistent across tasks whilst impairment in older adults seems to be more dependent on testing condition. The use of virtual tasks to assess and rehabilitate PM has great potential since they more closely mimic everyday activity and are relatively easy to implement (Knight & Titov, 2009; Shum, Levin, et al., 2011).

1.12. PM in Healthy Older Adults

As we grow older, our cognitive capacity is believed to decline, not necessarily because of any physiological diseases, but rather due to normal ageing process (Small, Tsai, DeLaPaz, Mayeux, & Stern, 2002). It is believed that changes in cognitive function associated with lifespan development is the foundation for the development of dementia-related cognitive impairments (Brayne & Calloway, 1988). It is also thought that of all higher-order cognitive functions, memory decline (of which EF is one) is the most sensitive to the ageing process (Buckner, 2004; Small et al., 2002), perhaps linked to changes in the hippocampus (Small et al., 2002). The effect of age on EF decline is as a result of a reduction in brain volume in the PFC following ageing (Cabeza & Dennis, 2012; Greenwood, 2000). This leads to the emergence of the frontal lobe hypothesis (Greenwood, 2000; West, 2000) which supposes that decline in EF is a result of age-related changes in PFC (Cabeza & Dennis, 2012; Greenwood, 2000; Kievit et al., 2014; Moscovitch & Winocur, 1992; West, 1996). In a review, Cabeza and Dennis (2012) observed several lines of evidence that supported the frontal lobe hypothesis. These include "(1) cognitive deficits in older adults are more pronounced in tasks that are highly dependent on executive control processes, which are assumed to be mediated by PFC, (2) age-related reductions in brain volume (atrophy) are more pronounced in PFC than in other brain regions, (3) age-related white matter deterioration is most pronounced in anterior brain regions including PFC, and (4) PFC is affected by age-related deficits in dopamine function" (Cabeza & Dennis, 2012, pp. 628-629). A similar observation was reported by (Buckner, 2004). This suggests that due to major changes in the part of the brain that supports intellectual capacity (PFC), EF processes necessary for PM functioning decline thereby leading to poorer PM functioning in older age.

Contrary to the frontal lobe hypothesis, analysis of the literature suggests that multiple brain areas are involved in memory decline including not only the PFC but also the medial temporal lobe memory system (Buckner, 2004; Cabeza & Dennis, 2012; Kievit et al., 2014). Other areas include the thalamus (De Rover et al., 2008; Gallo, Sullivan, Daffner, Schacter, & Budson, 2004; Xu et al., 2000) and basal ganglia (Bugiani, Salvarani, Perdelli, Mancardi, & Leonardi, 1978; Schwartz et al., 1985). However, the prevailing view is that age-related deficits are primarily the result of PFC decline which supports EFs (Cabeza & Dennis, 2012).

Several laboratory studies suggest that PM performance also declines with old age (e.g., Dobbs & Rule, 1987; Einstein et al., 2000; Gonneaud et al., 2011; Huppert et al., 2000; Mantyla & Nilsson, 1997; McDaniel & Einstein, 2011; Park et al., 1997; Scullin et al., 2011). Mantyla and Nilsson (1997), for example, in a study with a large sample size of participants between the ages of 30 and 80 years found that PM seems to decline linearly from the 5th decade. This was confirmed by Huppert et al. (2000) who found a similar pattern in an older population from 65 years of age in their PM task. Dobbs and Rule (1987) gave their participants a questionnaire to take home and complete after an experimental session. Participants were to write the date and time that they completed the questionnaire in the upper left hand corner of the questionnaire. In their study, Dobbs and Rule (1987) used two criteria to analyse their PM data (i.e. strict and lenient). They stated that the lenient criterion helps to reduce the impact of the RM component of the PM task, thereby making it easier to measure “PM proper” (Graf & Uttl, 2001, p. 438). In the strict criterion, PM performance was recorded as correct if participants wrote both the time and date in the correct location. With the lenient criterion, PM was scored as correct if the date or time was written in any location on the questionnaire. Dobbs and Rule (1987) observed a moderate influence of age on PM performance when the strict criterion was employed. In contrast, they observed a significant age-related PM decline with the lenient criterion.

Recent laboratory-based PM studies have consistently confirmed a decline in PM in old age (Altgassen, Phillips, Henry, Rendell, & Kliegel, 2010; Bisiacchi, Tarantino, & Ciccola, 2008; Henry et al., 2004; Ihle, Hering, Mahy, Bisiacchi, & Kliegel, 2013; Kliegel, Mackinlay, & Jäger, 2008). Altgassen et al. (2010), for example, examined whether emotional target cues would eliminate age differences in PM and observed that an age deficit was present when neutral cues were used. The deficit was reduced when emotion (positive and negative) related PM cues were presented. In a recent meta-analysis covering a period of 20 years, Uttl (2008) reported a substantial age-related PM decline depending on the aspect of PM being measured (i.e. vigilance, PM proper [irregular/non-routine PM tasks], habitual PM [regular/routine PM tasks]) as well as the study location (laboratory vs. naturalistic environment). He concluded that an age-related PM decline is generally observed between the ages of 50-69 and then rapidly deteriorates (Uttl, 2008).

An age-related decline in EFs is thought to be related to PM impairment (Glisky, 1996; Kliegel, Ramuschkat, & Martin, 2003a; Kliegel, Ramuschkat, & Martin, 2003b; Martin et al., 2003; Maylor, Smith, Sala, & Logie, 2002; Rose et al., 2010; Salat, Kaye, & Janowsky, 2001; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013; West, 1996). The PFC is widely believed to support EFs (Cabeza & Dennis, 2012; Demakis, 2004) and quite a number of researchers (e.g. Crawford, Bryan, Luszcz, Obonsawin, & Stewart, 2000; Daigneault, Braun, & Whitaker, 1992) have shown that EFs decline early in old age (between 45 to 65 years).

PM impairment in older adults is related to age-related deterioration in EF processes (West, 1996). For instance, West and Covell (2001) used ERPs (event-related potentials) to investigate the neural basis of EFs associated with age-related PM impairment. They observed an age-related reduction in the efficiency of the frontally mediated neural system related to PM remembering. Similarly Kliegel et al. (2003a), in hierarchical multiple regression analysis, discovered that five EF tests completely accounted for age-related variance in PM task performance: Stroop Test (Stroop, 1935), Wisconsin Card Sorting Test (WCST; Heaton, Chelune, Talley, Kay, & Curtiss, 1993), S-Words Test (Regard, Strauss, & Knapp, 1982) and Tower of London (Ward & Allport, 1997), Plan-A-Day Test (Funke & Krüger, 1993), completely accounted for age-related variance in PM task performance. This finding was supported by Kliegel, Eschen, et al. (2004) who reported poorer performance for older adults compared to younger adults on the WCST. Similarly, Schnitzspahn et al. (2013) in a study to identify the role of different EFs in older adults' PM performance, reported an age-related decline on both PM and EF tasks. Subjective ratings have also indicated that complaints of PM failures are common among the elderly (Glisky, 1996).

Other studies have revealed that in a naturalistic setting older adults tend to perform similar to or sometimes better than younger adults, especially on TBPM tasks, compared to performance in laboratory settings (e.g., Schnitzspahn, Ihle, Henry, Rendell, & Kliegel, 2011). The PM tasks required participants to “send two text messages per day with the content “a” at pre-specified target times to the investigator across three consecutive days” (Schnitzspahn et al., 2011, p. 586). Other naturalistic tasks have usually required participants to telephone the experimenter at a specific time over 5 days (Maylor, 1990), 2 weeks (Moscovitch, 1982), 3 weeks (Poon & Schaffer, 1982), and 4 weeks (Devolder, Brigham, & Pressley, 1990); periodically log the time on an electronic organizer (Rendell & Thomson, 1993; Rendell & Thomson, 1999) or mail postcards to the experimenter (Patton & Meit, 1993).

For instance, d'Ydewalle and Brunfaut (1996), in a series of experiments, found better performance for older than for younger adults when they requested the participants to telephone the experimenter on each of five consecutive days. In their first experiment, they allowed participants to use external aids of their own choice (e.g. mnemonics). In the second experiment, they imposed a restriction on the type of reminders to use (e.g., mnemonics or rehearsal). In experiment 3, participants were allowed to use remainders of their choice. The three different experiments revealed consistently higher performance in older compared to younger adults, suggesting that older adults outperformed younger adults on the PM task in a naturalistic environment with or without the help of reminders.

In order to confirm the benefit of naturalistic environment for PM performance compared to laboratory settings across different age groups, Rendell and Thomson (1999) compared young (18–28 years), old (60–69 years) and older-old (80–92 years) adults' PM performance in a laboratory-based setting that involved the completion of questionnaire and RM tasks. In this experiment, the authors embedded two time-based tasks where participants were asked to stop a clock after seven minutes into the test. The naturalistic task involved the participants pressing a specific sequence of keys on an electronic organizer at 4 specific times of the day outside of the laboratory. The participants were requested to perform this latter task for seven days. Rendell and Thomson (1999) reported that the older adults in general performed better than the younger adults on the naturalistic PM task but worse on the laboratory task compared to younger adults. Furthermore, within the older adult group, the older-old adults' performance on the laboratory tasks was lower than that of the old adults. However, old adults and younger adults performed similarly on these tasks.

In a subsequent study, Bailey, Henry, Rendell, Phillips, and Kliegel (2010) demonstrated that older adults were more able than younger adults to remember to respond to a set of questions via personal digital assistants (PDAs) outside the laboratory, but that younger adults performed better on the experimenter-controlled laboratory-based PM task that was embedded within the PDA questionnaire. This was confirmed in a meta-analysis by Uttl (2008) who found that in a naturalistic setting, older adults were more likely to perform PM tasks significantly better than younger adults. Even when the same participants were tested in both naturalistic and laboratory settings, the inconsistent findings remain the same (e.g., Rendell & Thomson, 1999; Schnitzspahn, Stahl, Zeintl, Kaller, & Kliegel, 2013). Rendell and Craik (2000) described this phenomenon of age benefit in a naturalistic setting and age-related deficit in a laboratory setting as the "age-PM paradox".

Several of the naturalistic studies involved the use of external cues or aids as prompts. The use of prompts and external aids in the naturalistic tasks might have reduced the need for self-initiated retrieval processes, thereby eliminating age-related PM deficits (Glisky, 1996). It was suggested that the probable finding in naturalistic PM might be due to lack of restrictions on the use of external aids (Henry et al., 2004). Maylor (1990), however, suggested that preventing the use of external aids reduces age-related naturalistic PM benefit. In some cases, the age-related benefit is no longer significant (Patton & Meit, 1993) although d'Ydewalle and Brunfaut (1996) demonstrated an age-related benefit despite the restrictions imposed on external aids.

Recently it has been suggested that motivation plays a role in the age-related benefit on naturalistic tasks (Aberle, Rendell, Rose, McDaniel, & Kliegel, 2010; Phillips, Henry, & Martin, 2008). Phillips et al. (2008) suggested a role for motivation in the age-related paradoxical findings, especially in naturalistic settings. Consistent with this suggestion, Aberle et al. (2010) found that the use of incentives eliminates the age-related benefit of PM performance such that younger adults were more likely to perform better than older adults when an incentive was provided. This indicates that older adults are more likely to be intrinsically highly motivated when performing naturalistic tasks compared to younger adults (Rendell & Craik, 2000). The degree of motivation associated with older adults' PM performance might be due to the need to sustain independent living. This was confirmed in previous research where older people were observed to have possibly attached more importance to the PM task compared to younger adults (Rendell & Thomson, 1999). What these findings suggest is that the consistent age-related decline in PM performance (Banville & Nolin, 2012; Henry et al., 2004; Ihle et al., 2013) calls for research on how PM in older adults could be improved given its high relevance to older adults' daily lives (Hering, Cortez, Kliegel, & Altgassen, 2014).

1.13. PM in Neuropsychological Populations

In a review, Gonen-Yaacovi and Burgess (2012) reported PM impairment for different neuropsychological populations compared to healthy controls. Difficulties in PM performance have been reported for patients with Parkinson's disease (Costa et al., 2008; Katai, Maruyama, Hashimoto, & Ikeda, 2003; Kliegel, Phillips, Lemke, & Kopp, 2005), although it should be noted that Altgassen, Zöllig, Kopp, Mackinlay, and Kliegel (2007) found that these patients can perform EBPM tasks to a normal degree if the prospective task component is prioritized. Impairment has also been found in patients with Schizophrenia (Altgassen, Kliegel, Rendell, Henry, & Zöllig, 2008; Henry, Rendell, Kliegel, & Altgassen, 2007; Kondel, 2002; Kumar, Nizamie, & Jahan, 2005), Obsessive Compulsive Disorder (Cuttler & Graf, 2007, 2008, 2009), Mild Cognitive Impairment (Tam & Schmitter-Edgecombe, 2013; Thompson, Henry, Rendell, Withall, & Brodaty, 2010) and Dementia and Alzheimer's disease (Hsu, Huang, Tu, & Hua, 2015; Huppert et al., 2000; Maylor et al., 2002; Smith et al., 2000) . EBPM and TBPM impairment has also been found in patients with other neurological problems, e.g., stroke patients (Brooks, Rose, Potter, Jayawardena, & Morling, 2004) and people with bilateral frontal lobe infarcts (Cockburn, 1995).

Difficulties with EBPM and TBPM performance have been found to be common and persistent in adults with TBI (Carlesimo et al., 2004; Fortin, Godbout, & Braun, 2002; Groot et al., 2002; Kinsella et al., 1996; Kliegel, Eschen, et al., 2004; Knight et al., 2005; Knight et al., 2006; Mathias & Mansfield, 2005; Potvin et al., 2011; Roche, Fleming, & Shum, 2002; Shum et al., 1999; Umeda et al., 2011). TBI patients' difficulty with retrieving PM intentions appears to be linked to impairments to prefrontal and temporal regions, brain structures which are particularly vulnerable following a TBI (Gonen-Yaacovi & Burgess, 2012).

1.14. PM in TBI

TBI has been identified as a significant public health challenge characterised by notable impairments in memory functioning (Schwarzbold et al., 2008). TBI is an injury to the brain resulting from sudden acceleration and deceleration of the head due to an external mechanical force or a "blow to the head" leading to diminished consciousness or altered state of consciousness or coma and/or post-traumatic amnesia (Lezak, Howieson, Bigler, & Tranel; Povlishock & Katz, 2005; Stratton & Gregory, 1994). Closed head injury is the most common outcome of TBI and often results in "focal and diffuse injuries to the brain due to rotational acceleration imparted to the brain and more localized impacts from blunt trauma" (Levin, Shum, & Chan, 2014, p. 3).

TBI is mostly caused by road traffic accidents, sport-related injuries and military conflict (Roozenbeek, Maas, & Menon, 2013). It has been identified as one of the leading causes of death and disability all over the world (Maas, Stocchetti, & Bullock, 2008). Every year, about 1.5 million affected individuals die and several millions receive emergency treatment (Bruns & Hauser, 2003; Fleminger & Ponsford, 2005; Roozenbeek et al., 2013). Hofman, Primack, Keusch, and Hrynkow (2005), moreover, observed that most of the burden (90%) is experienced in low and middle-income countries (e.g., Ghana where my first study was conducted).

Memory impairment relating to attention, EFs (e.g., planning, inhibition, monitoring), working and episodic memory, and processing speed are the most common sequelae of TBI (Barr, 2011; Belanger, Curtiss, Demery, Lebowitz, &

Vanderploeg, 2005; Chafetz, 2012; Dikmen et al., 2009; Finnanger et al., 2013; Lee, 2011; Lezak et al., 2012; Schoenberg & Duff, 2011; Shum et al., 2002; Shum, Levin, et al., 2011). Memory is important for many cognitive tasks (Shum et al., 2002) and its impairment can result in difficulties with, for example, planning, decision-making, remembering to carry future intentions and integration into the community (Dikmen et al., 2009; Finnanger et al., 2013; Knight et al., 2006; Kreutzer et al., 2003; Ponsford, Olver, & Curran, 1995; Schoenberg & Duff, 2011). These difficulties might not remit over time and their effects can be devastating and difficult to deal treat (Levin, 1991; Williamson, Scott, & Adams, 1996). One area of the brain that has been found to be susceptible to damage following TBI is the frontal lobes (Bigler, 2007, 2008; Bigler, 2013; Levine, Cabeza, et al., 2002), with the possibility of both executive and concomitant episodic memory dysfunction (Azouvi, 2000; Azouvi et al., 2004). Past research on memory functions and TBI has concentrated primarily on deficits in RM (Henry, Rendell, et al., 2007; Shum et al., 1999). However, there is increasing interest in investigating PM in individuals with TBI. This is due to the important role of PM in completing daily activities (Graf, 2011; Shum, Levin, et al., 2011; Uttl, Graf, Miller, & Tuokko, 2001)

Several studies suggest that PM failure is a common feature in the TBI population, compared to an intact control group, on both EBPM and TBPM (Carlesimo et al., 2004; Fleming et al., 2008; Groot et al., 2002; Hannon et al., 1995; Henry, Phillips, et al., 2007; Kinch & McDonald, 2001; Kliegel, Eschen, et al., 2004; Knight et al., 2005; Knight & Titov, 2009; Knight et al., 2006; Mathias & Mansfield, 2005; Mioni, Bertucci, et al., 2017; Mioni et al., 2013; Mioni et al., 2015; Potvin et al., 2011; Roche et al., 2007; Shum, Fleming, et al., 2011; Shum et al., 1999). The extent of impairment in PM performance also depends on the demands of the task (Fleming et al., 2008; Fleming, Shum, Strong, & Lightbody, 2005). Within the TBI population, patients have been found to be more impaired on time-based tasks compared to event-based tasks (Adda et al., 2008; Groot et al., 2002; Kinch & McDonald, 2001; Mathias & Mansfield, 2005).

TBPM tasks are thought to demand more strategic resources because they rely on self-initiation (Einstein & McDaniel, 2010). Difficulties on TBPM tasks might also be due to less strategic monitoring behaviour engaged by TBI patients (Ellis, 1996; McDaniel & Einstein, 2000; Mioni & Stablum, 2013). Groot et al. (2002), however, discovered that healthy controls have difficulties with TBPM tasks that are similar to those of the TBI group. Shum et al. (1999) reported worse performance for patients with long-term TBI compared to controls on TBPM and activity-based PM tasks. In common with Groot et al.'s finding, Shum et al. (1999) also observed that TBPM was poorer than EBPM for both TBI and control groups.

Groot et al. (2002) used the modified version of the Cambridge Behavior Prospective Memory Test (CBPMT; Wilson & Evans, reported in Kime, Lamb, & Wilson, 1996) to compare the PM performance of 36 people with brain injury and 28 control participants. They administered four-time- and four event-based tasks of the CBPMT to the participants where they were required to respond either verbally or non-verbally when these PM tasks were encountered. The responses sometimes necessitated interruption of neuropsychological tests that were serving as filler activities. A clock was positioned where participants were able to see the time and participants were informed that they could use any strategy that they thought could help them remember the PM tasks. They were also allowed to take notes to help them remember the tasks. Groot et al. (2002) found that participants had more difficulty with the TBPM than with the EBPM tasks. They also reported that the brain injury patients performed significantly worse on both the EBPM and TBPM tasks compared to the control group.

Shum et al. (1999) also investigated the effect of TBI on EBPM, TBPM, and activity-based PM with the help of a laboratory paradigm developed by Einstein et al. (1995). Their design increased the number of ongoing task items and cues and made further improvements by asking participants to repeat task instructions, counterbalancing the order of task presentations, and analysing performance on the ongoing task to avoid missing the possible effects of these variables on PM task performance. Twelve individuals with severe long-term TBI and 12 healthy matched controls participated in the study. The authors requested participants to answer general-knowledge questions on a computer (ongoing task). The time- and event-based PM tasks were integrated into the ongoing tasks. In the time-based task, participants were to telephone the experimenter to report their score at predetermined times during the general knowledge task (i.e. every 5 minutes) The participants were permitted to keep track of time by pressing the "t" key on the computer keyboard to bring up a digital clock for 3 seconds. In the event-based task, participants were to telephone the experimenter when they saw the word “Prime Minister” in a question on the computer screen. In the activity-based tasks, participants were required to switch off the computer monitor, write down their score on a whiteboard, and switch off a light outside the laboratory at the end of the general knowledge task. Shum et al. (1999) observed impaired performance by the TBI group across all the PM tasks in spite of similar performance on the ongoing tasks to that of the control group. Performance on the TBPM task was lowest for both groups but not disproportionately impaired relative to the EBPM task in either the brain-injured or the control group. The activity-based task yielded the best performance, possibly because of its minimal emphasis on self-initiated processes (Cockburn, 1995). Shum et al.'s findings have been replicated by Mathias and Mansfield (2005) and (Maujean et al., 2003).

Mathias and Mansfield (2005) in a study identified performance on EBPM and TBPM following moderate and severe TBI. Twenty five persons with a moderate (10) or severe (15) TBI and 25 matched healthy controls participated in the study. The EBPM task was measured on three subtests of the Rivermead Behavioural Memory Test (Wilson et al., 1985). The first subtest requires participants to remember to request the experimenter to return personal items taken from them at the beginning of the session and to recall where these items had been placed when the examiner signalled that assessment was finished. In the second measure, participants were to ask about a future appointment at the sound of a timer (Mathias & Mansfield, 2005). Finally, participants were expected to deliver a message at a specific time while completing the Rivermead Behavioural Memory Test. The TBPM task was measured over long and short intervals and adapted from the work of Einstein et al. (1995). The short interval PM task required participants to push a timer after 10 minutes of being instructed to do so. Participants were required to turn a visible digital clock in order to monitor the time. The second measure, the envelope test adapted from Sinnott (1989), required the participants to send a stamped return addressed-envelope to the experimenter two days after the test session. Mathias and Mansfield (2005) reported that the TBI group performed poorly on the Rivermead Behavioural Memory Test appointment subtest compared to control. However, they did not observe any significant difference between the TBI group and the control group when they were to ask for personal belongings and deliver a delayed message. Mathias and Mansfield (2005) also found that the TBI performed more poorly than the control group on the Timer and Envelope tests.

In all of the studies reviewed here, TBI patients' PM performance was impaired compared to healthy controls. Notwithstanding, it has been suggested that the deficit was more common in TBPM compared to EBPM (e.g., Carlesimo et al., 2004; Cheng et al., 2010; Kinch & McDonald, 2001; Kinsella et al., 1996). Kinsella et al. (1996), for example, assessed the interrelationship between objective tests of PM performance and subjective memory reports. Twenty-four TBI patients and 24 healthy controls participated in the study. The Rivermead Behavioural Memory Test (Wilson et al., 1985) was used to measure PM performance and the Memory Functioning Questionnaire (Gilewski, Zelinski, & Schaie, 1990) was used to measure participants' self-appraisals of their memory performance. This Questionnaire is a 64-item subjective rating on different aspects of memory and is subdivided into 4 subscales: retrospective functioning, seriousness of forgetting, general frequency of forgetting, and mnemonics usage (Gilewski et al., 1990). Kinsella et al (1996) observed that TBI patients performed significantly worse than healthy controls on the PM tasks and the Memory Functioning Questionnaire test indicated that TBI patients in comparison to healthy controls reported a significant recent decline in memory functioning. Kinsella et al. (1996) also reported that there were no significant correlations between the four scales of Memory Functioning Questionnaire and the traditional measure of PM for both control and TBI. It was suggested that the TBI patients might have lacked insight into the implications of memory decline in everyday life as the TBI patients acknowledged greater deterioration in memory functioning but less forgetting compared to healthy controls.

Carlesimo et al. (2004) also explored CHI patients PM performance by manipulating the retention interval on both EBPM and TBPM tasks. For the EBPM task, the ringing of a timer after a period following experimenter instruction signalled the moment to perform another set of three actions. In the TBPM, participants had to perform three different actions after either 10 or 45 minutes after experimenter instruction while engaging in cancellation tasks and other concurrent ongoing tasks. Failure to respond to cue presentation was viewed as a problem with the prospective component of the task. Carlesimo et al. measured the retrospective component of PM as failure to recall the content of the intention when queried about having to do something two minutes after there was no response to a cue. The authors observed that their patients' TBPM accuracy reduces significantly when performing a concurrent task. In contrast, they did not observe any significant reduction in accuracy on the EBPM tasks. They suggested that episodic memory deficits might explain their patients' difficulty with the retrieval of specific intentions.

Other studies (e.g., Henry, Phillips, et al., 2007; Kliegel, Eschen, et al., 2004; Knight et al., 2005; Knight & Titov, 2009; Knight et al., 2006; Maujean et al. 2003; Schmitter-Edgecombe & Wright, 2004) used only EBPM tasks in their experiments. For instance, Henry, Phillips, et al. (2007) manipulated PM tasks (by increasing the number of PM tasks) to determine the specific effect of PM task complexity on prospective remembering. Henry et al. (2007) discovered that unlike controls, TBI patients' EBPM performance was significantly poorer when the PM tasks were manipulated for complexity.

Many studies that have measured performance on EBPM and TBPM tasks have reported impairments in both PM tasks for both TBI and CHI compared to healthy controls (Carlesimo, Formisano, Bivona, Barba, & Caltagirone, 2010; Cockburn, 1996; Groot et al., 2002; Mathias & Mansfield, 2005; Shum et al., 1999). For example, Carlesimo et al. (2010) assess the sensitivity of severe CHI patients to the manipulation of attentional resources and encoding instructions during the execution of PM tasks. They varied attentional resources during the encoding and retrieval phase of both TBPM and EBPM tasks. The authors observed that, on average, the control group were more accurate in spontaneously recalling of PM tasks in contrast to the CHI group whose performance was considerably lower. They also observed that the use of verbal encoding and imagining at encoding enhanced the PM performance of the CHI group compared to the control group. Carlesimo et al. suggested that poor encoding strategies and reduced attentional resources accounted for the observed deficits in PM performance for the CHI group.

This review of the literature on PM performance of TBI patients suggests that PM deficits are frequently greater in TBPM tasks compared to EBPM tasks. Also, reduced cognitive resources at encoding might be implicated in PM impairments (Einstein & McDaniel, 2007; Einstein et al., 2000; Guynn, McDaniel, & Einstein, 1998; Kvavilashvili & Ellis, 1996). There is, therefore, a need to identify encoding strategies that can reduce the cognitive demand of PM tasks in order to enhance PM function in TBI patients' daily life.

1.15. Encoding Strategies in PM

Encoding a PM task involves forming a prior intention to perform a certain action at a designated occasion in the future (Kvavilashvili & Ellis, 1996; Searle, 1983) where what has to be done and when it has to be done are clearly defined (e.g., I will telephone Jane this afternoon; Ellis, 1996). This process, known as intention formation (Kvavilashvili & Ellis, 1996), has been discussed earlier in this chapter. In the PM literature, the encoded intention is usually performed after a delayed period (intention retention interval). This explains why PM is usually referred to as delayed intention

(Ellis, 1996) since it cannot be performed immediately after it is formed but must be retained and performed at an appropriate future particular moment (e.g., I will call Jane when it is 12 pm). For a number of reasons, one might fail to perform this pre-arranged intention (Kvavilashvili & Ellis, 1996). Failure to phone Jane at 12 pm is classified as a PM failure. The ability to retrieve encoded PM intention is believed to depend on the activation level of memory representation, characteristics of the retrieval cue, and the level of attentional resources available (Burgess & Shallice, 1997; Guynn et al., 1998). As a result, age-related or TBI related deficits in one or more of these factors might lead to PM difficulties. TBI patients are believed to often present with difficulties encoding PM tasks (Mioni, Bertucci, et al., 2017; Mioni, McClintock, et al., 2014; Mioni et al., 2013).

As stated previously (Section 1.8.2), McDaniel and Einstein (2000)'s multiprocessing framework suggests that PM encoding and retrieval can depend on either strategic or automatic processing, depending on the contextual demand of a situation. For instance, situations that require a deeper level of processing should require a much higher level of attentional resources compared to a situation requiring a shallower level of processing (Fludder, 2010). This suggests that the level of processing at encoding is important in PM remembering. Poor encoding will, therefore, reduce the amount of stored information about an intention which in turn might impair PM retrieval (Einstein & McDaniel, 1990)

Older adults are believed to be less efficient at creating a high number of cue-intention associations in comparisons with young adults, resulting in poor PM (Cohen, West, & Craik, 2001; West & Craik, 2001; West, Jakubek, & Wymbs, 2002; Zimmermann & Meier, 2006). For instance, when a single cue was used in an experiment (Einstein & McDaniel, 1990), no age-related decline was observed. However, a significant level of decline was observed when 3 or 4 cues or intentions were included (Cohen et al., 2001; West & Craik, 1999). It has been suggested that lack of elaborative encoding might have played a role in older adults' PM difficulty (Maylor, 1996). The use of elaborative encoding strategies such as imagery or enactment could potentially enhance encoding and hence successful retrieval (Altgassen et al., 2016, 2017; Altgassen et al., 2015; Pereira, Ellis, & Freeman, 2012; Pereira, Ellis, & Freeman, 2012; Raskin et al., 2017; Schnitzspahn & Kliegel, 2009).

Encoding strategy techniques have received relatively little attention in the PM literature (i.e., whether an intention is rehearsed verbally or mimed through enactment/ or imagined). Previous findings from the RM literature reveal that recall and recognition are superior when material-to-be-remembered is performed during encoding than for verbally encoded items (i.e., the subject-performed task effect; e.g., Cohen, 1989). They also indicate that the benefit of enactment is preserved (e.g. Feyereisen, 2009; Knopf & Neidhardt, 1989; Mangels & Heinberg, 2006; Nilsson & Craik, 1990) or is even enhanced (e.g. Bäckman, 1985; Nyberg, Nilsson, & Bäckman, 1992) in older adults. It has been postulated that enactment facilitates the episodic integration of the action and other information relevant to that action (e.g. Kormi-Nouri, 1995; Mangels & Heinberg, 2006). That is, enactment helps to integrate the different components of the encoding process to form a unique and organised memory representation. Miming a future intention during encoding (e.g., returning a book when you go to the library) might strengthen the link between the action (return book) and the retrieval cue (library) thus enabling spontaneous retrieval processes and removing the need for preparatory attentional processing (Pereira et al., 2012).

Other authors have suggested that future thinking (imagery) also plays a role in the formation of PM since forming an intention might involve a vivid mental visualization of oneself performing intentions at some point in the future (Atance & O'Neill, 2001; Schacter, Addis, & Buckner, 2008). Future thinking has been defined as mentally simulating events to be performed in the future thereby mentally pre-experiencing the future (Altgassen et al., 2015; Buckner & Carroll, 2007). Several terms have been used to describe future thinking. This include future imagination, episodic foresight, self-projection, prospection, chronesthesia, episodic future thinking, pre-experiencing, and mental time travel (Altgassen et al., 2015; Buckner & Carroll, 2007).

Imagery as a distinct construct associated with PM remembering has only recently begun to re-emerge in research investigations and it has generated much interest in cognitive psychology (e.g. Buckner & Carroll, 2007; Hassabis, Kumaran, & Maguire, 2007; Schacter et al., 2008; Szpunar, 2010; Szpunar & Tulving, 2011). Various authors (e.g. Atance & O'Neill, 2001; Schacter et al., 2008) believe that imagery plays a role in the encoding of a PM intention, since one might engage in a vivid mental visualization of oneself performing intentions in the future when forming an intention (Atance & O'Neill, 2001; Schacter et al., 2008). Based on Atance and O'Neill's (2001) assumption of the role of imagery in encoding, Altgassen et al. (2015) and Paraskevaides et al. (2010) suggest that mentally simulating the future visuospatial context in which PM tasks are to be performed might encourage deeper encoding of the intention and thus create a memory trace of the PM cue and the PM tasks. This might later expedite memory for the PM task during the delay period. In line with this assumption, Altgassen et al. (2016) demonstrated that deeper intention encoding through imagery enhances PM performance in adolescents. Grilli and McFarland

(2011) also discovered that self-imagination improves PM performance compared to rote rehearsal in individuals with neurological damage.

Atance and O'Neill (2001) suggested that there is a possible link between the planning aspects of PM encoding and PM performance. (See also Schacter & Addis, 2007). This would mean that planning PM via enactment or imagery has the potential to enhance PM performance. They argue that imagery (and possibly motoric miming) is essential in mobilizing cognitive resources to aid PM remembering. Research on the relationship between imagery and PM has indicated the possibility of enhanced performance (Altgassen et al., 2015; Leitz, Morgan, Bisby, Rendell, & Curran, 2009; Paraskevaides et al., 2010). Previous research has examined the benefit of future thinking or imagery in TBI (Mioni, Bertucci, et al., 2017; Raskin et al., 2017) and ageing (Altgassen et al., 2016; Altgassen et al., 2015). To date, however, there is virtually no research on the benefit of enactment on PM in the TBI population. Similarly, the effect of various types of imagery on PM performance in older adults has not been studied. Previous studies on the impact of enactment encoding on PM performance, have been conducted with healthy young and older adults (e.g., Pereira et al., 2012). The detailed literature on the potential benefit of enactment and different imagery techniques on PM performance TBI patients (Study 1) and older adults (Study 2) are discussed in Chapters 2 and 3 respectively.

1.16. Main Aims of Dissertation

A review of the literature reveals that patients with TBI and older adults have significant and frequent PM failures that hinder their daily functioning (Altgassen et al., 2010; Altgassen et al., 2015; Bisiacchi et al., 2008; Henry et al., 2004; Henry, Phillips, et al., 2007; Ihle et al., 2013; Kliegel, Mackinlay, & Jäger, 2008; Mioni, Bertucci, et al., 2017; Mioni, McClintock, et al., 2014; Mioni et al., 2013; Mioni et al., 2015; Schmitter-Edgecombe & Wright, 2004; Shum, Levin, et al., 2011). Individual studies report that TBI and ageing are associated with poorer PM performance as measured by experimental PM tasks, standardized tests, and self-report questionnaires (d'Ydewalle, Luwel, & Brunfaut, 1999; Hannon et al., 1995; Henry, Phillips, et al., 2007; Maylor, 1993; Maylor, 1996; Mioni et al., 2013; Raskin & Sohlberg, 2009; Rendell & Craik, 2000; Shum, Levin, et al., 2011; Smith et al., 2000; Vogels, Dekker, Brouwer, & de Jong, 2002) although older adults tend to outperform younger adults in naturalistic settings compared to laboratory settings (Bailey et al., 2010; Einstein & McDaniel, 1990; Henry et al., 2004; Uttl, 2008; West & Bowry, 2005). This has been classified as the PM age paradox (Rendell & Craik, 2000).

Additionally, most studies indicate that PM task characteristics and other cognitive functions influence PM in TBI and older adults (Banville & Nolin, 2012; Graf, 2012; McDaniel & Einstein, 2000; Mioni et al., 2013; Raskin et al., 2012; Shum, Levin, et al., 2011). Research aimed at enhancing PM performance via enactment and imagery is therefore necessary in order to improve the PM function of both older adults and TBI patients in the wider community.

The studies reported in this dissertation were designed to identify some of the factors (e.g. encoding, imagery) that might enhance PM performance in TBI patients and older adults. This information could be used to identify some strategies that would help them not only in completing laboratory tasks but also be potentially transferred to support prospective remembering in everyday life. We explored the benefit of enactment (Study 1) at encoding relative to verbal encoding on PM performance for adults with TBI and a matched control group. Furthermore, in Study 1, cognitive deficits, EF deficits, and quality of life measures in relation to PM performance were also addressed in both TBI and matched control groups. In Study 2, based on the findings in Study 1 we also examine the impact of task shifting and sustaining attention on PM performance in two groups of older adults.

1.17. Study Questions

The questions that Study one sought to address include:

- What is the difference in performance between TBI and matched healthy controls?
- What is the effect of enhanced encoding (enactment versus verbal) on EBPM and TBPM task performance in TBI patients and healthy matched controls?
- What is the relationship between EFs and PM performance?
- What is the relationship between PM performance and quality of life in TBI patients and healthy matched controls?

The questions that Study two sought to address include:

- Is there a difference in PM performance between younger-old (59-69 years of age) and older-old adults (70-79 years of age) ?
- Does the imagery perspective adopted at encoding influence EBPM and/or TBPM performance compared to verbal encoding in the above groups of older adults?
- What is the relationship between task shifting, sustained attention, visuospatial short-term working memory and PM performance in older adults?

In study one (Chapter 2), we explored whether enactment at encoding can improve PM performance compared to verbal encoding in TBI patients and healthy matched controls. Pereira et al. (2012) demonstrated superior performance for both younger and older adults on PM following enactment compared to verbal encoding. In the current study, the effect of enacting a PM task or rote rehearsal of PM tasks was explored in both TBI and healthy matched controls. Furthermore, we explored the possible relationship between PM performance and cognitive functioning, EFs, and quality of life in both TBI and healthy matched control groups.

In Study 2 (Chapter 3), we examined the role of the different type of imagery perspective in younger-old and older-old adults' PM performance. Previous studies (e.g., Altgassen et al., 2016, 2017; Altgassen et al., 2015) have shown that imagery enhances PM performance compared to rote rehearsal. However, the effect of different types of imagery perspective on PM has not been studied. This study, therefore, explored the effect of different type of imagery perspective (Field, Observer) on PM performance compared to verbal rehearsal. Also, the relationship between PM performance and EFs were examined in older adults. The two Studies made use of a measure of PM designed to reflect everyday life demands: the Virtual Week (VW; Rendell & Craik, 2000).

CHAPTER TWO

STUDY 1: Supporting everyday activity following TBI: An investigation of PM performance

Abstract

Prospective memory- memory for future intentions - is important for independent living. Previous research reports that individuals with traumatic brain injury have difficulties with prospective memory but few used assessments that closely represent everyday prospective memory. Moreover, only a small number of studies have investigated the benefits of encoding manipulations on prospective memory performance in traumatic brain injury patients (e.g., verbal versus enactment). The Virtual Week prospective memory task was administered to 30 traumatic brain injury participants and 30 demographically matched controls who either enacted or verbally encoded PM tasks. All participants also completed neuropsychological, executive function and quality of life tests. Results indicated that the healthy control group significantly outperformed the traumatic brain injury group on event-based prospective memory function. Furthermore, prospective memory performance is higher after enactment compared to verbal encoding for both traumatic brain injury patients and healthy matched controls, in event-based but not time-based tasks. Sustained attention and negative emotion evaluation were also implicated in prospective memory accuracy in the traumatic brain injury group. These findings have implications for the successful rehabilitation of prospective memory impairment in people with traumatic brain injury.

2.1. Introduction

PM is associated with functional independence and wellbeing and its impairment can affect daily functioning (Chasteen, Park, & Schwarz, 2001; Ellis, 1996; Ellis & Kvavilashvili, 2000). Research conducted to date has consistently demonstrated that PM failure is a common feature in the TBI population compared to an intact healthy control (HC) group, on both EBPM and TBPM (e.g., Carlesimo et al., 2004; Groot et al., 2002; Henry et al., 2004; Kinch & McDonald, 2001; Mathias & Mansfield, 2005; Mioni, Bertucci, et al., 2017; Mioni, M, & Stablum, 2014; Mioni et al., 2013; Mioni et al., 2015; Potvin et al., 2011; Shum, Levin, et al., 2011; Shum et al., 1999). TBI often results in damage to the prefrontal cortex (Levine, Katz, et al., 2002), a region that is associated with executive functions (EF; Stuss & Alexander, 2000). The completion of a PM task is thought to involve a number of processes such as planning and encoding of intention and action, retaining an intention, interrupting an ongoing activity, initiation and execution of intended action, strategy use and evaluation of outcome (Ellis, 1996; Shum et al., 2002). Several of these are described as EFs e.g., planning, task-switching, strategy selection and employment. This might explain why impaired EFs have been shown to predict PM impairment in persons with TBI (Fleming et al., 2008; Groot et al., 2002; Martin et al., 2003).

One of the major challenges for persons with TBI reintegrating themselves into the community is – potentially - their inability to recall delayed intentions in the future (Knight et al., 2006). This may have a negative impact on quality of life (QoL) through reduced independence and increased need for supervision (Turner, Ownsworth, Cornwell, & Fleming, 2009). This is because PM difficulty might limit an individual’s ability to return to work or daily activities, function independently (Barr, 2011; Mioni, McClintock, et al., 2014), participate in and benefit from post-TBI rehabilitation (Mioni et al., 2015)

Given the poorer performance of TBI compared to HC in the PM literature, we explored the situation further in the present study, to determine if TBI patients are impaired on EBPM and TBPM compared to HC. We also explore potential strategies (e.g. enactment encoding) that could remediate these impairments. This is because information on the causes of PM difficulty in the TBI population is important for their rehabilitation and integration into their community (Chaytor & Schmitter-Edgecombe, 2003).

Research on PM performance in TBI is relatively limited and recent. Several experimental paradigms have been used to measure PM performance in patients with TBI (Mioni, McClintock, et al., 2014; Shum, Levin, et al., 2011). Examples include paper and pencil tasks (e.g., Kinch & McDonald, 2001; Kinsella et al., 1996), psychometric tests (e.g., Mathias & Mansfield, 2005; Tay et al., 2010), computerized tasks (e.g., Henry, Phillips, et al., 2007; Maujean et al., 2003; Schmitter-Edgecombe & Wright, 2004; Shum, Valentine, & Cutmore, 1999), and virtual reality tasks (e.g., Kinsella et al., 2009; Knight et al., 2005; Knight et al., 2006). TBI patients' difficulty with PM remembering appears to depend on the specific task being measured (Banville & Nolin, 2012; Barr, 2011; Carlesimo et al., 2004; Henry, Phillips, et al., 2007; McDaniel & Einstein, 2000; Mioni et al., 2013). As stated earlier (Chapter 1), TBPM tasks are more cognitively demanding than EBPM tasks. This is because, with regard to TBPM tasks, individuals must independently monitor the time in order to execute previously formed intentions at the appropriate moment.

In contrast, EBPM cues serve as external triggers that can facilitate intention retrieval (Carlesimo et al., 2004; Henry, Phillips, et al., 2007; Mioni et al., 2013; Raskin et al., 2012; Schmitter-Edgecombe & Wright, 2004). Due to the need to constantly monitor the time in order to correctly perform TBPM task, TBI patients are always expected to display greater difficulty in TBPM compared to EBPM due to possible deficits in sustaining attention (Banville & Nolin, 2012; Mioni et al., 2013; Raskin et al., 2012; Schmitter-Edgecombe & Wright, 2004). Nevertheless, findings regarding performance on TBPM versus EBPM tasks in the TBI population are mixed (Mioni, Stablum, McClintock, & Cantagallo, 2012; Shum, Levin, et al., 2011). In some studies, TBI participants demonstrated greater impairment on TBPM as opposed to EBPM tasks (Groot et al., 2002; Mioni et al., 2015; Raskin et al., 2012), but not in others (Shum, Levin, et al., 2011).

Shum, Levin, et al. (2011) conducted a review of the literature and found comparable levels of impairment on EBPM and TBPM in TBI across several studies. However, they noted that TBPM tasks had less cognitively demanding ongoing tasks, which could explain the failure to observe any differences (Shum, Levin, & Chan, 2011). It would therefore be of great interest to examine what the situation is in the current study when different ongoing tasks are used to assess TBPM and EBPM task performance.

One major criticism of PM research has been that most of the experimental tasks lack ecological validity. This is because most of the findings in PM literature are based on performance on laboratory tasks that are not necessarily representative of the different types of PM tasks that individuals usually encounter in daily life. For example, Henry, Phillips, et al. (2007) requested participants to press a response key on a computer keyboard, when a particular target word appears. Participants had only one target word to recall in the 1-target condition (rake) and 4 target words in the 4-target condition (fork, truck, nose, soap). It is important to use a PM task that is more similar to everyday activities, as it would increase the ecological validity of the task and thus may be more indicative of performance of everyday delayed intentions. However, research using PM tasks that more closely mimic daily life events has been limited. A more ecologically valid PM measure that closely mimics the activities of daily life is needed in clinical populations such as TBI because the information can be used to guide rehabilitation and reintegration in everyday life (Chaytor & Schmitter-Edgecombe, 2003; Fleming, Shum, Strong, & Lightbody, 2005; Knight & Titov, 2009; McDaniel & Einstein, 2007; Mioni, Bertucci, et al., 2017; Mioni et al., 2013). Studies that have been conducted with this clinical group using "virtual tasks" that attempt to mimic the type of PM tasks encountered in daily life is limited (Kinsella et al., 2009; Knight & Titov, 2009; Knight et al., 2006).

Knight et al. (2006) assessed PM using a video-based task of a virtual street (created with the help of a series of photographs) in chronic TBI patients, under conditions of high and low distraction. Their Virtual Street task simulated the experience of walking along the main street of a shopping precinct with visual and auditory stimuli. The PM tasks included pressing a button on a computer keyboard to enter or exit a shop, approach a counter, and recall the appropriate task when a visual image of a shop assistant appeared and asked them what they would like to buy. Knight *et al*. (2006) found that people with TBI performed more poorly than the HCs and were more affected by distractors. In another study by Kinsella *et al*. (2009), with a virtual shopping trip task, participants were asked to identify items on a shopping list while watching a film of a supermarket trip and report these items to the experimenter. This also resulted in poorer performance for TBI participants compared to HCs.

Although research with virtual tasks indicates consistent impairments among TBI compared to HC groups, it has assessed only some types of PM tasks. For instance, these tasks have not included the assessment of TBPM performance (e.g., Kinsella et al., 2009; Knight et al., 2006). Other measures such as virtual environments do assess both EBPM and TBPM despite the use of only a few PM tasks. However, previous studies using virtual environments have failed to account for differences in performance on EBPM and TBPM (e.g., Banville & Nolin (2012).

Banville and Nolin (2012) investigated the benefit of immersive Virtual Reality (VR) in detecting PM difficulties in patients with TBI. They created and used a virtual environment which they integrated into the video game called “Max Payne™”. In Banville and Nolin’s (2012) study, participants entered two apartments (one small and one large) and chose the one they would like to inhabit. While performing this activity, participants were asked to perform three PM tasks, namely pick up a lease in the smaller apartment (‘LEASE’); feed a fish while saying “I am feeding the fish” upon seeing that the clock showed 11:41 (‘FISH’); and turning off a fan while saying “click” in the master bedroom of the large apartment (‘FAN’). Results revealed that TBI patients were less efficient on the VR ongoing task compared to HC (Banville & Nolin, 2012). However, both the TBI participants and the HC group performed similarly on PM tasks

In contrast to other virtual tasks, Rendell and Craik’s (2000) Virtual Week task - a computer-based board game that simulates a typical week with tasks to complete and decisions to make - can and does assess performance on a variety of PM tasks (Mioni et al., 2013). Moreover, unlike other laboratory PM tasks that include relatively very few observations (e.g., Henry, Phillips, et al., 2007; McDaniel & Einstein, 2007), the standard version of Virtual Week incorporates 70 PM observations (four regular, four irregular, and two stop-clock activities every day over seven virtual days). It allows the possibility to include both event and time-based tasks and directly compare PM performance on these tasks (Mioni et al., 2013). It has also been shown to have significantly higher levels of reliability (i.e. alpha level of .84 to .94) than has been typically reported in traditional laboratory tasks (e.g., Aberle et al., 2010; Henry, Phillips, et al., 2007; McDaniel & Einstein, 2007; Rose et al., 2010). This might be due to the wide variety of responses involved in the Virtual Week PM tasks. It also has the advantage of a practice ‘virtual day’ during which help messages are provided to allow participants to familiarize themselves with the PM tasks. The VW is also flexible such that the ongoing activities and tasks are self-paced (activities can also be time-paced depending on the research requirements) to enable participants to work with minimal pressure.

The VW, in its original and computerized form, has been used to explore PM performance in a number of populations and has been shown to be sensitive to the effects of normal and abnormal aging (e.g., Rendell & Craik, 2000; Rendell et al., 2011; Thompson et al., 2010) and various clinical conditions including multiple sclerosis (e.g., Rendell, Jensen, & Henry, 2007), schizophrenia (e.g., Henry, Rendell, et al., 2007), stroke (e.g., Kim, Craik, Luo, & Ween, 2009), substance abuse (e.g., Rendell, Mazur, & Henry, 2009), and alcohol intoxication (e.g., Leitz et al., 2009). It has been shown also to be engaging and sensitive to detecting difficulties in everyday activity in healthy young adults (Rendell & Craik, 2000). Notwithstanding, it has been used to assess PM function in people with TBI on only a few occasions (e.g., Mioni, Bertucci, et al., 2017; Mioni et al., 2013; Mioni et al., 2015).

Mioni et al. (2013) reported that people with TBI had significant difficulties executing PM tasks, with more pronounced deficits for TBPM than for EBPM tasks. This might be due to the proposal that TBPM task places more demands on attentional processes (McDaniel & Einstein, 2007). In a subsequent study (Mioni et al., 2015), in an attempt to find ways to improve PM performance, investigated the effect of using an implementation intentions strategy on PM performance in patients with TBI. An implementation intention involves an 'if-then' plan to do something in a specific manner in the future in the form e.g., 'When I see the bank, I will deposit the cheque' (Mioni et al., 2015). These verbal statements commit an individual to perform PM tasks when an opportunity arises by strengthening the mental association between the cue (seeing the bank) which is meant to initiate PM remembering and the intended action (depositing a cheque) (Gollwitzer, 1999; Gollwitzer & Brandstätter, 1997; McDaniel, Howard, & Butler, 2008). Webb and Sheeran (2007) have shown that implementation intentions strengthen the relationship between the (retrieval) cue and action (PM task) and support the spontaneous triggering of the retrieval of the PM task (McDaniel, Howard, et al., 2008). In spite of their expectation of the benefit of including an implementation intention, Mioni et al. (2015) failed to observe any enhancement in PM performance in the TBI patients who used this strategy. In contrast, improved PM performance was observed in the HC group. Mioni et al. (2015) concluded that implementation intentions may not have been an effective strategy to improve PM in TBI patients as it mainly targets the encoding phase i.e., TBI patients' difficulty with PM may lie primarily with problems at retrieval.

Mioni, Bertucci, et al. (2017) investigated alternative approaches to improving PM in patients with TBI. They tested the use of imagery or future event simulation. This involves mentally visualising oneself experiencing the events to be performed (Griffiths et al., 2012; Leitz, Morgan, Bisby, Rendell, & Curran, 2009; Paraskevaides et al., 2010; Platt, Kamboj, Italiano, Rendell, & Curran, 2016). The aim of Mioni et al.'s (2017) study was to investigate whether future event simulation improves PM performance in the TBI population. Using the VW task (Rendell & Craik, 2000) they found that future event simulation enhanced PM performance in TBI patients.

Importantly, for my thesis, in common with other VW studies, other potentially important variables include the relative benefits of enactment encoding manipulations on PM task performance (e.g., verbal versus enactment). Findings related to enactment encoding will allow us to contribute to the literature on improving PM performance in the TBI population. The benefits of visual imagery perspective is explored in Chapter 3.

2.2. Enactment in PM Performance

To our knowledge, there are no studies that have looked at the effect of enactment encoding on PM performance in individuals with TBI. In theory, it has been postulated that enactment facilitates the episodic integration of the action and other information relevant to that action (e.g., Mangels & Heinberg, 2006). That is, enactment helps to integrate the different components of the encoding process to form a unique and organised memory representation. Thus miming a future intention during encoding (e.g., return a book when you go to the library) might strengthen the link between the action (return book) and retrieval cue (library) thereby enabling spontaneous retrieval processes and removing the need for preparatory attentional processing (Pereira et al., 2012) .

Previous findings from the retrospective memory literature with older adults have shown that recall and recognition are superior for material that is performed during encoding than for verbally encoded items (i.e., the subject-performed task effect; e.g., Cohen, 1989; Silva, Pinho, Souchay, & Moulin, 2015). Other findings indicate that the benefit of enactment is preserved in older adults (e.g., Feyereisen, 2009; Knopf & Neidhardt, 1989; Mangels & Heinberg, 2006; Nilsson & Craik, 1990) or is even enhanced (e.g., Bäckman, 1985; Nyberg et al., 1992).

Using the VW task, Pereira et al. (2012) studied the impact of enactment on PM performance with healthy young and older adults and found that "while older adults retrieved fewer irregular intentions than young adults after verbal encoding, there was no age difference following enactment" (p. 549). This suggests that TBI patients might also benefit from enactment at encoding, possibly because they have cognitive deficits similar to older adults (Kinsella, Olver, Ong, Gruen, & Hammersley, 2014) and this might have significant implications for rehabilitation (Barr, 2011).

2.3. Role of EF on PM Performance

As mentioned earlier, EF has been found to predict PM impairment in persons with TBI (Fleming et al., 2008; Groot et al., 2002; Kinch & McDonald, 2001; Maujean et al., 2003; Mioni et al., 2012). Groot et al.'s (2002) study was probably the first in which PM was investigated in a group of people with brain injury, together with an analysis of the relationship between PM and both episodic (retrospective) memory and EF. Groot et al. found that within the TBI group, better memory, attention and EF was associated with better PM performance. This supported their assumption that EF is an important underlying mechanism for PM functioning (Groot et al., 2002). They also found that TBPM tasks were more difficult to complete than EBPM tasks for both TBI and HC.

TBPM tasks, in particular, are thought to demand more strategic resources because they rely on self-initiation in the absence of an external cue (McDaniel & Einstein, 2007). For instance, Mioni, Stablum, McClintock, and Cantagallo (2012) in a study on the relationship among TBPM, time perception and EF discovered that EF, particularly updating and inhibitory control, were strongly related to TBPM performance in both the TBI and HC groups. Inhibition was more related to TBPM performance for the HC group while updating was more related to TBPM performance in the TBI group, suggesting that the TBI group were constantly monitoring the time for the performance of the TBPM task (e.g., press the key at the target time while performing an ongoing activity; Mioni et al., 2012).

Several researchers have also reported that EF measures are unique predictors of TBPM tasks compared to EBPM tasks, indicating that the increased monitoring demand of TBPM tasks overburdens even intact executive processes (Cockburn, 1995; Groot et al., 2002; Kinch & McDonald, 2001). For instance, Kinch and McDonald (2001) examined the relationship between RM, PM and EF (using the WCST and the Controlled Oral Word Association Test) following severe TBI. The Controlled Oral Word test is a test of spontaneous flexibility (Maujean et al., 2003). Kinch and McDonald (2001) found that EF was strongly associated with TBPM performance but not EBPM performance. In contrast, Maujean et al. (2003) reported a significant relationship between performance on the EBPM task and the Controlled Oral Word Association Test in a high cognitively demanding condition in TBI participants. However, Fleming et al. (2008) in a study to examine factors that predict PM performance in adults with TBI, found that EF predicted both EBPM and TBPM performance in TBI patients.

Other studies have failed to observe a significant relationship between EF and PM performance (Mathias & Mansfield, 2005). Although Mathias and Mansfield (2005) reported that verbal memory (viz., Rey Auditory Verbal Learning Test) was related to PM performance in their HC group, they failed to find a significant relationship between EF (viz., WCST and the Controlled Oral Word Association Test) and PM performance for both their TBI and their HC groups. Similarly, several researchers have failed to observe a straightforward relationship between EF and PM (e.g., Carlesimo, di Paola, Fadda, Caltagirone, & Costa, 2014; van den Berg, Kant, & Postma, 2012). In a study to investigate the role of EF in PM impairment following PFC damage, Carlesimo et al. (2014) reported the case of 2 patients with focal damage to the anterior portions of the frontal lobe following TBI. The authors found that in one patient, PM impairment was associated with poor performance on tests of planning, working memory, and mental shifting. In contrast, they observed that the other patient's performance was in the normal range on all executive tests indicating that PM deficit is not always dependent on EF deficits. Similarly, van den Berg et al. (2012) in a recent meta-analysis in patients with Alzheimer's disease or mild cognitive impairment found that EF was moderately correlated with PM performance.

From the literature, it is possible that the variation in findings in the literature might be due to the heterogeneous nature of the cognitive deficits associated with TBI, indicating that the pattern of findings might reflect the underlying cognitive impairment that each TBI individual experiences but not the injury *per se* (Kinch & McDonald, 2001). It is also possible that the reported variation in the role of EF in PM performance might be due to the sample size and the tasks used, particularly with regard to the domain of EF. This is because EFs are not a unitary system but an umbrella body measuring a variety of tasks (e.g., updating, inhibition and switching; Miyake et al., 2000)

Given the previously described relationship between EF processes and PM performance, we explored the role of EFs in PM performance in the current study. Specifically, we used the WCST, Trail Making Test, Stroop Task test and Verbal Fluency test to assess EF and their relationship to PM performance. Detailed information on the measures of EF used in the current study is provided in the method section.

2.4. Quality of Life (QOL), Social Perception and PM

Successful PM functioning is fundamental to maintaining better QoL (Woods et al., 2015). Defining QoL has been the subject of much debate (Barcaccia, Matarese, Bertolaso, Elvira, & De Marinis, 2013). The World health organization (WHO) however identified QoL as an "individuals' perception of their position in life in the context of the culture and value system in which they live and in relation to their goals, expectations and standards and concerns. It is a broad ranging concept affected in a complex way by the person's physical health, psychological state, level of independence, social relationships, and their relationship to salient features of their environment" (WHOQOL Group, 1995, p. 1403). In terms of health, QoLis defined as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (WHOQOL Group, 1995, p. 1403). From the above definition, it is clear that the subjective perception of the individual plays a role in determining quality of life (Polinder, Haagsma, van Klaveren, Steyerberg, & Van Beeck, 2015). In the current study, the focus is on the effect of TBI on subjective rating of quality of life and its role in PM performance.

Although there are several literature reviews on the effect of TBI on QoL (see Polinder et al., 2015 for review), the association of QoL measures with PM performance in TBI patients has received very little attention to date. Frequent PM failures might result in poor QoL. For instance, remembering to take medication on time (e.g. at 12:00pm) or attend rehabilitation appointment may enhance the physical and cognitive health of TBI patients. This might enable them to carry out activities of daily living such as decision making, performing domestic chores, going to work, and maintaining finance. In addition, remembering to deliver messages might help to maintain social relations essential for reducing the incidence of loneliness, boredom, anxiety, depression, and anger/aggression. Similarly, remembering to post a letter or pass by the shop to buy groceries might enhance TBI patients' self-esteem and motivate them to hope in the future since they are able to maintain independent life. Taken together, this suggests that intact PM might play a role in enhancing self-reported QoL.

Research on the relevance of PM function in QoL has focused primarily on ageing (e.g., Doyle et al., 2012; Woods et al., 2015) and other clinical populations such as HIV (e.g., Woods, Moran, Dawson, Carey, & Grant, 2008) and Parkinson disease (e.g. Pirogovsky , Woods, Filoteo, & Gilbert, 2012).

Doyle et al. (2012) conducted a study on ageing, PM, and health-related QoL. Using the Prospective-Retrospective Memory Questionnaire, the authors observed that the self-reported symptoms of PM difficulties in everyday life were significantly associated with lower health-related QoL (using the 36-Item Short Form [SF-36] Health Survey) in younger and older adults with HIV. Woods et al. (2015) also reported that lower performance on the Memory for Intention Screening Test and the Prospective and Retrospective Memory Questionnaire were significantly associated with lower QoL (measured by World Health Organization Quality of Life-8 questionnaire[WHOQOL]) in older adults.

Pirogovsky et al. (2012) examined the relationship between PM deficits and poorer everyday functioning in Parkinson's disease. They administered performance-based and self-report measures of PM and everyday functioning (measured by instrumental activities of daily living [iADLs]), including medication and financial management to 33 individuals with Parkinson disease and 26 demographically matched control. Pirogovsky et al. observed that within the patient sample, self-reported PM failures was significantly associated with perceived declines in iADLs, worse medication management, and poorer health-related quality of life. However, no significant relationship between laboratory based PM and health-related quality of life and overall iADLs. This is in line with the literature suggesting a discrepancy between subjective ratings and actual task performance (e.g., Woods, Carey, Moran, Dawson, Letendre, & Grant, 2007; Zeintl et al., 2006).

Woods et al. (2008) examined the relationship between HIV-associated PM impairment and the successful management of iADLs. In a cohort of 66 HIV-infected individuals, the authors observed that PM accounted for a significant proportion of variance in self-reported IADL dependence. Taken together, these studies suggest that PM failures in daily life might play a role in lower QoL. It would be interesting to know the extent to which PM performance might be associated with QoL in the TBI population. The Quality of Life after Brain Injury (QOLIBRI; von Steinbuechel, Richter, Morawetz, & Riemsma, 2005) has been identified as a TBI specific measure and is employed to measure QoL in our current study. This is because unlike other HRQoL measures (e.g. SF-36 and WHOQOL) following TBI, the QOLOBRI was designed to assess areas of health affected by TBI (von Steinbüchel et al., 2010). As described by von Steinbüchel et al., the QOLIBRI measures perceived physical, psychological, daily life and psychosocial changes typical of TBI. The QOLIBRI assesses six domains namely, Cognition, Self, Daily life and Autonomy, Social Relationships, Emotions and Physical Problems. The first four scales assess 'satisfaction' and the final two scales 'feeling bothered' with key aspects of life (von Steinbüchel et al., 2010).

One other deficit associated with TBI is social perception difficulty (McDonald, Flanagan, Rollins, & Kinch, 2003). Social perception has been defined as the ability to evaluate varieties of social phenomena through observation in order to understand, recognise and make decisions about others' behaviour, attitudes and emotions and social situations (Archer & Akert, 1977; Boice, 1983; McFall, 1982). Some of the cues include eye gaze, facial expression and tone of voice, a potential conflict of interest between speakers, gesture, body language, contextual information, knowledge of the world and the type of social relationships (McDonald et al., 2003). Inferring and understanding other people's intentions and beliefs is also called 'theory of mind' (Channon & Crawford, 2000; Happé, Malhi, & Checkley, 2001). A deficit in social perception has the potential to affect PM performance if it makes it difficult to accurately evaluate social signals in the environment that might be related to PM execution (McDonald, Flanagan, Martin, & Saunders, 2004), especially social cues that might be needed to trigger to-be-performed PM tasks.

Poor sensitivity and recognition of social perception cues are common following TBI (Croker & McDonald, 2005; Green, Turner, & Thompson, 2004; Hopkins, Dywan, & Segalowitz, 2002; McDonald & Flanagan, 2004; McDonald & Saunders, 2005;

Milders, Fuchs, & Crawford, 2003; Milders, Ietswaart, Crawford, & Currie, 2006, 2008; Spell & Frank, 2000). For instance TBI patients have been reported to demonstrate deficits in recognizing sarcastic remarks (McDonald, 1992; McDonald & Pearce, 1996), the nature of interpersonal relationships (Cicerone & Tanenbaum, 1997; Kendall, Shum, Halson, Bunning, & Teh, 1997; Van Horn, Levine, & Curtis, 1992), interpreting ambiguous advertisements (Pearce, McDonald, & Coltheart, 1998), and faux pas (Milders et al., 2003). To date, I have not come across any study that examines the relationship between social perception and PM performance. This is a major shortcoming since emotional processing and the ability to infer others' intentions could help to identify PM task cues necessary for survival. For instance detecting and understanding the intended meaning of literally untrue statements such as lies and ironic comments (e.g., 'when you see John, tell him that you did not see me but ask him to call me') is essential when responding to PM cues. To detect that someone is lying depends on being able to understand that one party is aware of the truth while the other is not. An ironic comment is based on the assumption that both parties know the truth (Sullivan, Winner, & Hopfield, 1995).

In summary, the extent of perceived QoL and social perception deficit in TBI patients and its relationship to PM performance is not well known and was explored in the current study. The Awareness of Social Inference Test (TASIT; McDonald et al., 2003) was used to measure social perception. This test was developed to assess the ability to infer intentions, recognise others emotion, theory of mind judgments, and understand social situations occurring in everyday settings. It has been found to be sensitive to social perception deficits following TBI (McDonald et al., 2003) and also predictive of real-world challenges in social situations (McDonald et al., 2004).

2.5. Aim of Study

Following a review of the literature, the aim of the current study was

1. To determine the difference between TBI and HC on PM performance (EBPM vs. TBPM)
2. To explore the benefit of enactment at encoding compared to verbal encoding on PM performance for adults with TBI and (HC) group. It addresses the possibility that TBI patients' difficulty to adequately recall future intentions is due to deficits in encoding the intention. The use of different encoding modalities allows us to determine whether this is the case and to identify strategies that could enhance encoding in a TBI group and thereby help reduce such deficits.
3. A secondary aim was to examine the role of EF in PM performance.
4. Finally, the relationship between PM performance and QoL as well as social perception was explored in order to determine if difficulties with PM are associated with poorer QoL and social inference.

Specific questions the current study addressed were as follows:

1. Do TBI patients perform significantly worse than HC on PM functioning? And is this difficulty evident on EBPM or TBPM or both?
2. Does enactment encoding benefit PM performance in both TBI and HC compared to verbal encoding?
3. Is there a relationship between EF and PM performance? If so is EF more correlated with TBPM compared to EBPM or both?
4. Does better PM relate to better QoL and social perception?

2.6. Hypotheses

On the basis of previous research, the hypotheses are;

1. There will be a significant difference between TBI and HC's PM performance on both EBPM and TBPM tasks (cf. Mioni et al., 2013).
2. Participants will perform significantly better on EBPM compared to TBPM (cf. Groot et al., 2002).
3. Enactment at encoding will enhance EBPM performance in TBI patients and matched HC compared to verbal encoding (cf. Pereira et al., 2012).
4. EF will play a role in PM performance for both TBI and HC (cf. Groot et al., 2002)
5. There will be a positive relationship between PM performance and QoL and social perception. That is better PM will be related to better QoL and social perception.

2.7. Methods

2.7.1. Participants

2.7.1.1 Power Analysis

Sample size calculation was based on the means and standard deviations of previous studies on PM in TBI vs. HC (Carlesimo et al., 2010; Fleming et al., 2008; Henry, Phillips, et al., 2007; Kinsella, Ong, Storey, Wallace, & Hester, 2007; Knight et al., 2005; Knight & Titov, 2009; Knight et al., 2006; Mioni et al., 2013; Roche et al., 2007; Shum, Levin, et al., 2011). Most of these studies found a medium to large effect size using Cohen's (1992) conventions. Based on the above studies, a sample size estimation using G-Power (Faul *et al*., 2013), a priori power analysis was conducted using an interaction in a 2 (group: TBI, HC) x 2 (Encoding: Enact, verbal) x 2 (TBPM, EBPM) mixed design ANOVA.. With an effect size of 0.5, an alpha level of .05, and power established at .95, a minimum sample size of 24 per condition was necessary to find a statistically significant effect and .98 power in the model. As a result, it was determined that a sample size of 30 TBI patients with 30 matched HC was appropriate for this study.

Thirty TBI patients (17 males, 13 females) and 30 HC (15 males, 15 females) completed this study. The mean post-injury duration for the TBI participants was 8 months. There was no gender difference between the two groups, $\chi 2(1, N = 60) = 0.267, p = .61$). The TBI participants' data were obtained from the 37 Military Hospital and the Korle-Bu Teaching Hospital in Accra in Ghana (main referral points for TBI). Patients who met the inclusion criteria were contacted and appointments scheduled for those who agreed to participate.

The criteria for TBI patients' participation in the study included: *(i)* diagnosis of mild to severe TBI showed by earliest Glasgow Coma Scale ((GSC; Teasdale & Jennett, 1974) score; *(ii)* age between 21 to 50 years. Previous research has shown a significant effect of ageing on PM performance (e.g., Pereira *et al*., 2012, Rendell & Craik, 2000; Rendell *et al*., 2011). Younger adults (18-33, 18-26, 19- 27) tend to outperform older adults (64-84, 69-81, and 66–75) on a PM task. The consistent finding of age differences indicates the possibility of an effect of age on performance. To reduce the effect of age, only adults between the ages of 21-50 were considered for this study; *(iii) post-injury duration*. Previous research indicates that most TBI participants time post-onset ranges between 6 months to 4 years (Carlesimo et al., 2004; Carlesimo et al., 2010; Fleming et al., 2008; Groot et al., 2002; Henry, Phillips, et al., 2007; Kinsella et al., 2007; Knight et al., 2005; Knight & Titov, 2009; Knight et al., 2006; Maujean et al., 2003; Mioni et al., 2013; Roche, Fleming, & Shum, 2002; Roche et al., 2007; Shum, Levin, et al., 2011). The duration of TBI post-injury is considered important to investigate the sensitivity of PM functioning in TBI based on previous research. Due to the fact that individuals must have lived in the community after hospitalization in order to be able to identify the difficulties of everyday life, a minimum duration of 6 months post-injury was required for participation in the current study; *(iv) basic* e*ducation level*. For the purpose of understanding basic instructions a minimum of 8 years of education was required; *(v)* no p*re-existing neuropsychological disorders.* Pre-existing mental health issues, neurological impairments and substance abuse have the potential to confound results (Carlesimo et al., 2004; Fleming et al., 2009; Fleming et al., 2008; Mioni, Bertucci, et al., 2017; Mioni, McClintock, et al., 2014; Mioni & Stablum, 2013; Potvin et al., 2011; Schmitter-Edgecombe & Wright, 2004; Umeda et al., 2011; Yip & Man, 2013). As a result, patients' clinical record and an interview was used to screen potential participants. Patients with pre-existing mental health issues, neurological impairments, and substance abuse were excluded.

Using the hospital database, 109 potential participants were identified. At follow-up, 5 of the patients had died, 41 could not be traced since their contact number was no longer active and 8 were brought to the hospital by good Samaritans. The Samaritans contact was reported in the hospital files but they had no idea who the patients were. As a result, valid contact address could not be obtained. Twenty-one had no education and therefore could not meet the inclusion criteria, and 2 were in a vegetative state and bedridden. Finally, 32 participants who met the inclusion criteria were invited to take part in the study. Two participants dropped out because of their busy schedules.

Sixteen of the patients had sustained brain injury from motor vehicle accident, of which 8 were pedestrians, 6 passengers and the remainder drivers (Table 2.1). Patients gave written informed consent before participating in this study. The HC group were patients' caregivers who had never sustained a TBI. The average age of the TBI group who took part in the study was 31.7 years (range 21–50; SD = 7.49) with an average of 10.73 years of education (range 8-18; SD = 2.63). All had suffered a mild-moderate brain injury as seen by their scores on the Glasgow Coma Scale (GSC; Teasdale & Jennett, 1974). The HC group was matched to the TBI patients based on age and educational level. Their mean age was 32.8 years (range 21–51; SD = 8.86) with an average of 12 years of education (range 8-17; SD = 2.63). The TBI and HC groups did not differ significantly either on age, $t(58) = 0.551$, $p = .58$, or years of education, $t(58) = 1.947$, $p = .06$. None of the HC participants had any neuropsychiatric disorder or history of substance abuse. All the participants were physically and mentally able to understand and complete the tests. Data collection took place in participants' homes. Further details of the participants are provided in Table 2.2.

Ethical approval for the conduct of this study was obtained from the School of Psychology and Clinical Language Sciences' Ethics Committee (code: 2014/069/JE) at the University of Reading. All participants were informed that any data collected would be completely kept confidential, anonymous, and stored for 5 years and disposed of according to the UK Data Protection Act and Quality Assurance procedures of the University of Reading. Participants provided written informed consent prior to taking part in the study and all data were collected in compliance with regulations of the University of Reading Ethics Committee. All information in relation to ethical procedures can be found in Appendix 1.

2.7.2. Materials and procedure

2.7.2.1. Cognitive Tests

The two groups of TBI and HC were compared on pre-morbid intelligence quotient (IQ), National Adult reading test (NART), and a cognitive functioning test (Montreal Cognitive Assessment [MOCA]). Unless otherwise stated, an independent samples *t*-test was used to examine group differences. Results are displayed in Table 2.2.

NART (Nelson & O'Connell, 1978)

The NART is a single word oral reading test of vocabulary knowledge used to estimate premorbid ability irrespective of brain damage or dementia. The test requires participants to read aloud 50 irregular English words of increasing difficulty. The words are devoid of the common rule of phonetic pronunciations (e.g. debt). Thus, the pronunciation of the words could not be deduced from their spellings. The test takes about 5 minutes to complete. The participants read aloud down the list of words and the number of errors made was recorded. It is thought that the NART does not require much cognitive capacity (Nelson & O'Connell, 1978) although it may be language bias. Thus, the individual must have knowledge of the language within which it is used. Research suggests that the NART performance appears to be immune to the effects of many neurological and psychiatric conditions (Crawford, Deary, Starr, & Whalley, 2001).

MOCA (Nasreddine et al., 2005)

The MOCA was developed as a rapid screening instrument for mild cognitive impairment. It assesses cognitive domains such as orientation, memory, visuo-constructional skills, attention and concentration, conceptual thinking, calculations, language, EF, and visuo-constructional skills (Nasreddine et al., 2005). A score of 26 or above is considered normal. The MOCA was used to identify any difference between the groups that might influence PM performance in the current study.

Table 2.1

Demographic Characteristics of Participants in the TBI (including clinical features) and HC

	TBI		HC		X^2	*p*
Variable	n	%	n	%		
Gender						
Male	17	56.7	15	50	.267	.61
Female	13	43.3	15	50		
Employment						
Employed	6	20	8	26.7		
Self-Employed	13	43.3	16	53.3		
Student	4	13.3	4	13.3		
Unemployed	7	23.3	2	6.7		
Injury Type						
Open head injury	1	3.3				
Closed head injury	29	96.7				
MVA						
Driver	2	6.7				
Passenger	6	20				
Pedestrian	8	26.7				
Motor Bike	3	10				
Fall	9	30				
Assault	2	6.7				

Note. *p* >.05; MVA= Motor Vehicle Accident.

Table 2.2

Demographics Characteristics and Cognitive Assessment of Participants in the TBI and HC Groups

	TBI n=30	HC n=30	*t*	*p*
Variable	M (SD)	M(SD)		
Age	31.67 (7.49)	32.83 (8.86)	0.551	.58
Education	10.73 (2.63)	12.10(2.81)	1.947	.06
GCS on Admission	12.43 (2.97)			
GCS on discharge	14.67 (0.55)			
Injury duration (years)	1.5 (0.8)			
MOCA	18.00 (4.64)	23.20 (6.32)	3.633**	.001
Premorbid IQ (NART)				
Full scale IQ	94.33 (21.30)	101.62 (8.56)	1.668	.10
Verbal IQ	95.88 (10.72)	99.55 (9.39)	1.327	.19
Performance IQ	101.07 (7.70)	104.27 (8.43)	1.434	.16

Note. $*p<.05$; $**p<.01$, GCS= Glasgow Coma Scale; MOCA= Montreal Cognitive Assessment, NART= National Adult Reading Test, IQ= Intelligence Quotient.

Table 2.2 shows that, on the MOCA, the HC displayed better cognitive functioning compared to the TBI, $t(58) = 3.633$, $p = .001$. However, there was no significant difference between the groups on the NART scales namely Full scale IQ, $t(58) = 1.668$, $p = .10$, Verbal IQ, $t(58) = 1.327$, $p = .19$, and Performance IQ, $t(58) = 1.434$, $p = .16$. This lack of difference on the NART might be due to the relatively low level of education in the two groups (M=11.42, SD= 2.78).

2.7.2.2. Experimental Measures

After administration of the cognitive tests, participants were then given the experimental tasks. These tasks included PM, neuropsychological and EF tests**.** The experiment was conducted in 4 sessions with varying periods depending on the participants' speed. The experiment took place in participants' homes. The tasks employed in these sessions included the VW (PM tasks; Rendell & Craik, 2000), Cattell's Culture Fair Test (current IQ; Cattell, 1973), Digit Span (Short term memory span; Wechsler & Stone, 1987), and tests of EF: WCST (switching, perseveration; Heaton, 1993), Stroop Test (inhibition; Stroop, 1935), Trail Making Test (visual attention, task switching; Reitan, 1958), Verbal Fluency (Verbal functioning; phonemic fluency; Lezak, 2004). In addition, we measured current QoL after brain injury (QOLIBRI; von Steinbuechel et al., 2005) and the TASIT (Inferring intentionality; McDonald et al., 2003).

2.7.2.3. Test Administration

All participants were tested individually in 4 sessions lasting approximately 4 hours over 2 days in a quiet and serene atmosphere in the participant's home (in some cases HC participants were tested in 2 or 3 experimental sessions depending on their willingness to continue). All of the participants began the session with cognitive tests. The participants were first given the MOCA, which lasted for 10 minutes. Participants were then administered the NART where they were given a list of 50 words and asked to read each word aloud and any errors were recorded (approximately 15 min). Participants were then administered the Cattell Culture Fair Test (Scale 2, approximately 30 minutes) and the Digit Span (approximately 5 minutes) after a 30 minutes break. In the second session, they undertook the EF tasks (approximately 25 minutes). After a one hour break, they were administered the QoL questionnaire (approximately 5 minutes). In session three, participants performed the VW tasks (45-60 minutes). In session 4 they performed the TASIT tasks (approximately 1½ hrs). Instructions for each test are found in Appendices 2-10.

2.7.2.4. PM Tasks: Virtual Week (VW)

The VW was used to assess PM performance. The irregular PM tasks on the VW were piloted on 6 psychology students at the University of Reading, UK to identify any possible difficulties that might need to be revised (e.g., complex instructions, jargons, ceiling or floor effects and so on). Following the first 3 administrations, the instructions and terms were revised to enhance clarity. After the modification, no further issues were identified. Data collection with TBI patients and HCs occurred primarily in Ghana. Before the commencement of the data collection, another pilot was conducted on 5 individuals in Ghana to make sure that the items on the VW were culturally appropriate. Some items were revised accordingly, for instance, peanut butter was replaced with groundnut paste. Following amendments on the basis of this pilot study, the tasks were considered easier to understand in terms of simplicity of instructions and level of task difficulty.

A computerised version of Rendell and Craik's (2000) Virtual Week (VW) was used to measure PM performance (see Figure 1). The VW with instruction manuals was obtained and used with permission from the author, Peter G. Rendell (School of Psychology, Australian Catholic University Melbourne, Australia).

Figure 1. Virtual Week Board Game

In the VW, participants perform tasks on a laptop computer with a touchscreen, using their hand (or mouse depending on whichever the participant was comfortable with) to interact with the software and move around the board with the simulated roll of a dice. As described by Rendell and Craik (2000), the times of day that people are typically awake are marked on the board (7:00), with each circuit of the board representing a day. Every virtual day starts at 7 am and ends at 10 pm. The time of the virtual day moves according to the number obtained on the dice: every 2 squares equal 15 minutes. The process of rolling the dice, moving the token around the board and making decisions about the activities, serves as the ongoing activity for the PM tasks. When participants land on or pass over an event square they click an event card which describes an event (e.g., ‘‘you sit with your friend Jim’’); the participant is required to make choices about the event (e.g., whether to attend a lecture or tutorial. See Figure

2). In some events, participants need to remember to carry out either an EBPM (e.g., buy a paper when shopping next; see Figure 3) or TBPM (e.g., phone the plumber at 4 pm; see Figure 4) task.

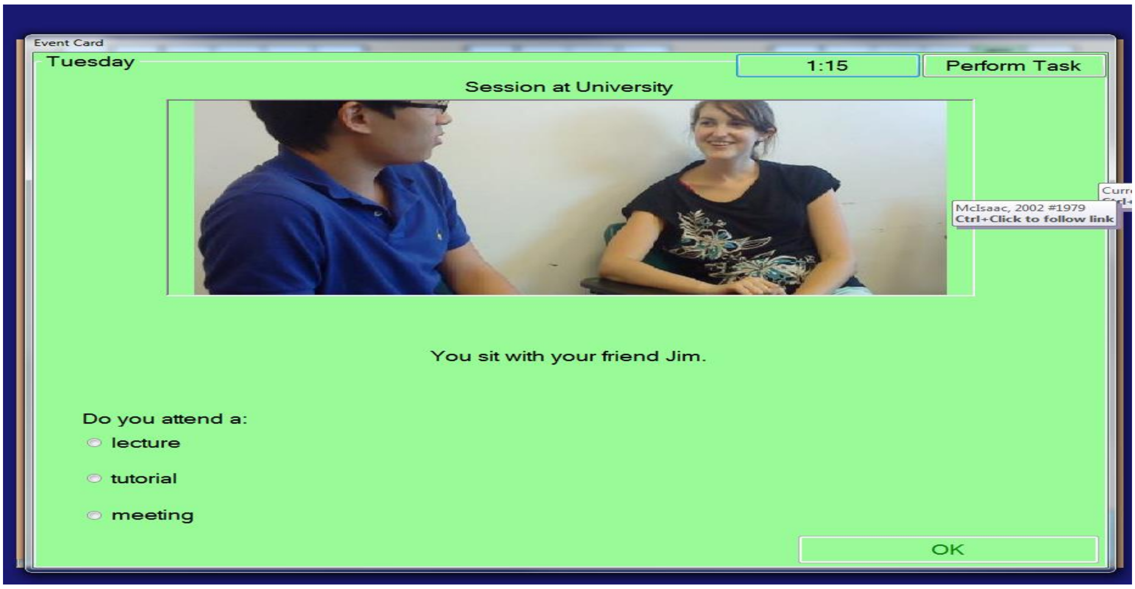

Figure 2. Example of VW computer screen display of an event card

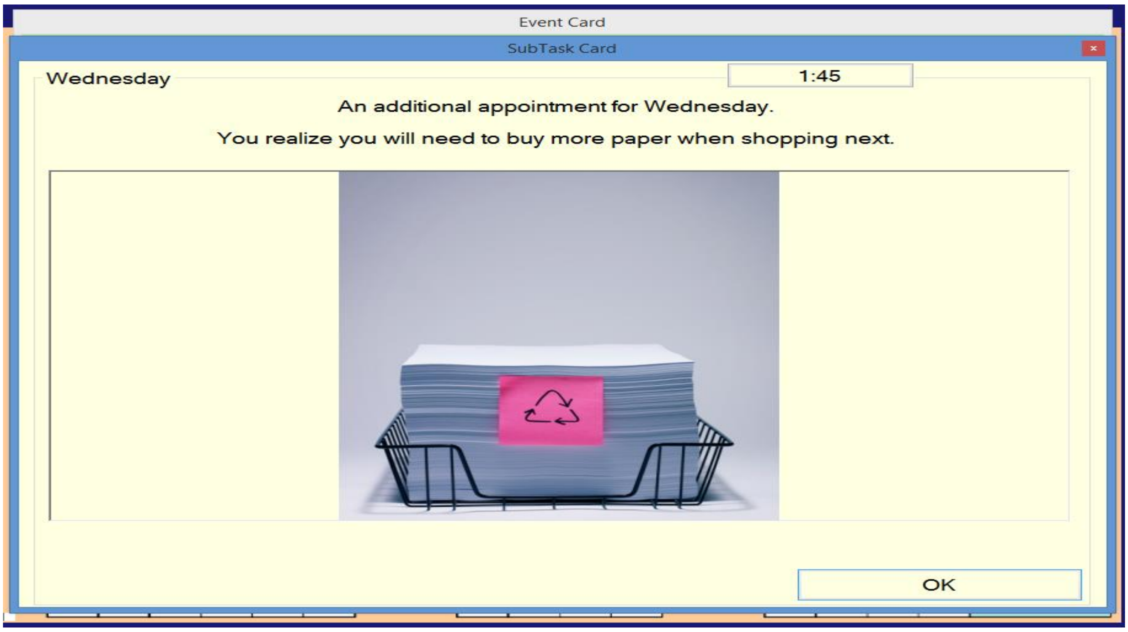

Figure 3. Example of VW computer screen display of EBPM task

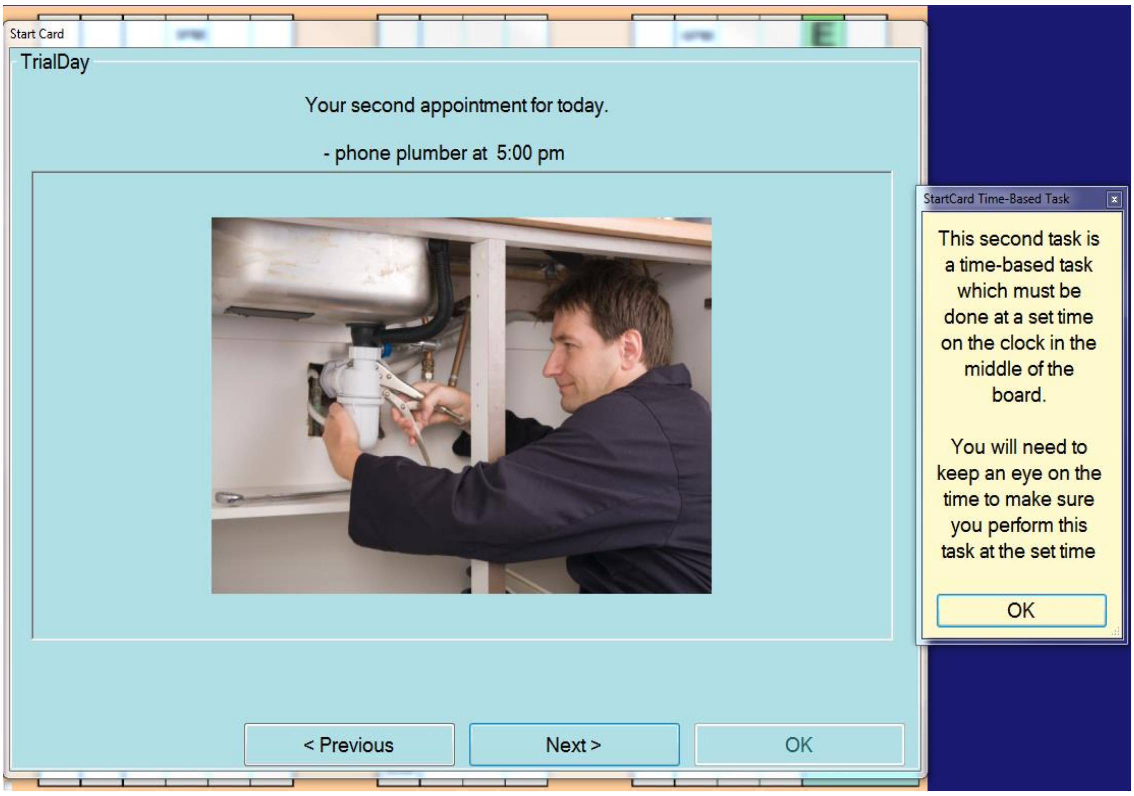

Figure 4. Example of VW computer screen display of TBPM task

They carry out the PM task by clicking on the 'perform' task button and selecting the required activity from a list that appears (Figure 1). Minor changes to the original task took account of cultural differences between Australian (original) and Ghanaian (target) populations; for example, on the Breakfast event card, peanut butter was replaced with groundnut paste.

On each virtual day there were four TBPM tasks (passing a particular time on the board) and four EBPM (encountering a specific event). Two of these tasks were either regular (performed on every virtual day) or irregular (performed on only one virtual day) for both the time and event tasks. The current study focused on irregular tasks. This is because regular tasks are habitual activities that need to be performed every day. As a result, regular tasks become automatic and require little strategic mental effort. In order to enhance PM performance, it was important to identify the difficulty that TBI patients encounter in daily life when doing irregular tasks.

Participants therefore completed four days with 4 PM (irregular) tasks per day – 2 EBPM and 2 TBPM tasks (*cf*. Mioni *et al*., 2013) yielding a total of 8 time-based and 8 event-based irregular/PM tasks. The encoding manipulation was performed on irregular tasks with only one type of encoding used on each day (e.g., Days 1,3 verbal; days 2,4 enactment). The reliability for the VW ranges between .84 to .94 (Rose et al., 2010).

Participants received pre-game instructions and a practice virtual day (see appendix 2.1 for details). They were asked to either systematically mime or read aloud when they received the instructions for the irregular PM tasks, either at the start of a virtual day or on specific event cards picked up during the circuit. An example instruction for an enactment task was as follows (e.g., an EBPM task was displayed on computer);

"Read the task silently (e.g., you need to return a book when you visit the library). Now stand up and make yourself comfortable, look away from the computer and mime/enact the process doing what you just read".

And an example instruction for verbal task was as follows (e.g., a TBPM task was displayed on computer):

"read the task silently (e.g., phone the plumber at 5:00pm), look away from the computer and say aloud what is written on the card".

Participants were closely observed throughout the task to ensure that they followed the appropriate encoding procedure when encoding. Following Rendell and Craik's (2000) scoring description, PM responses were classed as either *correct, missed, little late, late, little early, or early*, and expressed as a proportion of the total number of PM tasks (four) in each of the four categories: event-verbal, event-enact, time-verbal, time-enact (Mioni et al., 2013). There were 16 PM tasks in total and 4 in each of the four categories. *Correct* scores indicated that the target item was remembered at the correct time (correct time was after the dice roll for the move that took the token onto or past the target square and before the next roll of the dice); *missed* indicated that the participant did not remember the target item at any time; *little late* was after the correct criterion: for the TBPM tasks if they were made before the next hour on the virtual clock and for the EBPM tasks if they were made before the next event card; *late* were those responses made after the little late criterion and before the end of the virtual day; *little early* was if the response was made before the correct time and after the little late criterion, which was the previous event card for the EBPM tasks, and one hour before the expected time for the TBPM tasks. Finally, *early* responses were those made before the little early criterion and after the start of the virtual day (Mioni, Stablum, et al., 2017; Rendell & Craik, 2000).

The session lasted between 45-60 minutes. The proportion of correct responses was used in the current study for the analysis of PM performance. The reliability coefficient for the VW tasks(16 PM tasks, four per virtual day) in the current study was .70 for TBI group and .70 for HC group.

2.7.2.5. Neuropsychological Tests

Culture Fair Intelligence Test Scale 2 (CFIT; Cattell, 1973)

CFIT is a cultural free fluid intelligence measure without any element of verbal content. It is a pencil and paper-based test that was used to measure the general mental ability of participants. The CFIT consists of novel problem-solving items not specific to any particular culture. It is in the form of multiple choices answers made up of four subtests that include Series Completion, Classification, Matrices, and Conditions. The items in each subtest are presented in degrees of difficulty from simple to complex. There are three scales on the CFIT. Scale one was designed for use with children 4-8 years of age, or mentally handicapped adults. Scales 2 and 3 were designed for older children from age 13 or 14. Scale 3 has higher difficulty level items and is therefore suitable for college or university students. Scale 2 was used for the current study due to the low level of education among the most of the participants.

The CFIT involves only answers for a set of matrices from which participants must select the correct answer. Similar to White and Zammarelli (1981) procedure, participants were tested individually on the CFIT (Cattell & Cattell, 1973) scale 2 as follows: ”Each participant was presented with a sheet containing 5 examples of answers sets (i.e. correct answers accompanied by their distractors). The examples chosen were the answers only since there were no questions related to the items on the CFIT. The correct answer in each answer set was indicated on the example sheet. The nature of the contents of the example sheet was explained to the participants and they were invited to try to develop ways of deriving the correct answers from their respective answer sets. Participants were then presented with the answer sets (alone) for all the items of Test 1 to Test 4 of Scale 2 of the CFIT and asked to do their best to derive the correct answer to each item” (White & Zammarelli, 1981, p. 25).

In Test 1, participants had 3 minutes to complete the test, and 4 minutes for Test 2, 3 minutes for Test 3, and 2½ minutes for Test 4 (Appendix 2.7). The participants were not provided with any hints or ideas as to what principle they were to apply to solve the puzzles involved in the set of answers. Similarly, there were no questions that might give them a clue as to what was expected of them since they were required to deduce correct answers based on the examples provided. The test was scored using the conventional scoring standard such that each item adds up to a total score of 46. The scores could also be converted to percentiles according to norms derived from a standardization sample. Testing and retesting by the developers have proven that the Culture Fair IQ test is consistently reliable (Cattell & Cattell, 1973). The short form of Scale 2 has an internal consistency estimate of .76 (Cattell & Cattell, 1973). Research demonstrated that the CFIT loads highly on a general factor (along with the Raven's Progressive Matrices Test, another acceptable measure of fluid intelligence) in psychometric studies of intelligence (Carroll, 1993). Scores on the CFIT were computed and converted to standard scores in order to determine the mental ability of participants in the current study.

Digit Span (Wechsler, 1987)

The Digit Span subtest (forwards and backwards) of the WMS-R (Wechsler, 1987) was used to assess working memory and attention. In this test, participants were required to immediately remember a string of numbers presented and repeat them aloud immediately after the presentation. This test is made up of two subscales, Digits Forward and Digits Backward spans. In the forward span, sequences of stringed digits were read to participants who were then asked to repeat them orally in the same correct sequence. In the backward span, they were to orally repeat stringed numbers in a correct reverse order. The number of digits in each string increased from 3 to 9 forward and 2 to 8 backward if participants correctly repeat strings (forward or backward). If the participant failed two consecutive trials, the test was discontinued. Total score corresponds to the maximum number of digits that the participant was able to repeat correctly. The digit span requires adequate auditory attention and both the forward and backward span depend on short-term retention capacity (Ostrosky-Solís & Lozano, 2006)

2.7.2.6. Measures of EF

The WCST (Heaton, et al., 1993)

We used the computerised version of the WCST. This measures the ability to shift cognitive strategies or sets in response to changing situational occurrences (Greve, Brooks, Crouch, Williams, & Rice, 1997; Greve, Williams, Haas, Littell, & Reinoso, 1996; Martin et al., 2003). The WCST (Appendix 2.8) requires participants to sort a deck of 64 cards to match 1 of 4 set of cards (Martin et al., 2003). The computer gave feedback to the participant of whether the answer was right or wrong. The test proceeded through a number of arrangements along three categories of colour, form and number.

In the WCST task, participants were expected to first identify the correct principle by which they will sort the deck of cards following feedback from the computer. If successful, they were expected to sustain this sorting principle until all the cards are finished. In a situation where the participant failed to notice the computer feedback displayed on the screen, the researcher says out loud if the answer was right or wrong. Once the participant made 10 consecutive "correct" matches to the initial sorting principle (i.e., colour), the computer changes the rule for the sorting principle to 'form' or 'number' without a warning. The participants were expected to use the computer feedback or feedback from the experimenter to develop a new sorting rule or, in other words, to "shift sets" (Martin et al., 2003, p. 200). The test continued until the six categories were correctly sorted or until all the 64 cards were exhausted (Heaton, 1993).

Scores on the WCST were based on the "number of trials administered, total number of correct responses, number of errors, number of perseverative responses, number of perseverative errors, number of non-perseverative errors, number of categories completed, number of trials to complete the first category, conceptual level responses, failure to maintain set, and learning to learn" (Varanda & Fernandes, 2017, p. 4). Research in neuroimaging has shown that that PFC is the most specifically activated brain area while participants perform the WCST test (Buchsbaum, Greer, Chang, & Berman, 2005; Sumitani et al., 2006; Yuan & Raz, 2014).

Stroop Test (Stroop, 1935)

The computer version of the Stroop colour-word (cf. Stroop, 1935) was used to measure task interference and inhibitory control (Dempster, 1992; Martin et al., 2003; Spieler, Balota, & Faust, 1996). We used the same Stroop materials that were employed by Mueller and Piper (2014) in their pebl software ® (www.pebl.sourceforge.net). Participants sat in front of a laptop at a viewing distance convenient for their eyesight. The stimuli were made up of four names written in different colours (red, blue, green, and yellow). The words appeared individually on a black background on the computer screen. Two categories of words appeared in the centre of the computer screen: coloured words (RED, BLUE, GREEN, and YELLOW) and neutral words (AND, HARD, WHEN, and OVER).

The experiment involved three trials: Trial 1 involved neutral words (neutral condition) presented in any of the four colours; Trial 2 involved a colour word presented in its own colour (congruent condition); Trial 3 involved colour word presented in any of the three colours (incongruent condition) other than the presented word (e.g., the colour word 'blue' presented in 'green'). During each trial, participants were asked to identify a colour in which a word was written by depressing one of four keys on a keyboard. The colour-labelled response keys were 1, 2, 3, and 4 for the colours red, blue, green, and yellow, respectively (Appendix 2.6). Participants were encouraged to be as fast and accurate as possible. The number of correct responses and mean stimulus reaction time in milliseconds were recorded. The Stroop interference or effect was also recorded (i.e. the performance cost in the mismatch condition – known as the incongruent condition – relative to the matched/congruent conditions).

Trail Making Test (TMT; Reitan, 1958)

The TMT (computerised version) assesses the EF of planning ability. It consists of two parts: Part A and B. In Part A, participants were required to use the mouse to click or touch circles that are numbered consecutively, thereby drawing lines to connect the circles. In Part B, participants connected circles that contained numbers or letters (i.e. 1-A-2-B-3….), alternating between the numeric and alphabetic sequences. This test took approximately 5 minutes to complete and the participant's score was the total time taken to complete the task. Lower scores on the TMT indicate higher levels of planning ability. If an incorrect response was made, no line is drawn to indicate that an alternative response should be made.

The outcome measure was the time taken to complete each test and the ratio of the difference between TMT A and TMT B. Prior to administration of either the TMT-A or B, instructions were presented on the screen along with information on what would happen if an incorrect response was made (Appendix 2.4). The TMT test requires 100% accuracy so errors increases the total time taken to complete the test (Ellis et al., 2016)

Verbal Fluency (Phonemic; Lezak, 2004)

The phonemic (letter) Verbal Fluency (VF) task was used to measure EF. In the task, participants were instructed to generate as many words as they could that began with a particular letter (e.g., F, A, S) of the alphabet. Sixty seconds were allowed for each letter. The participants were instructed that names of people, places and numbers were not acceptable responses. Grammatical variants of previous responses (plurals, altered tenses, and comparatives) were also not acceptable responses (Appendix 2.5). All responses were recorded by the examiner. The total number of correct words was calculated for each participant. VF has been used widely as a test of executive control ability (e.g., Fitzpatrick, Gilbert, & Serpell, 2013; Henry & Crawford, 2004). The VF test requires focused attention in order for one to choose words that meet the expectation of the task and avoid repetition and this process involves executive control processes (Fisk & Sharp, 2004; Shao, Janse, Visser, & Meyer, 2014). As a result, the presence of any serious deficits in either the verbal ability or executive control should manifest themselves in poor performance in the fluency tasks (Shao et al., 2014).

2.7.2.7. Measures of QoL and Social Perception

The following measures were used to assess QoL and social perception.

Quality of Life after Brain Injury (QOLIBRI; von Steinbuechel et al., 2005)

The QOLIBRI was used to assess health-related QoL (HRQoL) of individuals after TBI. As described by the authors (e.g., von Steinbüchel et al., 2010; von Steinbuechel et al., 2005) the QOLIBRI is a comprehensive questionnaire with 37 items that measure six dimensions of HRQoL after TBI. The time taken to complete the test is usually between 7-10 minutes. The items on the QOLIBRI scale measures physical, psychological, daily life and psychosocial changes typical of TBI. The subscale scores can be used separately or can be combined to give a profile of QoL(von Steinbuechel et al., 2005).

Areas covered by the questionnaire include physical condition (e.g., slowness/clumsiness other injuries, pain, seeing/hearing, TBI effects), cognition (e.g., concentration, ability to express self, everyday memory, problem solving, making decisions, navigation, speed of thinking), emotions (e.g., loneliness, boredom, anxiety, depression, anger/aggression), function in daily life (e.g., independence, getting out, domestic, finances, work, social, feeling in charge), personal and social life (e.g., affection, family, friends, partner, sex life, attitudes of others) , and current situation and future prospects (e.g., energy, motivation, self-esteem, looks, achievements, self-perception, future). See Appendix 2.10 for details. Responses to each item were scored 1 ('Not at all') to 5 ('Very') and the sum of all items was converted arithmetically to a percentage scale, with 0 representing the lowest possible HRQoL on the questionnaire and 100 the best possible HRQoL (von Steinbüchel et al., 2010; von Steinbuechel et al., 2005). The Cronbach's alpha on the QOLIBRI scales ranges from 0.75 to 0.89 and shows good test-retest reliability (intraclass correlations ranged from 0.78 to 0.85; von Steinbuechel et al., 2005).

TASIT (McDonald et al., 2003)

The TASIT as described by McDonald et al. (2003) is made up of short videos depicting social interactions, which are common in everyday life activities. The test has three parts, each with alternate forms for retesting. The part one measures the ability to evaluate others' emotions The expectation of the test is that participants should be able to recognise the basic emotion expressed by others. The expressed emotions include; fear, anger, happiness, disgust, surprise, and sadness (McDonald et al., 2003). The emotions are depicted by professional actors in the short video vignettes simulating real-life situations. After identifying the emotions, participants were expected to differentiate them from neutral expressions.

Part two assesses minimal social inference. It requests participants to be able to evaluate the meaning of comments made by speakers in a conversation. They view professional actors in the video interacting with others while using some expressions of everyday conversations. The remarks of the speaker are presented in either a sarcastic or sincere tone. The sarcastic remarks are not meant to be taken literally but to rather infer the opposite (e.g, "you have been of great help" McDonald et al., 2006, p. 5). The conversational structure is complicated and the participants were expected to be able to recognise and answer questions concerning the feelings (including insignificant emotions such as annoyance and embarrassment), thoughts, intentions and meaning of the remark by the speaker based upon their countenance such as gesture, tone of voice and facial expression (McDonald, 2002; McDonald et al., 2006; McDonald & Flanagan, 2004).

Part three assesses enriched social inference. In this section, the speakers tried to please others by lying contrary to what they actually feel and think of the other person (e.g., "of course you don't look fat!", McDonald et al., 2006, p. 5). In some instances, the comments are sarcastic while inferring the opposite. Commentary or visual synopsis is included in Part 3 in the form of a prologue. This gives the viewer an idea about the true belief of the speaker contrary to what they say to the recipient of their remarks (e.g., the speaker makes a prior statement to the friend that her husband is fat before she enters the room where her husband was changing his clothing). The aim of this part was to enable viewers/participants to recognise and take note of explicit context of information with regard to the speaker's actual belief. The participants were also expected to evaluate feelings, thoughts, and meanings similar to part two (McDonald et al., 2004; McDonald et al., 2003).

The total playing time for all the three parts is approximately 35 minutes. The TBI and HC in each participants home watched the video together. However, each was provided with separate answer sheets with multiple choices on which they were to indicate their answers. Prior to the commencement of the video session, participants were informed that they would be shown short video vignettes of some people interacting and that they would be asked questions about these based on the TASIT manual. Each video vignette has a practice element at the beginning to enable participants to familiarise themselves with task requirements. During the session, the video was paused after each vignette and the participants asked to respond to questions concerning the content of the video. Depending on the number of items, the part 1 of the test yields a total score of 28, part 2-score 60, and part 3-score of 64. The assessment followed the guidelines provided for the test (McDonald, 2002; McDonald et al., 2006; McDonald & Flanagan, 2004; McDonald et al., 2004; McDonald et al., 2003). See Appendix 2.11 for details.

2.7.3. Design and Statistical Analysis

The design of the study was a 2*2*2 mixed ANOVA with two within-subject factors and one between subject factor. The between subjects factor is Group (TBI, HC) and the within subject factors are Encoding (verbal, enactment) and PM task (EBPM, TBPM). Both groups performed the same PM tasks (i.e., enactment/verbal; event/time) and some cognitive and EF tests. Participants' QoL and social perception were also measured. Levene's test of homogeneity of variance revealed that the data did not violate the assumption for the use of a mixed ANOVA. A post-hoc Bonferroni correction was used to test for simple effects following significant main effect. An Alpha level of 0.05 was used to determine the level of significance and effect sizes were measured by partial eta-squared (η_p^2) with small, medium, and large effects defined as .01, .06, and .16, respectively (Cohen, 1977). A one way ANOVA was used to determine the difference between the TBI and HC groups on PM performance and whether the difference was on EBPM or TBPM, or both. Mixed ANOVA was used to examine the effect of enactment vs. verbal encoding on PM performance for both TBI and HC.

Spearman ranked order correlations were computed separately for the TBI and HC groups to assess the relationship between PM performance with neuropsychological measures, EF, and QoL including social perception. Separate correlations were run for two measures of PM performance: proportion correct on EBPM and on TBPM tasks.

2.8. Results

Data analysis was based on the four specific aims of the study; namely, to determine (1) difference in performance between TBI and HC on PM performance and whether performance was better for EBPM compared to TBPM, (2) effect of enactment vs. verbal encoding on PM performance, (3) the relationship between EF and PM performance, and (4) the relationship between QoL, Social perception and PM performance.

2.8.1. PM Performance

A preliminary analysis was conducted to determine the mean difference in performance between two groups of TBI and HC on EBPM and TBPM tasks. Descriptive statistics for the two groups are presented in Table 2.3. A one-way ANOVA was conducted to investigate if there is a difference in PM performance between the two groups of TBI and HC.

Table 2.3

Means, Standard Deviation, and ANOVA Result of the Difference in Performance Between TBI and HC on the VW

	TBI N=30 Mean(SD)	HC N=30 Mean(SD)	*F*	*p*	$\eta_p 2$
PM					
Event	3.60 (2.31)	4.77(2.13)	4.132*	.05	0.067
Time	1.43 (1.45)	1.93(1.80)	1.401	.24	0.024

Note. *p<.05.

As Table 2.3 illustrates better performance for HC compared to the TBI group was observed on EBPM, $F(1, 58) = 4.132$, $p = .05$, $\eta_p 2 = .067$, but not on TBPM, $F(1,58) = 1.401$, $p = .24$, $\eta_p 2 = .024$. This indicates that the HCs (M = 4.77, SD = 2.13) responded more accurately on EBPM tasks compared to the TBI group (M = 3.60, SD

= 2.31). However, the HCs (M =1.93, SD = 1.80) performed equally on TBPM tasks compared to TBI (M = 1.43, SD = 1.46).

2.8.2. Encoding and PM performance

The effect of encoding techniques on PM performance was examined in terms of accuracy of responses. The means and standard deviations of responses were calculated. Summary results are presented in table 2.4 below.

Table 2.4

Means and Standard Deviations of Correct Responses on the Four Encoding Conditions on PM Task by the TBI and HC Groups

Task		Time		Event	
Encode		Verbal M(SD)	Enact M(SD)	Verbal M(SD)	Enact M(SD)
Group	TBI (n =30)	0.97(1.03)	0.47(.90)	1.60(1.25)	2.00(1.17)
	HC (n = 30)	1.27(1.17)	0.67(.88)	2.13(1.17)	2.63(1.13)

The above data was subjected to a 2x2x2 mixed ANOVA with one between (Group: HC vs. TBI) x two within (Encoding: enactment vs. verbal), 2 (Task: EBPM vs. TBPM). A summary of results is displayed in Table 2.5.

Table 2.5

The Effect of Group and Encoding Strategy on PM Tasks Performance

	SS	df	MS	F	p	$\eta_p 2$
Group	10.42	1	10.417	4.115*	0.047	0.066
Task	93.750	1	93.750	73.397**	< .001	0.553
Task * Group	1.667	1	1.667	1.305	0.258	0.010
Encode	0.150	1	0.150	0.269	0.606	0.005
Encode * Group	0.000	1	0.000	0.000	1.000	0.000
Task * Encode	15.000	1	15.000	34.320**	< .001	0.370
Task* Encode * Group	0.150	1	0.150	0.343	0.560	0.004

Note. *$p<.05$, **$p<.001$.

The results, illustrated in Table 2.5, revealed a marginally significant effect of group, $F(1,58) = 4.115$, $p = 0.047$, $\eta_p^2 = .066$ with numerically poorer performance in the TBI (M = 5.03, SD = 3.19) compared to the HC (M=6.70 SD=3.17) group on PM Tasks. However, no group*encode *task interaction was observed, $F(1,58) = .343$, $p = .56$, $\eta_p^2 = 0.004$. The effect of encode was also not significant, $F(1,58) = 0.269$, $p = .61$, $\eta_p^2 = 0.005$. However, the effect of task was significant, $F(1,58) = 73.397$, $p<.001$, $\eta_p^2 = 0.553$ with a large effect size. Participants performed significantly better on EBPM (M = 4.18, SD = 2.28) compared to TBPM (M =1.68, SD = 1.64). This indicates that TBPM places a greater demand on cognitive resources since it involves constant monitoring of the clock and therefore difficult to remember. Finally, there was a significant interaction between encode and task, $F(1,58) = 34.320$, $p< .001$, $\eta_p^2 = 0.370$.

Post-hoc tests using Bonferroni correction revealed that enactment encoding (M = 2.23, SD = 0.15) enhances EBPM compared to verbal encoding (M = 1.87, SD = 1.56), $p<.001$ while verbal encoding (M =1.87, SD = 1.56) enhances TBPM compared to enactment encoding (M = 0.57, SD = 0.12), $p = 0.001$. The interaction is illustrated in Figure 5 below.

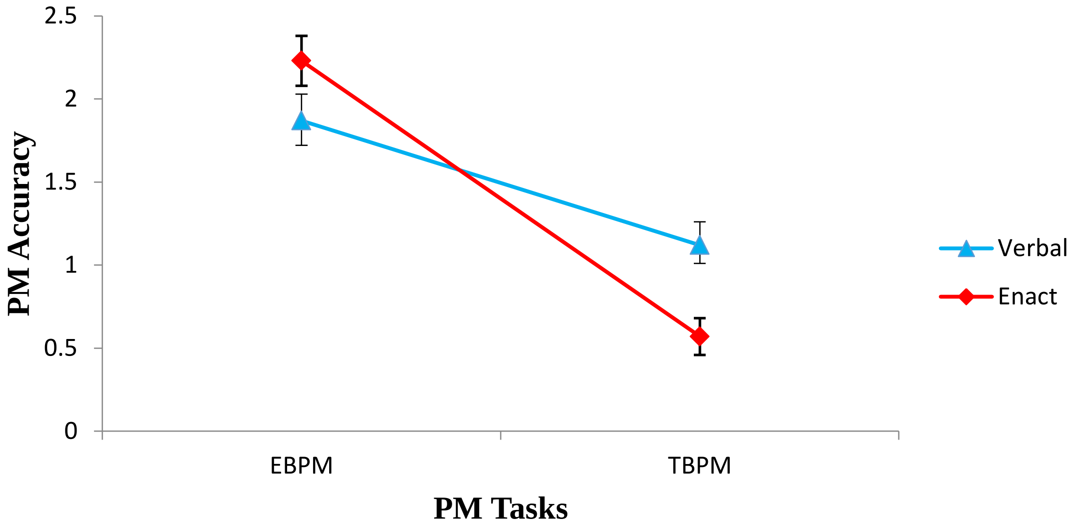

Figure 5. Effect of Enactment vs. Verbal Encoding on PM Performance

These findings show that participants in both groups benefit similarly from both encoding strategies indicating that verbal and enactment encoding enhances PM performance of individuals irrespective of their clinical status.

2.8.3. Difference in Performance on Neuropsychological and EF Test

A series of one-way ANOVAs were conducted to determine if differences exist between the two groups of participants on neuropsychological and EF tests. The performance of the two groups is summarized in Table 2.6 below. Due to the large number of comparisons, a more conservative alpha level of $p<.01$ was used to establish level of significance.

Table 2.6

Means, Standard Deviation, and ANOVA Result of Neuropsychological and EF Tests

	TBI (*n* = 30) *M (SD)*	HC (*n* = 30) *M (SD)*	*F*	*p*	η_p^2
Neuropsychological tests					
CFIT	69.77(13.08)	76.27(11.76)	4.098	0.048	.023
Digit span score	11.2(4.73)	14.07(3.98)	**6.449***	0.01	.715
Digit span forward score	7.03(3.12)	8.47(2.47)	3.882	0.054	.504
Digit span backward score	4.27(2.33)	5.83(2.51)	6.28	0.02	.686
EF					
VF	18.34(11.19)	24.1(9.77)	4.436	0.04	.317
TMT	111.5(111.86)	56.97(34.29)	**6.517***	0.01	.320
TMT-A	34.22(16.5)	24.69(9.61)	**7.097***	0.01	.054
TMT-B	63.3(63.91)	29.7(19.9)	**7.559***	0.008	.337
TMT Ratio	1.54(1.15)	1.23(0.88)	1.354	0.25	.221
TMT Difference	18.99(58.38)	6.09(42.3)	0.96	0.33	.219
Stroop task					
Congruence interference RT(ms)	1104.77(251.01)	11933.97(59979.44)	0.978	0.33	.184
Incongruent interference RT(ms)	1197.9(232.35)	1062.97(195.32)	5.928	0.02	.250
Neutral RT (ms)	1149.12(242.75)	1014.52(179.77)	5.957	0.02	.148
Stroop effect	8.55(5.94)	1.08(38.25)	1.119	0.29	.025
Stroop ratio	0.09(0.06)	0.01(0.38)	1.119	0.29	.025
WCST					
Perseverative response	13.98(11.92)	15.63(9.83)	0.345	0.56	.236
Percentage perseverative response	19.56(18.23)	24.56(15.47)	1.313	0.26	..236
Perseverative errors	9.35(10.66)	12.62(13.93)	1.046	0.31	.140
Percentage perseverative errors	11.12(12.04)	13.8(10.79)	0.82	0.37	.388
Non Perseverative errors	54.64(163.1)	24.98(16.31)	0.982	0.33	.143
Percentage non perseverative error	37.86(25.78)	35.46(22.79)	0.146	0.70	.071
Failure to maintain set	0.37(0.61)	0.43(0.63)	0.173	0.68	.006
Learning to Learn	5.6(11.31)	-4.22(5.18)	3.749	0.08	.206
Conceptual level responses	22.13(15.08)	22.93(13.55)	0.047	0.83	.003
Percentage conceptual level of response	34.59(23.57)	33.55(21.16)	0.032	0.86	.069

Note. *p<.01, **p<.003, CFIT= Culture Fair Intelligence Test; MS= Milliseconds; RT= Reaction Time; TMT= Trail Making Test A and B; WCST= Wisconsin Card Sorting Test; VF= Verbal Fluency.

Table 2.6 reveals that in the neuropsychological tests, HCs performed significantly better than the TBI group on the digit span total score which is a test of working memory, $F(1, 58) = 6.449$, $p = .01$, $\eta_p^2 = 0.715$. On tests of EF, HCs performed significantly better than the TBI group on TMT-A, $F(1, 58) = 7.097$, $p= .01$, $\eta_p^2 = 0.054$, TMT-B, $F(1, 58) = 7.559$, $p= .008$, $\eta_p^2 = 0.337$. The groups did not differ significantly on most of the outcomes of tests assessing EF (WCST [Heaton, 1993]; Stroop [Stroop, 1935]). As seen from the effect size calculations, the most discriminating of all the measures in Table 2.6 is the TMT total score. Performance on the TMT indicates that the TBI participants present with poor planning ability compared to HC.

2.8.4. Relationship between PM Performance, EF, Neuropsychological Function and Clinical Features

An exploratory correlation analysis was conducted to investigate whether PM performance (EBPM vs. TBPM) was related to measures of neuropsychological and EF tests for each group of TBI and HC. Correlations were also computed for TBI group's injury characteristics (i.e., injury duration, Glasgow Coma Scale [GCS] on admission and GCS on discharge) and PM performance. The results are reported in Table 2.7. Due to the large number of correlations a more conservative alpha of .01 was used to establish level of significance.

Table 2.7

Correlations among PM tasks, Clinical (including demographics) Features, Neuropsychological Measures, and EF Measures

	TBI				HC			
	EBPM	*p*	TBPM	*p*	EBPM	*p*	TBPM	*p*
Clinical Features								
Injury duration (months)	-.060	.75	-.268	.15				
GCS on admission	.398	.03	**.460***	.01				
GCS on discharge	.267	.15	.390	.03				
Demographics								
Education (years)	.158	.41	.367	.05	.340	.07	**.579****	.001
Neuropsychological Tests								
NART Full Scale IQ	-.047	.83	.096	.65	.074	.71	**.508***	.006
MOCA	.123	.52	.415	.02	.072	.71	.281	.13
CFIT	.211	.26	.257	.17	.232	.22	.324	.08
Digit Span	-.085	.66	-.081	.67	-.048	.80	.264	.16
EF								
Verbal Fluency	.192	.32	.367	.05	.058	.76	.429	.02
TMT								
TMTA	-.233	.24	-.265	.11	.026	.89	-.093	.63
TMT-B	-.275	.14	-.365	.05	-.089	.64	-.205	.28
TMT-RATIO	-.016	.94	-.029	.88	-.240	.20	-.240	.20
Stroop Task								
Stroop effect	.066	.73	.321	.08	.241	.20	.238	.20
WCST								
Categories Achieved	.075	.69	.145	.45	.370	.04	.230	.22
Percentage Correct Responses	.362	.05	.308	.10	.341	.067	.196	.30
Percentage total errors	-.363	.05	-.310	.10	-.344	.06	-.233	.22
Perseverative Errors	-.093	.63	.178	.34	.105	.58	.164	.39
Non-perseverative errors	-.178	.57	-.386	.04	-.221	.24	-.005	.97
Failure To Maintain Set	**.637****	P<.001	.397	.03	-.120	.53	-.261	.16

Note. CFIT= Culture Fair Intelligence Test; MOCA= Montreal Cognitive Assessment Test; NART= National Adult Reading Test; TMT =Trail Making Test; WCST= Wisconsin Card Sorting Test.

*p<.01, **p<0.001.

Table 2.7 shows that for the TBI group, GCS on admission correlated positively with TBPM (*r* =.460, *p* =.01) while WCST failure to maintain set correlates positively with EBPM (*r* =.637, *p*<.01). These findings indicate that the TBI participants who had better GCS tended to exhibit better TBPM. In addition, the TBI participants who had difficulty maintaining set also tended to demonstrate better EBPM. This advantage could be due to the presence of external cues that aid EBPM remembering.

In the HC group, the NART full-scale IQ (*r* =.508, *p*=.006) and years of education (*r* =.579, *p* =.001) correlated significantly with performance on TBPM. This means that HC participants who had better education and verbal intelligence tend to perform well on TBPM. No significant correlations were found between EF measures and the PM tasks for the HC group. However, given that the majority of the participants were performing close to the mean on the PM measure, the lack of significant correlation most likely reflects the lack of variability in the PM scores.

2.8.5. Difference in Performance on QoL and Social Perception Measures

We also explored the difference in performance between the two groups of TBI and HC on QoL and social perception measures. The findings are summarized in Table 2.8 below. Due to the large number of comparisons, a more conservative alpha level of *p*<.01 was used to establish level of significance.

Table 2.8

Means, Standard Deviations, and the outcome of a One-Way ANOVA Tests Group differences on QoL and Social Perception Measures

	TBI *n=30* Mean(SD)	HC *n=30* Mean(SD)	*F*	*p*	η_p^2
QOLIBRI					
Cognition	61.19 (17.79)	79.52(17.66)	16.039**	<.001	.203
Self-view	60.48(21.30)	77.62(15.50)	12.705**	.001	.172
Independence	62.38 (19.76)	77.62(16.27)	10.634**	.002	.141
Social Relationships	59.86 (17.66)	74.72(17.09)	10.970**	.002	.158
Emotions	46.33 (21.45)	50.33(22.59)	.495	.49	.009
Physical Problems	50.67(22.54)	52.00(30.47)	.037	.85	.000
QOLIBRI Total	57.64(13.51)	70.36(11.48)	15.519**	<.001	.198
TASIT					
Emotion evaluation	14.47(5.23)	17.40(5.01)	4.916	.03	.085
positive emotion	7.23 (2.25)	8.50(2.56)	4.144	.05	.069
negative emotion	7.17(3.65)	8.90(3.10)	3.931	.05	.071
Social inference (Minimal)	31.45(6.86)	32.00(5.93)	.107	.75	.002
sincere	10.52(3.55)	10.66(2.47)	.029	.66	.000
simple sarcasm	10.07(3.45)	10.66(3.070)	.466	.50	.007
Paradoxical sarcasm	10.34 (2.18)	10.41(2.80)	.011	.92	.003
Social inference (enriched)	32.68(6.30)	32.25(8.00)	.050	.63	.001
lie	16.46 (3.36)	16.25(4.41)	.042	.64	.001
sarcastic	16.29(4.67)	16.36(4.34)	.004	.95	.000

Note. *QOLIBRI= Quality of life after Brain Injury, TASIT= The Awareness of Social Interference.*$*p<.01$ $**p< .003$.

The data from Table 2.8 reveals that the HC group performed significantly better than the TBI group on overall QOLIBRI, $F(1, 58) = 15.519$, $p<.001$, $\eta_p^2 = 0.198$. This indicates that the TBI group presented with poorer QoL following brain injury compared to HC. Similarly, the HC group are better able to evaluate others' emotions on the TASIT measure compared to the TBI group, although the difference was not statistically significant via the strict alpha value (*p*<.01).

2.8.6. Relationship between PM performance and QoL

To further examine the role of QoL and social perception in TBI's PM failures, we conducted correlational analyses. For each group, we examined the relationship between PM performance and QoL and social perception measures of QOLIBRI and TASIT. Due to the large number of correlations, a more conservative alpha of .01 was used. Summaries of the correlation results are reported in Table 2.9 below.

Table 2.9

Correlations between PM Tasks, QOLIBRI, and TASIT scores

	TBI				HC			
	EBT	*p*	TBT	p	EBT	*p*	TBT	*p*
QOLIBRI								
Cognition	.259	.17	.350	.06	-.177	.35	.177	.35
Self- view	.295	.11	.294	.12	.033	.86	.237	.21
Independence	.031	.87	.304	.11	.019	.92	.164	.39
Social Relationships	.260	.17	.198	.30	.019	.92	.240	.20
Emotions	.291	.12	.332	.07	-.056	.77	.278	.14
Physical Problems	.367	.05	.087	.64	-.061	.75	.093	.62
QOLIBRI Total	.344	.06	.345	.06	-.040	.84	.326	.08
TASIT								
Emotion evaluation test	.301	.11	**.463***	.01	.324	.08	**.486***	.006
Positive emotion	.281	.13	.344	.06	.265	.16	.347	.06
Negative emotion	.298	.11	**.520***	.003	.413	.02	.423	.02
Social inference (Minimal)	-.421	.02	.030	.88	-.059	.76	.018	.92
sincere	-.171	.37	.143	.46	-.268	.16	-.054	.78
simple sarcasm	.002	.99	.166	.39	.117	.54	.113	.56
paradoxical sarcasm	-.379	*.04*	*-.064*	*.74*	*.181*	*.35*	*.070*	*.72*
Social inference (enriched)	-.262	.18	.029	.88	.097	.62	-.123	.53
lie	*-.227*	*.19*	*.138*	*.45*	*.036*	*.86*	*-.114*	*.56*
sarcastic	*-.075*	*.71*	*-.100*	*.61*	*.068*	*.73*	*-.184*	*.35*

Note. *QOLIBRI= Quality of life after Brain Injury, TASIT= The Awareness of Social Interference*

*p<.01,**p<0.003;

From Table 2.9, it can be seen that significant positive correlations emerged between emotion evaluation and TBPM for both the TBI (r =.463, p =.01) and HC (r = .486, p =.006) groups. However, it is the negative aspect of the emotion evaluation that is strongly associated with better performance on TBPM task in the TBI group (r =.520, p =.003) and moderately associated with better performance on TBPM task in the HC group (r =.423, p =.02). These findings indicate that TBI and HC participants who are able to evaluate the negative aspect of others emotion tends to exhibit better TBPM performance.

2.9. Discussion

The current study investigated the effect of encoding strategies on PM performance in two groups of TBI and HC respectively. We also explored the role of EF, QoL and social perception in PM performance for the two groups of TBI and HC. We expected that PM performance would be poorer for the TBI group compared to HC. We also expected performance to be poorer on TBPM compared to EBPM since TBPM require self-initiated processes. A significant correlation between PM and EF was also expected. Finally, it was anticipated that QoL and social perception would also play a role in PM performance.

2.9.1. PM Performance

The first question that this study sought to answer was 'do TBI patients perform significantly worse than HC on PM performance? Moreover, is this difficulty evident on EBPM or TBPM or both?' The results showed that HC participants performed marginally significantly better than the TBI participants on PM functioning. This suggests that TBI affects prospective remembering and that this may be due to possible deficits in the frontal and temporal lobes, the areas responsible for processes involved in PM tasks (e.g., planning, cue recognition, initiation and execution of planned actions, and interruption of an ongoing activity; Glisky, 1996; Shum et al., 1999).

The above finding is consistent with previous studies which found PM to be impaired following TBI (e.g., Cockburn, 1996; Hannon et al., 1995; Kinch & McDonald, 2001; Kinsella et al., 1996; Mioni, Bertucci, et al., 2017; Mioni, McClintock, et al., 2014; Mioni et al., 2013; Shum, Levin, et al., 2011). Unlike previous studies, however, the present study demonstrated impairments in TBI patients for only EBPM. We did not expect that HC would perform similarly to TBI on TBPM.

TBPM tasks are often regarded as more difficult than EBPM tasks since they are believed to require participants to use more cognitive resources to monitor the time and initiate the action without being requested to do so (Carlesimo et al., 2004; Einstein & McDaniel, 1990; Kinch & McDonald, 2001; Mathias & Mansfield, 2005; Potvin et al., 2011). It is possible that the link between a specific time and a specific action is arbitrary and is not easily enacted by either TBI or HC participants (Potvin et al., 2011). For instance, it is possible to enact taking medication after breakfast than at 10:00 pm, since breakfast involves the intake of food, which is more closely related to the intake of medication compared to an arbitrary time.

Another possible explanation for the lack of difference between the groups on TBPM performance could be that both groups of participants might have been checking the time less often within tasks and, while the TBI participants might have difficulty estimating the time (Potvin et al., 2011), the HC participants seem to present more with lapses of attention (Mioni et al., 2012). Overall, as with other studies (e.g., Kinch & McDonald, 2001; Mathias & Mansfield, 2005), participants performed significantly better on EBPM compared to TBPM. This was expected since it is consistent with the proposal that TBPM requires more self-initiation than EBPM, which relies on an external cue to help recall the task to be performed (McDaniel & Einstein, 1993; McDaniel et al., 1999; McFarland & Glisky, 2009).

2.9.2. Effect of Enactment vs. Verbal Encoding on PM Performance

The second question this study sought to answer was ‘does enactment encoding benefit PM performance in both TBI and HC compared to verbal encoding?’ Findings indicate that ‘miming through enactment’ enhances an action that needs to be performed in the presence of an external cue for both TBI and HC. The benefit of enactment for EBPM at encoding suggests that performance on EBPM tasks could be enhanced if they are planned such that individuals could symbolically mime, during encoding, the action they intend to carry out in the future together with the cue for that recall. TBPM remembering may also be enhanced if individuals verbally rehearse time-based actions that they intended to carry out in future. The benefit of enactment over verbal encoding on EBPM provides support for previous studies (e.g., Mioni et al, 2017; Pereira et al., 2012). However, unlike the current study which did not find an effect of enactment encoding on TBPM performance, Mioni et al. (2017) found improved PM performance for TBI patients on both EBPM and TBPM tasks after employing a future event simulation strategy, although their HC group improved only on the EBPM tasks.

The absence of a benefit of enactment for TBPM tasks might reflect difficulties in miming the enactment of performing an action at a particular time on the clock. Also, time is an abstract concept requiring mental imagination rather than bodily action. This might also explain why enactment did not benefit time-based tasks in the current study. Indeed TBPM performance worsened following enactment compared to verbal encoding. The possible explanation is that time as a TBPM cue might have been ignored during the enactment of TBPM tasks. This is because participants might have focused on the component of the action being performed (e.g., take medication) and any information which is not inherently relevant to the task (e.g., at 12:00) might not have been integrated into the action (of taking medication). This has support in literature which suggest that enactment enhances episodic integration of an action and other information relevant to that action (e.g. Pereira et al., 2012; Kormi-Nouri, 1995; Mangels & Heinberg, 2006) while weakening the integration of actions and cues external to the action.

Future studies may consider the use of an imagery strategy where intentions are visualised vividly. This will help determine if vivid visualization will benefit TBPM tasks. Although there is evidence suggesting that individuals with TBI present with deficits in the capacity to engage in imagery when assessed using phenomenological paradigms requiring vivid description of a series of hypothetical future events (Coste et al., 2015), they did not experience any difficulty engaging in imagery (Coste et al., 2015; Mioni, Bertucci, et al., 2017; Rasmussen & Berntsen, 2014). Mioni et al. (2017) demonstrated that simulating future intentions helps to improve the PM performance of TBI patients as it appears to be effective for TBPM tasks which do not easily lend themselves to visualization since they are cued by time rather than by an event which is a more salient cue (Mioni, Bertucci, et al., 2017).

Thus, the main effect of task confirms the usual finding that performance is better with EBPM tasks than with TBPM tasks. However, this advantage is influenced by the modality employed at encoding (verbal – the norm – versus enactment) such that that it is only observed in EBPM tasks and is reversed in TBPM tasks – for both HC and TBI patients. This shows enactment encoding might play a role in reducing difficulties associated with remembering EBPM. This suggests that it is possible to include enactment in rehabilitation settings to help improve EBPM in the real world setting for clinical patients. For example, in order to remember to take medication in the afternoon, patients could be instructed to enact or mimic taking medication before engaging in an activity that is part of their afternoon activities (e.g., have lunch).

It seems that enacting a future event-based intention allows participants to mentally pre-experience the visuospatial context in which the intention was to be carried out. In turn, entering the environment within which the intention was to be carried out might have caused the mentally pre-experienced visuospatial context to reactivate and act as cues that prompt the intention to be carried out (Leitz et al., 2009). These findings support the constructive episodic simulation hypothesis (Schacter & Addis, 2007). The hypothesis suggests that both past events (information on PM cue and PM tasks) and future thoughts (PM remembrance and execution in the presence or absence of a cue) rely on a common pattern of neural activity in memory (Schacter & Addis, 2007). As a result, when an intention is enacted, the information is represented together with the retrieval cue and the to-be-remembered intention in the same manner as observed in other episodic memory tasks. Indeed, in order to enact a PM task (e.g. buy a pen) together with its retrieval cue (e.g. when shopping), we must successfully draw information from previous experience (knowledge of the structure of the shop and item location) to envision the future (walking in inside shop to pick pen and going to counter to pay for it), so that when we enter the environment (shop) where intention must be completed, the cue (shopping) triggers PM remembering and execution (Leitz et al., 2009). This is consistent with the multiprocess model formulated by (McDaniel & Einstein, 2000) which suggests that enacting EBPM facilitates spontaneous retrieval processes thereby removing the need to monitor the environment for a cue such that it frees up cognitive resources for other tasks. Thus for participants in the current study, enactment created familiarity with EBPM cues, which might have triggered recollection of EBPM tasks.

The interaction between encoding and task is independent of groups (TBI, HC). This suggests that enactment enhances PM remembering irrespective of an individual's clinical presentation such that it strengthens the link between an action (post letter) and retrieval cue (post office) thereby allowing reliance on potentially spontaneous retrieval process and removing or reducing the need for attentional processing (Einstein & McDaniel, 2005, 2010).

2.9.3. Role of EF, Neuropsychological Function and Injury-Related characteristics in PM Performance

The second goal of our research was to determine whether there was a relationship between EF and PM performance. If so, is EF more strongly correlated with TBPM compared to EBPM? Findings were however mixed. Initial analysis on group performance revealed the TBI participants present with difficulties of working memory and attention as measured by the digit span. However, this was not related to performance on the PM tasks. The TMT test as part of the measures of EF also showed the planning aspect of EF is impaired in TBI compared to the HC group but not related to PM performance. Only the WCST 'failure to maintain set' as an EF measure correlated strongly with performance on EBPM for the TBI participants. Failure to maintain set has been identified as the inability to continue with a strategy that has been successful due to stimulus interference (Strauss et al., 2006). It reflects an inability to sustain attention and might be related to the susceptibility of TBI patients to distraction and interference, or to problems integrating temporally separated events (Fuster, 2007; Knight & Grabowecky, 2000; Lezak, 1995). The positive correlation of failure to maintain set with EBPM in the TBI groups indicates that despite TBI patients' difficulty in keeping track of previously performed EBPM tasks, they continued to improve EBPM performance. This could be due to the benefit of enactment that the participant engaged in while performing PM tasks.

Although failure to maintain set was the only subcategory of EF test that was associated with performance in the TBI participants, it reflects prior literature showing that aspects of EF difficulties are often related to reduced PM (Carlesimo et al., 2014; Fleming et al., 2008; Groot et al., 2002; Kinch & McDonald, 2001; Maujean et al., 2003; Mioni et al., 2012). EF processes are reported to place high demands on the executive abilities of TBI patients (Maujean et al., 2003; Strauss, Sherman, & Spreen, 2006) thereby reducing the level of sustained attention. This might explain why these aspects of EF were found to correlate with PM performance. It is possible that EF measures such as WCST, which has various subcategories, measure different cognitive processes; for example, failure to maintain set, which is a subcategory of WCST performance, appears to be a measure of sustained attention. If failure to maintain set reflects difficulties with sustained attention, then future research should identify and include other tests that have been shown to measure sustained attention to investigate whether TBI patients' PM performance, particularly on TBPM tasks, reflects difficulties in this aspect of attention. In addition, the current findings did not support previous research that EF is highly associated with performance on TBPM compared to EBPM (Fleming et al., 2008; Kinch & McDonald, 2001) and this might be due to the limited power of the current study and/or the selection of the EF tasks employed in this study. We further examined the role of sustained attention in PM performance in Study 2 of this dissertation in Chapter 3.

Other findings indicated that better premorbid ability (NART) was associated with better TBPM remembering in the HC. This suggests that the HC groups who are well able to verbally encode time-based tasks tend to perform well on TBPM. Higher educational level was also associated with better TBPM remembering in the HC participants. Previous research has found a significant positive relationship between education and better performance on NART (Crawford, Stewart, Garthwaite, Parker, & Besson, 1988). It is therefore not surprising that both are associated with better TBPM performance in HC. Indeed, within the HC participants, the ability to strategically monitor and self-initiate TBPM retrieval is associated with higher education and better verbal ability. The finding within the HC group is particularly consistent with the findings of Groot et al. (2002) and Mathias and Mansfield (2005) who observed that only verbal memory was related to PM in their HC group. Unlike the current study and that of Mathias and Mansfield (2005), Groot et al. (2002) combined the scores of EBPM and TBPM to provide an overall measure of PM performance.

In contrast to Fleming et al. (2008) and Groot et al. (2002), who reported PM performance to be related to EF, these findings were not wholly confirmed in either group, especially HC, in the current study. In addition, when the size of the correlations were considered in relation to their statistical significance, PM performance was marginally-to-moderately related to EF. This provides support for the work of Carlesimo et al. (2014) and van den Berg et al. (2012) who found moderate relationships between EF and PM performance. However, it contrasts with the findings of Groot et al. (2002) and Fleming et al. (2008) who reported a stronger relationship between EF and PM performance. Groot al.'s decision to combine EBPM and TBPM scores might account for the difference in findings. Similarly, both Groot et al. and Fleming et al. used a conventional laboratory-based measure (Cambridge Prospective Memory Test) which might not reflect everyday PM performance, at least in comparison to the Virtual Week. Moreover, most of our participants performed close to the mean in our PM measure thereby reducing variability in scores with its subsequent effect on the correlational analysis.

2.9.4. QoL and PM performance

The third goal was to determine whether there is a positive relationship between PM performance, QoL and social perception as measured by QOLIBRI and TASIT. Our results revealed that emotional evaluation as measured by TASIT was associated with better TBPM performance in both the TBI and HC groups. However, it is the negative aspect of the emotion evaluation that is highly associated with better TBPM performance. The association of emotion to heightened PM performance is well documented in ageing literature (e.g., Altgassen et al., 2010; Rendell et al., 2011). Rendell et al. reported better PM performance for positive compared to neutral cues for both younger and older adults. Similarly, Altgassen et al. found a significantly better PM performance for emotional compared to neutral PM targets. The benefit of emotional based PM cues was reliable for older but not younger adults. This suggested that emotionally related cues might play a significant role in PM performance compared to neutrally related cues (May, Owens, & Einstein, 2012). May et al. (2012), in a study to investigate the impact of emotion on PM and monitoring, found that both negative and positive emotional cues enhances PM remembering compared to neutral emotion. Theoretically, it seems plausible that emotional PM cues could benefit PM performance either by increasing the saliency of a cue or boosting monitoring effort or by enhancing spontaneous-retrieval (May et al., 2012).

Despite the possible benefits of emotional evaluation on PM performance, our research question was not answered. This was because no significant correlation was identified between PM performance and overall QoL. This is rather surprising since TBI is known to negatively impact on QoL through reduced independence and increased need for supervision (Turner et al., 2009; Turner, Fleming, Ownsworth, & Cornwell, 2011). This is in line with previous literature suggesting a lack of significant relationship between subjective ratings and actual PM performance (e.g., Pirogovsky et al., 2012; Woods et al., 2007; Zeintl et al., 2006). It is possible, that the TBI patients might have overestimated or underestimated difficulties encountered in daily life. Future studies could include valid, reliable, and evidence-based measures in QoL evaluation. This may help to present a clearer picture of QoL of TBI patients

2.9.5. Conclusion

In conclusion, this study is one of several to investigate whether encoding improves PM performance in TBI patients compared to HC. Results showed that while EBPM benefits from enactment, TBPM does not. These findings are important in highlighting that improving PM performance in TBI patients could be a complex process. Future studies could explore the encoding and execution phase of PM tasks and determine whether vivid imagery could be helpful in further enhancing PM performance.

Given that sustained attention was implicated in PM accuracy, future studies should also explore the impact of sustained attention and possibly task switching on PM performance in TBI patients. The aim would be to develop efficient cognitive strategies to enhance PM performance. QoL is also important to assessing difficulties associated PM performance. Including evidence based measures in addition to the evaluation of perceived QoL could help determine actual QoL and its relationship with better PM performance.

Overall, there is the potential to use a larger sample size provided there that there is easy access to patient data. However, the current study is one of only a few studies aimed at developing effective interventions designed to attenuate the difficulties associated with consistent failures of PM among TBI patients and thereby improve their ability to manage the complexities of daily life.

CHAPTER THREE

STUDY 2: Benefit of visual imagery perspectives on prospective memory performance in older adults

Abstract

This study explored the potentially beneficial effects of imagery on prospective memory performance in older adults. The first aim was to explore possible differences in performance on event-based prospective memory and time-based prospective memory in two groups of older adults: younger-old (59-69 years) and older-old adults (70-79 years) using a relatively naturalistic task environment – the Virtual Week. In addition, we explored the benefits of employing either a Field imagery perspective (imagining an event as if seeing it through one's own eyes) or an Observer imagery perspective (imagining seeing oneself engaging in that event) for prospective memory performance in both young-old and older-old adults. Prospective memory performance was assessed using two different criteria i.e., a strict criterion (prospective memory accuracy) and a lenient criterion (little-late, accuracy, little-early). Using the *strict criterion* we observed better performance for event-based prospective memory compared to time-based prospective memory tasks. Additionally, adopting an Observer imagery perspective enhanced prospective memory performance compared to both Field imagery and Verbal encoding for all participants. When the *lenient criterion* was employed, there was an effect of age on time-based prospective memory tasks and Observer imagery enhanced time-based prospective memory performance for all participants. The findings further revealed that short-term visuospatial working memory and reaction time plays a role in prospective memory performance for older-old adults but not younger-old adults. Moreover, here was some indication that sustained attention

enhances event-based prospective performance in younger-old adults. The findings are considered in relation to those reported in previous relevant studies. Overall, the results indicate that the use of Observer imagery might be a powerful strategy to enhance PM performance in both young-old and older-old adults.

3.1. Introduction

In Study 1 (conducted in Ghana) we found that remembering future intentions (PM) was enhanced after enacting (motoric encoding) the intention compared to saying it aloud (verbal encoding) for both TBI patients and HC. However, enactment was beneficial only when the to-be-performed action should be performed when a particular event occurs (EBPM task). In contrast, enactment did not improve PM for time-based tasks. Importantly, the data suggested that TBI patients' difficulty in sustaining attention was associated with their better performance on event-based prospective remembering (EBPM tasks). We speculated that the latter relationship might be due to the benefit of enactment that the TBI participants engaged in while performing EBPM tasks. A positive association was also observed between sustained attention and TBPM tasks although it did not reach significance suggesting that attention might play a role in TBPM performance. Based on the above findings, we wanted to take a further look at the impact of sustained attention, in relation to executive processes, on PM functioning in the TBI population in the UK. However, due to difficulties in recruiting TBI patients in England, we had to look for a different population who might present with a pattern of EF and PM impairment that shares some similarities with a TBI population.

In Study 1 it was noted that TBI often results in damage to the PFC (Levine, Katz, et al., 2002), a region that is associated with executive functions (EF;Stuss & Alexander, 2000). The completion of a PM task is thought to involve a number of processes such as planning and encoding of intention and action, retaining an intention, interrupting an ongoing activity, initiation and execution of intended action, strategy use and evaluation of outcome (Ellis, 1996; Shum et al., 2002). Several of these processes are described as EFs e.g., planning, task-switching, and strategy selection and employment. Research has also shown that the brain shrinks with age (Cabeza &

Dennis, 2012; Cabeza, Nyberg, & Park, 2016) and that the PFC is the most affected compared to other cortical regions of the brain (Raz, Ghisletta, Rodrigue, Kennedy, & Lindenberger, 2010; Raz, Gunning-Dixon, Head, Dupuis, & Acker, 1998; Raz et al., 1997; Raz & Rodrigue, 2006; Raz, Rodrigue, & Haacke, 2007). Cross-sectional and longitudinal studies, moreover, have revealed that the PFC decline is rapid in old age (Raz & Rodrigue, 2006; Raz et al., 2007). As discussed in Chapter 1, age-related executive control deficits are thought to result from PFC dysfunction (Cabeza & Dennis, 2012; Cabeza et al., 2016), similar to that observed in TBI (Azouvi, 2000; Levine, Katz, et al., 2002).

Significant correlations have been reported between EF and PFC deficit in older adults (Cabeza et al., 2016; Cardenas et al., 2011; Gong et al., 2005; Gunning-Dixon & Raz, 2003; Head, Kennedy, Rodrigue, & Raz, 2009; Head, Raz, Gunning-Dixon, Williamson, & Acker, 2002; Kennedy & Raz, 2009; Kennedy, Rodrigue, Head, Gunning-Dixon, & Raz, 2009; Kievit et al., 2014; Paul et al., 2009; Raz et al., 1998; Zimmerman et al., 2008). For instance, in a study using a large group of older adults (50-81 years), Gunning-Dixon and Raz (2003) found that the number of perseveration errors in the WCST was negatively associated with PFC volume. Similarly, Head et al. (2009) observed that PFC volume was a significant mediator of age-related deficits in the WCST and working memory tasks. Likewise, in an analysis of longitudinal changes in cognition, Cardenas et al. (2011) discovered that smaller lateral PFC volume predicted executive function decline. Taken together, the evidence suggests that declining functionality of PFC plays a role in age-related EF deficits (Cabeza & Dennis, 2012; Cabeza et al., 2016; West, 1996). Thus, it was decided to investigate further the moderate positive relationship between sustained attention and TBPM observed in Chapter 2 in younger-old and older-old healthy adults, based on research that indicates that ageing is associated with decrements in attention and also with difficulties in completing TBPM tasks (Maylor, 1996; Maylor et al., 2002). The current study provided an appropriate participant population for exploring further the relationship between sustained attention skills and the successful completion of TBPM tasks.

Ageing is believed to be associated with a decline in cognitive control and attentional resources, thereby affecting PM performance (Kliegel, Ramuschkat, & Martin, 2003; Martin et al., 2003; Maylor et al., 2002; Rose et al., 2010; Salthouse, 1991; Salthouse & Babcock, 1991) and quality of life (Hering, Rendell, Rose, Schnitzspahn, & Kliegel, 2014). Salthouse (1991) reported that cognitive processes, such as attention, speed of information processing, and working memory capacity, reduce with age. Maylor (1996) and Craik and Kerr (1996) are also of the view that age-related changes in attention and EF could have a negative effect on PM tasks due to the need to switch from an ongoing task to perform the PM task which requires considerable cognitive resources. This was supported by previous research (e.g., Kliegel et al., 2003a; Kliegel et al., 2003b; Martin et al., 2003) which revealed that EF processes are associated with PM task performance. Logie, Maylor, Della Sala, and Smith (2004) also reported that increased task demand significantly affects PM performance.

As noted in Chapter 1, the majority of research on ageing and remembering has focused on retrospective memory (RM; memory for past events; Light, 1991) and has revealed a consistent deficit in older adults. Recently, however, the focus of research on memory in ageing has shifted to PM. As one grows older, successful PM is very crucial to sustaining healthy and secure independent life (McDaniel, Einstein, & Rendell, 2008). For instance, for older adults who need to adhere to medication regime in order to relieve age-related chronic disease, PM failures could have important implications.

3.2. Age-Related factors in PM performance

Craik's (1986) functional account of age differences in memory suggests that an interaction between external factors such as environmental cues and cognitive demands (e.g., monitoring) influences memory task performance. Thus, memory tasks that provide little environmental support and rely more on monitoring should be susceptible to age decline and difficult to execute. Therefore, when PM requires more self-initiated processes (monitoring) compared to RM it should be more sensitive to age-related decline. However, extensive research in ageing and PM performance has indicated a more complex picture than at first thought (Henry et al., 2004).

Of the two main types of PM tasks, TBPM is thought to be more difficult because it does not provide an external cue that can act as a direct reminder and is thereby reliant on internal control mechanisms (Henry et al., 2004). Following from the above, it is believed that TBPM performance should be more impaired following ageing (Einstein & McDaniel, 1990; Maylor, 1995; Maylor et al., 2002; Smith et al., 2000). For instance, Einstein and McDaniel (1990) compared remembering to make a phone call when you next see a telephone with remembering to make a telephone call at 1600 hours and in a series of experiments with young and older adults observed a greater age deficit in TBPM compared to EBPM. Similarly, in laboratory studies that investigated both EBPM and TBPM performance, (Einstein et al., 1995), no age-related effect was found in the EBPM task but older participants performed poorer on TBPM tasks, thus supporting Craik's prediction. This finding was confirmed by subsequent studies (Cherry & LeCompte, 1999; Cherry et al., 2001; d'Ydewalle, Bouckaert, &

Brunfaut, 2001; Einstein & McDaniel, 1990; Marsh, Hicks, Cook, & Mayhorn, 2007; Reese & Cherry, 2002). d'Ydewalle et al. (2001), for example, tested 48 younger participants (aged 18-25 yrs) and 48 older participants (aged 60-86 yrs) using an ongoing task arithmetic test which was designed to use more executive resources with increasing complexity of the arithmetic operation. They found that when the complexity of the ongoing task was increased TBPM performance among older adults reduced significantly. Moreover, when the interval between EBPM cues increased, an age-related impairment was observed. The authors suggested that this was due to a general slowing associated with age (Gonen-Yaacovi & Burgess, 2012).

Contrary to Craik's (1986) hypothesis, some studies have reported age-related deficits in EBPM tasks (e.g., Maylor, 1993; Maylor, 1996, 1998; Maylor et al., 2002; Park et al., 1997; Smith & Bayen, 2006; West & Craik, 1999, 2001; Zimmermann & Meier, 2006). This suggests that an age-related decline in PM might not be restricted to TBPM tasks (Gonen-Yaacovi & Burgess, 2012). It is possible that the difference in the reported findings might be due to variations in experiment designs (Gonen-Yaacovi & Burgess, 2012). For example, an analysis of most of the studies that failed to find an age-related deficit revealed that the majority of researchers had reduced the difficulty of the ongoing task for older participants (Kvavilashvili et al., 2009).

Errors of omission and errors of commission have also been observed in the performance of younger and older adults on PM tasks (Marsh et al., 2007; McDaniel, Bugg, Ramuschkat, Kliegel, & Einstein, 2009; Zogg, Woods, Sauceda, Wiebe, & Simoni, 2012). Maylor (1996) suggested that these errors could be due to reduced output monitoring which is believed to deteriorate with age (Cohen & Faulkner, 1989; Koriat et al., 1988; Marsh et al., 2007). In summary, the use of self-initiated processes with reduced processing resources has the potential to affect PM performance in older adults.

Older adults and patients with frontal lobe damage (e.g., many people with traumatic brain injury) are more vulnerable to PM failures due to possible difficulty of using self-initiating processes in prospective remembering (Craik, 1986). Craik and Grady (2002) described this age-related deficit as a loss of "resolving power" due to changes in prefrontal cortical function (Levine, Svoboda, Hay, Winocur, & Moscovitch, 2002, p. 678). According to Glisky (1996), because PM task provides little in the way of environmental support or cue information, older participants must initiate mnemonic activities spontaneously while performing PM tasks. Craik (1986) suggested that the initiation of such processes requires considerable mental resources which would impair older adults' performance on PM tasks.

Theoretically, McDaniel and Einstein (2000) argued that PM tasks can be triggered either spontaneously or by strategic monitoring processes depending on the characteristics of the task. However, age-related PM difficulties are a result of effortful monitoring compared to spontaneous processes (Altgassen et al., 2015). This suggests that that more efficient encoding of intentions might reduce the need for strategic monitoring during the delay period (while performing an ongoing activity), and thus help to improve older adults' PM performance (Altgassen et al., 2015; McDaniel & Einstein, 2000).

Recent studies have reported that within the older adult population, differences in PM performance are still evident (Huppert et al., 2000; Kliegel & Jager, 2006a; Kvavilashvili et al., 2009; Mantyla & Nilsson, 1997; Rendell & Thomson, 1999; Schnitzspahn & Kliegel, 2009; Uttl et al., 2001; Zeintl, Kliegel, & Hofer, 2007). These studies were based on the assumption that older adults (60 years and above) are a heterogeneous group and therefore recommended that older adults should be grouped into different age categories in order to obtain a more accurate interpretation of age-related PM function (Ellis & Kvavilashvili, 2000; Schnitzspahn & Kliegel, 2009). For instance, Kliegel and Jager (2006a) compared the PM performance of four age groups ; a younger age group (22–31 years), a younger-old age group (60–69 years), a middle-old age group (70– 79 years) and an older-old age group (80–91 years). They reported a gradual age-related decline in PM performance in the older adults' age groups. Thus, the younger age group and the young-old age group differed significantly in performance compared to the old-old age group. However, the younger age group, young-old group, and the middle-old group performed similarly on PM tasks (Kliegel & Jager, 2006a). In an extended study, Zeintl et al. (2007) confirmed Kliegel and Jager's (2006a) finding with three EBPM tasks using a narrower age interval (65-80 years). They found a persistent age effect for PM performance in spite of the restricted age intervals, even though they had accounted for individual variations in the speed of processing and working memory (Schnitzspahn & Kliegel, 2009; Zeintl et al., 2007).

Kliegel and Jager (2006a) and Zeintl et al. (2007) in their studies on the age-related decline on PM in older adults used only EBPM tasks. Others (e.g., Kvavilashvili et al., 2009; Rendell & Thomson, 1999; Schnitzspahn & Kliegel, 2009) have included TBPM tasks. Rendell and Thomson (1999), for example, studied three age groups (18-28, 60-69, and 80-92 years). They expected to observe poorer performance on TBPM compared to EBPM tasks but contrary to expectation, they observed a substantial age-related decline in both TBPM and EBPM. Kvavilashvili et al. (2009) also examined EBPM and TBPM performance in older adults and reported significant age effects in the TBPM but not in the EBPM condition. Their analysis of TBPM tasks, however, was based on two scoring criteria, namely a strict criterion (i.e. 15 seconds early/late) and a lenient criterion (i.e. 60 seconds early/late). The aim of the scoring criteria was to determine if participants' PM performance was constrained by a limited evaluation period. When the strict criterion was applied Kvavilashvili et al. (2009) did not observe any significant difference between the younger-old (61– 70 years) and older-old (71–80 years) participants on TBPM performance. In contrast, the younger (18–30 years) participants performed significantly better than the younger-old (61– 70 years) and older-old (71–80 years) participants. Following the lenient criterion, the performance of the younger and younger-old participants was reliably better than the performance of older-old adults (Kvavilashvili et al., 2009). Recently Schnitzspahn and Kliegel (2009) explored an age-related decline in PM performance of older adults with two age groups of older adults (60-75 years vs. 76-90 years). They found a general effect of age on both EBPM and TBPM tasks with older-old adults performing significantly worse than younger-old adults.

In summary, recent studies suggest a consistent decline in both EBPM and TBPM performance using different scoring criteria. In the current study we sought to investigate further age-related deficit in older adults' PM functioning and identify strategies to enhance PM performance in older adults. Specifically, we recruited two age groups of older adults (younger-old adults from 59 to 69 years and older-old adults from 70 to 79 years).

3.3. Strategies to enhance PM performance in older adults

Previous attempts to improve PM in older adults has made use of various strategies including cognitive training (mental exercise; Brom & Kliegel, 2014; Hering, Rendell, et al., 2014), planning (Kliegel, Martin, McDaniel, & Einstein, 2002; Kliegel et al., 2007; Kliegel, Martin, & Moor, 2003), implementation intentions (Bugg, Scullin, & McDaniel, 2013; Burkard et al., 2014a; Burkard et al., 2014; Burkard, Rochat, Van der Linden, Gold, & Van der Linden, 2014c; Chasteen et al., 2001; Liu & Park, 2004; McFarland & Glisky, 2009; Schnitzspahn & Kliegel, 2009) and imagery or future event simulation (Addis, Wong, & Schacter, 2008; Altgassen et al., 2015; Lyons, Henry, Rendell, Corballis, & Suddendorf, 2014; Terrett et al., 2016).

The training strategies have involved the use of mnemonics, rehearsal, method of loci, and so on (Hering, Rendell, et al., 2014). Previous research on training strategies has shown promise in maintaining cognitive health and improving PM performance. Nevertheless, it has been suggested that the benefit derived from the training techniques are mostly limited to the training task itself (Brom & Kliegel, 2014; Hering, Rendell, et al., 2014) and the outcome of most of the training strategies are not known in real life environment (Hering, Rendell, et al., 2014). For instance, McDaniel and Bugg (2012) stated that asking older adults to utilize memory aids in learning a list of items (e.g., grocery list) might be easy, but not necessary for everyday activity due to the convenience of other compensational strategies or technological devices (e.g.,taking picture of a list with the help of iphone; Hering, Rendell, et al., 2014).

Planning has also been shown to support PM performance (e.g., Kliegel et al., 2007). Kliegel et al. (2007), for example, demonstrated that the use of some planning aids enhances older adults' PM performance similar to younger adults They asked participants to develop a plan with a clearly defined cue (e.g., "I intend to write *Tuesday* on the top right corner of every sheet of paper I receive", p. 1738). They were also to state when they intend to begin work on their PM task (participant generated PM tasks). Kliegel et al. (2007) observed that drawing a successful plan was similar to the structure of implementation intentions, which take the form ''If situation X arises, then I will perform behaviour Y'' (Gollwitzer, 1999, p. 494). An implementation intention specifies when, where, and how an intended intention should be executed. As discussed earlier, an implementation intention is expected to strengthen the link between a cue and PM task such that the presence of the specific cue should automatically elicit remembering and execution of the PM task (Gollwitzer & Sheeran, 2006). Previous research demonstrated that implementation enhances PM performance in older adults in both laboratory (Chasteen et al., 2001; McDaniel, Howard, et al., 2008; McFarland & Glisky, 2011; Pereira et al., 2015) and real-life settings (Burkard et al., 2014a; Liu & Park, 2004). In a meta-analysis, Chen et al. (2015) observed a medium to large effect size on PM performances for older adults (d= 0.68). Notwithstanding the benefit of implementation intention in older adults' PM performance, negative findings have been reported (e.g., Schnitzspahn & Kliegel, 2009) such that participants' EBPM performance declined following the use of an implementation intention. Schnitzspahn and Kliegel (2009) suggested that the formation of implementation intentions might have increased the cognitive load associated with older adults PM performance thereby affecting their PM functioning. Although the authors included imaging in the implementation intention encoding, they concluded their participants might have had difficulty concentrating while forming the implementation intentions together with imaging. Since older adults demonstrated difficulty with inhibition, the extra cognitive load associated with forming implementation intention together with imaging might have affected older-adults' concentration (Schnitzspahn & Kliegel, 2009).

A previous study (e.g., McDaniel & Scullin, 2010) demonstrated that the cognitive demand of the task could affect the role of an implementation intention. For instance, McDaniel and Scullin (2010) reported that implementation intention encoding produced lower levels of PM response on tasks with high-cognitive-demand. This suggests that although implementation intentions might strengthen the link between encoding and retrieval, that encoding does not support a completely spontaneous PM response (McDaniel & Scullin, 2010).

Recent studies using implementation intentions have included an imagery component (Brewer & Marsh, 2010; Kardiasmenos, Clawson, Wilken, & Wallin, 2008; McDaniel, Howard, et al., 2008; McDaniel & Scullin, 2010) to the verbal statement proposed by Gollwitzer (1999). For example, research demonstrated that older adults who formed an implementation intention (e.g., 'I will write the word Friday when I see the word birthday') and imagine themselves carrying out PM tasks, outperformed participants who used rote rehearsal (Chasteen et al., 2001). In a review, however, Wilson and Kapur (2008) revealed that using visual imagery without implementation intention is clearly superior to other encoding strategies such as rote rehearsal. This suggests that mentally visualizing to be performed future intentions might help performance of that intention (Burgess et al., 2005), although older adults might have more difficulties imagining tasks (Addis et al., 2008; Levine, Svoboda, et al., 2002; Rendell et al., 2012).

According to Addis et al. (2008) implementation intentions are similar to the mental simulation involved in imagery since they involve associating a PM task with a specific future cue. The only difference is the verbal element involved in implementation intention (e.g. 'I will do Y when I see X'). Thus, for older adults, visualizing the specific intention that will later be performed might serve as an easy-to-implement strategy that enhances PM function in everyday life (Altgassen et al., 2015). In line with the revelation by Wilson and Kapur (2008), we investigated whether the use of different types of imagery encoding enhances PM performance in older adults compared to verbal encoding (rote rehearsal).

3.4. Imagery and PM Performance

As discussed in Chapter 1, imagery has been defined as the episodic mental projection of the self into the future in order to 'pre-experience' an action in the future (Paraskevaides et al., 2010). According to Atance and O'Neill (2001), imagery involves mentally visualizing a personal experience which is directed towards performing a future action.

Previous research investigated the use of imagery in reducing the failures of PM following alcohol use in younger adults (Leitz et al., 2009; Paraskevaides et al., 2010). Leitz et al. (2009) used the VW task (Rendell & Craik, 2000) to examine the effect of imagery in PM performance following alcohol consumption. They observed that the alcohol group did not benefit from imagery. However, imagery significantly improved EBPM performance in the control group compared to TBPM. Paraskevaides et al. (2010) in an attempt to replicate the findings of Leitz et al. (2009) found that imagery improved EBPM but not TBPM in the alcohol group but not the control. The authors suggested that a ceiling effect in the control group might have accounted for lack of imagery benefits for controls (Paraskevaides et al., 2010). They also suggested that the use of mental simulation might have been easier and specific for EBPM tasks compared to TBPM tasks and thus enhanced EBPM performance (Paraskevaides et al., 2010).

Other studies have shown that when participants engage in imagery their PM performance was enhanced in older and young adults respectively (e.g., Altgassen et al., 2015; Neroni, Gamboz, & Brandimonte, 2014). For example, in a study to determine whether the use of imagery improves PM performance equivalently at different stages of the adult lifespan, Altgassen et al. (2015) asked older and younger participants to complete the Dresden Breakfast Task. While generating the breakfast plan, half of the participants were asked to visualize completing the task in the future (imagery condition), while the other participants were asked to generate a breakfast plan without the use of imagery (control condition). Altgassen et al. (2015) observed that older and younger adults who engaged in imagery while generating the breakfast plan benefited equally from imagery instructions, as reflected in a higher proportion of PM responses and more accurate plan execution.

Previous research that compared older and younger adults following imagery instructions found consistently better performance for younger adults compared to older adults (Addis et al., 2008; Lyons et al., 2014; Terrett et al., 2016). For instance, Terrett et al. (2016) while assessing the role of imagery in improving PM performance discovered that imagery did not account for unique variance in PM within the older adult group although the benefit was observed in the younger adult group. The authors concluded that age-related reduction in attentional resources or the use of compensatory mechanism might have played a role in this pattern of results.

To date, no published study has identified the benefit of the different types of visual imagery on PM remembering (e.g., Field imagery and Observer imagery) especially in older adults. Field imagery involves imagining events “from one’s own perspective or experiencing situations through one’s own eyes”(Holmes, Coughtrey, & Connor, 2008, p. 875). That is, when forming visual imagery, you do not “see” yourself in the image but rather you “see” the environment through your own eyes (Libby, Shaeffer, Eibach, & Slemmer, 2007). Observer imagery involves seeing oneself engaging in an activity, experiencing the event as if you were observing yourself engaging in that event (Holmes et al., 2008; McIsaac & Eich, 2002; Nigro & Neisser, 1983). That is when you form the visual image, you see your image carrying out the intended action, as well as your surroundings (Libby et al., 2007). Research on different types of visual imagery has been conducted in social and behavioural psychology (e.g. Holmes et al., 2008; Libby et al., 2007). Another name for field imagery is the first-person perspective while observer imagery is also known as the third-person perspective (Holmes et al., 2008; McIsaac & Eich, 2004). Libby et al. (2007) observed that when participants were instructed to visualise themselves voting in a 2004 election in the United States of America from either first-person or third-person person perspective, the use of 3rd person perspective encouraged the participants to develop a stronger pro-voting mindset which was consistent with imagined behaviour. Libby et al. observed that participants who used the observer imagery perspective were significantly more likely to report that they had voted in the election. In contrast, Holmes et al. (2008) found that first-person perspective imagery benefits positive mood compared to the third-person perspective and verbal description of mood. The question then is whether both or one of the perspectives will positively affect PM performance, especially in older adults? From Libby et al.'s (2007) findings, we could expect that an observer imagery perspective would be more beneficial for PM performance, given that an intention to vote during the following day is a PM task. Moreover, Ellis et al. (2014) reported that an observer imagery perspective benefitted young adults' prospective memory performance in an N-2 back laboratory task while performance after a Field imagery perspective was no different from the (PM task only) Control group. This study sought to follow-up on this finding and to explore the benefits of Field and Observer imagery perspectives in a VW task for older adults.

In line with prior evidence that imagery enhances PM performance, Leitz et al. (2009) found a significant benefit of imagery for EBPM compared to TBPM in younger adults. This might be due to the fact that TBPM requires self-initiated time monitoring, while EBPM relies on external cues that might prompt retrieval of the intended action during the delayed performance interval (Einstein & McDaniel, 1996; Mioni & Stablum, 2013). As a result, imagery might have easily facilitated the retrieval of EBPM tasks compared to TBPM task (Paraskevaides et al., 2010). Surprisingly, however, in a study to determine if imagery improves PM, Altgassen et al. (2015) did not find any interaction between imagery and PM tasks (event-based vs. time-based task). It was possible that the Dresden Breakfast Task (Hering, Cortez, et al., 2014) was not engaging enough since participants had to prepare actual breakfast, and the habitual nature of preparing breakfast in real life might make participants make less use of the clock and switch between tasks spontaneously (Altgassen et al., 2015). To this end, we used Virtual Week (VW; Rendell & Craik, 2000), which is a computer-based measure of PM presented in a game-type format that simulates everyday activities. The VW task can and does assess performance on a variety of PM tasks. It is very engaging and sensitive to the effects of normal and abnormal ageing (Rendell & Craik, 2000; Rendell et al., 2011; Thompson et al., 2010).

Based on the findings that imagery potentially enhances PM performance, the purpose of the present study was to determine whether different types of imagery perspective can attenuate age-related PM deficits. The second aim was to investigate which type of imagery perspective could potentially enhance either or both EBPM and TBPM using the VW task.

3.5. Role of EF Measures in the PM Performance of Older Adults

As stated earlier, PM performance declines with old age due to possible EF decay. It is possible that EF deficits are associated with PM difficulties in older adults since they are thought to be important for "remembering to remember", including sustained attention to monitor the environment for cues or monitor the time, and interrupting ongoing activity to in order to perform a delayed intention (Grilli & McFarland, 2011, p. 849). Earlier evidence to support the relationship between EF and PM comes from the work of McDaniel et al. (1999) which showed that poor performance on EF was associated with worse performance on PM in older adults. Martin et al. (2003) also demonstrated that EF was significantly correlated with both EBPM and TBPM performance in older adults. EF task shifting is also associated with a decline in PM performance due to ageing (Gonneaud et al., 2011; Rose et al., 2010; Salthouse, Berish, & Siedlecki, 2004; Schnitzspahn et al., 2013). For instance, Schnitzspahn et al. (2013) in an effort to separate the role of different EFs on age-related PM performance, compared 175 young and 110 older adults on a battery of different PM tasks and cognitive tests measuring speed, inhibition, set shifting, working memory, and updating. Schnitzspahn et al. discovered that both shifting and inhibition were unique predictors of PM performance. Similarly, Salthouse et al. (2004) assessed EF as well as other cognitive abilities such as speed, memory, and fluid intelligence in 330 participants between 18 and 89 years of age. Salthouse et al. observed that EF was a significant mediator of age-related effects on PM performance, with a significant relationship between PM and EF (r =.74).

Further, sustained attention has been identified to play an important role in maintaining the conscious awareness of the PM intention to be performed (Brandimonte, Ferrante, Feresin, & Delbello, 2001; Graf & Uttl, 2001; Rose et al., 2010). Rose et al. (2010) in a study to identify the role of sustained attention (measured by a vigilance task) in PM performance (using the Virtual Week board game) discovered that sustained attention failed to predict irregular PM performance with either focal or non-focal cues (Rose et al., 2010). Rose et al. concluded that participants might not have sustained attention while performing the PM task due to the demanding nature of the tasks.

It has also been suggested that short-term visuospatial working memory (SVWM) might be a key contributor to PM performance in older adults due to its role in several phases of PM (Rose et al., 2010) and possibly imagery processes (Altgassen et al., 2015; Paraskevaides et al., 2010). SVWM has been defined as the capacity to store and manipulate visual and spatial information over a brief period of time (Baddeley & Hitch, 1974). For instance, the planning of an intended action, imagining the intended action, maintain the intention while shifting attention between the simultaneous engagements of other ongoing tasks might involve active SVWM (Kliegel et al., 2002; McDaniel & Einstein, 2007; Rose et al., 2010; Smith, 2003; Zeintl et al., 2007). Previous research indicated that age declines with SVWM ability (Bopp & Verhaeghen, 2005).

Following from the above, we sought to investigate whether SVWM and EF (shifting and attention) would be significantly associated with performance on both EBPM and TBPM for the two groups of older adults. Moreover, since TBPM tasks usually place greater demand on self-imitated monitoring (Einstein et al., 1995), we expect a stronger relationship between WM, EF and TBPM compared to EBPM in the current study.

3.6. Aim of Study

Following the review of literature, the aim of the current study was;

1. To assess whether there is a difference in PM (EBPM vs. TBPM) performance between two groups of older adults.
2. To investigate whether field and observer imagery perspective at encoding enhances TBPM and/ or EBPM performance in two groups of older adults compared to verbal encoding.
3. Examine the role of SVWM, task shifting and sustained attention in PM performance for the two groups of older adults.

Specific questions the current study addressed were as follows:

1. Is there a difference in PM performance between older-old and younger-old adults? In addition, is the difference more evident on TBPM compared to EBPM?
2. Does field and observer imagery enhance PM performance compared to verbal encoding? If yes which aspect of PM (event vs. time)?
5. What is the role of SVWM, task shifting and sustained attention in PM (EBPM vs. TBPM) performance for both older-old and younger-old adults respectively?

3.7. Hypotheses

The following hypotheses were tested based on the aims of the study.

On the basis of previous research, we investigated the following hypotheses;

1. There will be a significant difference in performance between older-old adults and younger-old adults on both EBPM and TBPM tasks (cf. Schnitzspahn & Kliegel, 2009).

2. Imagery at encoding will enhance EBPM and TBPM performance in older-old and younger-old adults compared to verbal encoding (cf. Libby et al., 2007).
3. There will be a stronger relationship between sustained attention, SVWM, and TBPM compared to EBPM (cf. Martin et al., 2003; Rose et al., 2010).

3.8. Method

3.8.1. Participants

Our previous research on the effect of enactment vs. verbal encoding on PM performance, using ANOVA, repeated measure within-between interaction, we had an effect size of 0.37 for encoding*PM task interaction, $F(1,58) = 34.320$, $p < .001$. From Cohen's (1992) effect size classification, the above could be considered large effect size for ANOVA test. In order to achieve an 80% chance of finding an effect with a similar study using two groups of older adults, but different encoding strategies (i.e. field and observer imagery) including verbal encoding, we assumed a small effect size. A sample size estimation using G-Power (Faul, Erdfelder, Buchner, & Lang,, 2013), a priori power analysis was conducted using ANOVA test, repeated measures, within-between group interaction. With an effect size of 0.5, an alpha level of .05, and power established at .80, a minimum sample size of 30 per condition was necessary to find a statistically significant effect and .80 power in the model. As a result, it was determined that a sample size of 60 (30 younger-old; 30 older-old) was appropriate for this study.

Older adults, who were native English speakers, were recruited through the Older Adult panel in the Department of Psychology of the University of Reading. Participants were required to be able to read on a computer screen (with glasses or contact lenses, if necessary) in order to participate in the study. To ensure the understanding of basic instructions, a minimum of 8 years of education was also required. based on information from the Older Adult Panel, None of the participants presented with a current history of drug or alcohol abuse or history of psychiatric or neurological disorder. A token gift of £10 was provided for their participation in the study.

The sample consisted of 60 participants, 30 younger-old-adults (M = 65.93 years, SD = 3.36, range 59–69) and 30 older-adults (M = 74.5 years, SD = 2.78, range 70-79). There was no gender difference between both samples (13 men and 17 women in the younger and 13 men and 17 women in the older group respectively), $\chi 2(1, N = 60) = 1.067$, $p = .30$). On average, older-old-adults had 15.16 (SD = 2.39) years of education and this is not statistically different from the younger-old-adults (M =15.20, SD = 1.71). Demographic information is summarised in Table 3.1. None of the participants had any neuropsychiatric disorder or history of substance abuse. All participants were mentally and physically able to understand and complete the tests. Data collection took place in the testing room in the Department of Psychology at the University of Reading.

Approval for the conduct of this study was obtained from the School of Psychology and Clinical Language Sciences' Ethics Committee (2016-06-JE). As discussed in Chapter 2, a similar ethical procedure was adopted for this study (Appendix 1.2).

3.8.2. Materials and Procedure

3.8.2.1. Cognitive Tests

The two groups of older-old and younger-old were compared on the cognitive functioning test (MOCA; Nasreddine et al., 2005). Unless otherwise stated, an independent samples *t*-test was used to examine group differences. Results are displayed in Table 3.1.

MOCA (Nasreddine et al., 2005)

The MOCA was developed as a rapid screening instrument for mild cognitive impairment. It assesses cognitive domains such as orientation, memory, visuo-constructional skills, attention and concentration, conceptual thinking, calculations, language, and EF skills. A score of 26 or above is considered to be in the normal range (Nasreddine et al., 2005). The MOCA was used to identify any difference between the groups that might influence PM performance in the current study.

Table 3.1

Demographic Characteristics of Older-Old and Younger-Old Participants

Variable	Older-Old n= 30 M(SD)	Younger-Old n=30 M(SD)	*t*	*p*	*D*
Age	74.57(2.67)	66.33(3.55)	10.547	<.001	2.78
Years of Education	15.17(2.39)	15.2(1.71)	.062	.95	.02
MOCA	27.43(1.59)	27.73(1.44)	.767	.45	.20

Note. **p*<.01, MOCA= Montreal Cognitive Assessment

As Table 3.1 illustrates the two groups did not significantly differ in their mean length of full-time education, t(58) = 0.62, p = .95, d = .02 or their cognitive functioning as measured by the MOCA, t(58) = 0.767, p = .45, d = .20.

3.8.2.2. Experimental Measures

After the administration of the cognitive tests, participants were administered the experimental tasks. These tasks included PM, SVWM, and EF tasks**.** The experiment was conducted across 2 sessions with variable timeframes depending on participants' speed on the tests. These tasks included the VW (PM tasks; Rendell & Craik, 2000), and tests of EF: Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) and Plus-Minus Task (Miyake et al., 2000). We also assessed SVWM using the Corsi Block-Tapping test (Kessels, Van Zandvoort, Postma, Kappelle, & De Haan, 2000) to determine if visual attention control might also play a role in PM performance (cf. Rose et al., 2010). Since participants used different types of imagery techniques while encoding PM tasks, it was important to explore the role of visual attention control in relation to PM Performance.

3.8.2.3. Test Administration

Participants were invited to take part in the study and tested individually in a testing room in the Department of Psychology at the University of Reading. After providing an informed consent, participants read an explanatory note describing the procedure for the research. In the first individual testing session, demographic information (e.g., age, sex, years of education) was collected. MOCA and EF tests were administered in Session one (approximately 30 min). The VW task was administered in Session two (approximately 2 hrs). The PM task procedure was explained to the participants before they started the session. The PM tasks were presented on a 15-inch laptop computer screen. In the imagery at encoding task, participants were first instructed to engage in imagery within the practice session of the VW (e.g., TBPM: visualize picking the phone to call Jane at 9 pm; EBPM: vividly imagine picking up dry cleaning on the way back home from shopping). Pre-study practice trials were used to ensure that the participant understood the instructions and how to engage in self-imagination. Following from Altgassen et al.'s (2015) imagery process, participants were asked to visualise in detail performing PM tasks in the presence of a cue or time. They were then asked to apply this encoding strategy to performing the main VW PM tasks on the computer. The instruction for imagery as provided by (Libby et al., 2007, p. 200) was as follows:

Field Imagery;

"*You should picture doing the action from a first-person visual perspective. With the first-person visual perspective, you see the event from the visual perspective you would* *have if the event were actually taking place. That is, you are looking out at your surroundings through your own eyes".*

Observer imagery:

"You should picture doing the action from a third-person visual perspective. With the third-person visual perspective, you see the event from a visual perspective an observer would have if the event were actually taking place. That is, you ".

Further details were provided in situations where participants were unable to clearly understand the instructions. In line with the literature on the use of imagery (D'Argembeau & Van der Linden, 2004, 2006; Szpunar, 2010; Szpunar & McDermott, 2008; Szpunar & Tulving, 2011), participants were encouraged to "close their eyes and to imagine as many sensory details (e.g., sights, sounds) as possible to ensure development of a vivid personal experience of the tasks" (Altgassen et al., 2017, p. 543). On each day at the end of the VW task, participants asked to rate how vivid the image was on a five-point Likert scale.

3.8.2.4. PM Task (VW)

Participants performed the PM task in the second Session. The PM task was measured using the VW Task (Rendell & Craik, 2000). Details of the VW tasks are provided in Study 1 (Appendix 2.1). In the current experiment, participants were required to do 3 extra tasks on each day. On two days (Monday, Thursday) they were instructed to read tasks to themselves (rote rehearsal, e.g., Pay a fine when you go to the library**).**

An instruction for a verbal task was as follows (e.g., a TBPM task was displayed on computer);

"read the task silently (e.g., phone the plumber at 5:00pm), look away from the computer and say aloud what is written on the card".

On the other 2 days (Tuesday, Friday), they read the tasks silently after which they imagined themselves performing the task from a Field perspective (e.g., phone plumber at 5:00 pm). On the final two days (Wednesday, Saturday) they read tasks silently and imagined themselves performing the task from an Observer perspective (e.g., post a letter when you pass by the post office). Participants were closely observed throughout the task to ensure that they follow the appropriate encoding procedure when encoding. One potential limitation of the imagery techniques was the risk of contamination when alternating between field and observer imagery. This is because there was no objective way of measuring if participants stuck to a particular imagery technique during encoding. Thus, although participants were given enough time and encouraged to systematically perform a particular imagery technique (field vs. observer), when imagining for instance, from field perspective, they may switch to observer perspective unknowingly and vice versa. To minimise the effect of contamination, participants were asked at the beginning of the encoding processes to hold the image in mind and respond yes or no if they have the right imagery perspective in focus, if the response was no, they were encouraged to switch.

All participants had a practice day and if necessary, a second practice day to help them understand what was expected of them. PM tasks were scored based on the proportion of correct, little-late, late, little-early, early, miss responses. Details of the scores are described below.

Correct: a response was deemed correct if it occurred after the dice roll for the move that took the token on or past the target square and before next roll of the dice. **Note:** to be on-time, the token has to be moved at least to the target square. (Time-check tasks are correct at the target time but also within the next 10 seconds after target time)

Little-late: after the correct time criterion and before next event card (event-based) or before one hour has passed (time-based) and before 30 seconds have passed (time-check)

Late: after little late criterion and before end of the virtual day

Little-early and *early* are the converse of late items

Little-Early: before the on-time criterion and after the little late criterion which was previous event card (event-based), one hour (time-based) and 30 seconds (time-check)

Early: was before the little-early criterion and after the start of the virtual day

Miss: indicates the participant did not remember the target item at any time

In the current study, we made use of correct, little early and little late to describe the data. We did not make use of the time-check since time monitoring is beyond the scope of the current study. In the first Session, participants were tested on WM and EF tasks as follows.

3.8.2.5. EF Tests

The following tests were used to assess EF.

SART (Robertson et al., 1997)

The SART is a short (5 min) test, requiring participants to frequently respond to a set of digits (1-9) by pressing the space bar button on a keyboard, but withhold a response for digit number "3". The digits were presented in the centre of a computer screen inked in white colour against a black background. All the digits were displayed 225 times in total (each number appeared 25 times) for 250ms for each digit. After the display of each digit, an "X" within a 29mm ring was displayed for 900ms. The interval between each presentation was 1150ms. The participants were instructed to press the button anytime they saw a number (except 3) before the next number appeared. The importance of speed and accuracy was also emphasized (Manly et al., 1999; Robertson et al., 1997). The participants could still respond even if “x” within a ring was displayed before the appearance of another number. Participants had the opportunity to do a practice trial in order to familiarize themselves with the task of the test. The dependent measure for the SART (Appendix 2.13) was the total error score, made up of, firstly, pressing a key when the response should have been withheld (i.e., when 3 appeared i.e., a commission error), and secondly withholding a response when a key should have been pressed (i.e., omission errors). Another outcome measure was the reaction time to response task (RT). That is how quickly participants pressed a key when a number other than 3 appeared (Manly, Robertson, Galloway, & Hawkins, 1999; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997).

Plus-Minus Task (Miyake et al., 2000)

The plus-minus task (Appendix 2.12), adapted from Jersild (1927) and Spector and Biederman (1976), consisted of three columns of 30 two-digit numbers (10-99 pre-randomized without replacement) on a single sheet of paper. In the first column, participants added 3 to each of the two-digit numbers and wrote down their answers on the sheet of paper by the two-digit numbers, in a space provided for that purpose. In the second column, they subtracted 3 from each of the two-digit numbers and wrote the answers down. Finally, in the 3rd column, they alternated between adding 3 to and subtracting 3 from the two digit numbers (i.e., add 3 to the first number on the list, subtract 3 from the second number on the list and so on). Participants were asked to complete this as quickly and accurately as possible and a stop clock was used to measure the time taken for participants to complete each column. The outcome measures were the time cost of shifting between addition and subtraction list by subtracting the average time of the first two columns from the total time on the third column. The number of errors made on the items in the third column was also recorded.

Corsi Block-Tapping Test

The Corsi block-tapping test (Kessels et al., 2000), a computerized version, is a nonverbal variant of the Digit Span task(Wechsler, 1987). It was used to assess SVWM (Appendix 2.14). It involved repeating a pattern presented on a computer screen by tapping nine identical spatially separated blocks in sequence. The digital version (on the computer) was used for the current study. The block span can be measured either forwards or backwards. We used both forward and backward to assess controlled attention and SVWM such as temporal encoding and reconstruction of ideas (Baddeley, 1992) or ability to imagine future tasks.

In the forward process, the Corsi block-tapping task required participants to observe the sequence of blocks lit up on the computer screen and then repeat the sequence in the same order, by touching the screen of the computer or by the help of a mouse to click on the blocks. The task started with the computer displaying a small number of blocks (starting from 2) and gradually increased in length up to nine blocks (eight trials). The test measured both the number of correct sequences and the longest sequence remembered (Kessels et al., 2000). In the backward task, instead of mimicking the researcher's pattern, the participants repeated the sequence in reverse order. The primary outcome of the Corsi test is the number of items remembered (span length).

3.8.3. Design and Statistical Analysis

The present study follows a 2 ×2 x 3 Mixed ANOVA. That is a between-subject factor of Age (younger old adult; older old adult), and two within-subject factors of PM task type (EBPM; TBPM), and imagery (verbal, field imagery, observer imagery).

Two scoring criteria were used for the PM tasks. The scoring criteria were based on the assumption that older adult participants would be able to remember PM tasks despite being a little-early or little-late in their responses (Ellis, 1996). Naturalistic PM tasks, particularly VW tasks, are limited by an artificial boundary since participants must perform the task immediately in the presence of a cue or at an exact time. However, this does not necessarily reflect a real-life situation, for instance, one might be asked to remember to deposit a cheque at the bank on their way home. They may see the bank but forget that they needed to deposit the cheque. However, if they remember while a few metres away from the bank, they could turn back to deposit the cheque. This suggests that the memory for the event was still present but the performance was affected by duration (Kinch & McDonald, 2001). It was with this principle that two forms of analysis were conducted in the current study in order to capture PM performance. This was in lieu of the fact that older adults' might present with a slow speed of processing while performing PM tasks in real life (Schnitzspahn et al., 2013). Details for scoring the tasks are provided in the description of the VW task. The criteria include;

Strict Criterion (PM; EBPM vs. TBPM): Accurately performing PM task when an event or time is due in response to a cue or time monitoring on the VW game task.

Less Strict Criterion (PM1; EBPM1 vs. TBPM1): The combined score of "correct"+ "little-early" +"little-late" response to PM cue on the VW game task.

Both groups performed the same PM tasks (i.e., observer imagery/field imagery/verbal; event/time) and some cognitive, SVWM and EF tests. Levene's test of homogeneity of variance revealed that the data did not violate the assumption for the use of an ANOVA. An Alpha level of 0.05 was used to determine the level of significance and effect sizes for the ANOVA analysis were measured by partial eta-squared (η_p^2) with small, medium, and large effects defined as .01, .06, and .16, respectively (Cohen, 1988). An independent one-way ANOVA test was used to determine the difference between the younger-old and older-old groups on PM performance and whether the difference was on EBPM or TBPM, or both. Mixed repeated ANOVA was used to examine the effect of imagery (observer, field) vs. verbal encoding on PM performance for both groups of older adults. A post-hoc Bonferroni correction was used to test for simple effects following a significant main effect.

Spearman ranked order correlations were computed separately for the younger old group and older-old group to assess the relationship between PM performance and EF. Separate correlations were performed for the two measures of PM performance: strict and lenient scores on EBPM and on TBPM tasks.

3.9. Results

Data analysis was based on three specific aims of the study; namely, to determine (1) difference in performance between younger-old and older-old on PM performance and whether performance was better for EBPM compared to TBPM, (2) effect of observer imagery and field imagery vs. verbal encoding on PM performance, (3) the relationship between SVWM, EF and PM performance.

3.9.1. PM Performance

A preliminary analysis was conducted to determine the mean difference in performance between two groups of younger-old adults and older-old adults on PM tasks. Descriptive statistics for these two groups are presented in Table 3.2. The one-way ANOVA test analysis was conducted to investigate whether there is a difference between the two groups of younger-old and older-old on PM performance.

Table 3.2

Means, Standard Deviation, and One-Way ANOVA Test Result of the Difference in Performance Between Younger-Old and Older-Old Adults on PM Tasks

	Older-Old n= 30	Younger-Old n=30			
Variable	M(SD)	M(SD)	*F*	*p*	η_p^2
EBPM	5.40(4.12)	6.37(3.95)	.859	.36	.02
TBPM	4.30(2.74)	5.67(2.7)	3.753	.06	.06
EBPM1	6.03(3.59)	7.00(3.56)	1.097	.30	.02
TBPM1	5.23(2.76)	7.24(2.65)	8.234**	.006	.12
Vividness of imagery	4.50(0.51)	4.67(0.48)	1.706	.20	.03

Note. PM = Prospective Memory Accuracy (Strict Criteria), PM1 = Prospective Memory Accuracy + Little-Early + Little-Late (Less Strict)
**p*<.05, ***p*<.01.

Following the strict scoring criterion, no significant difference was observed between younger-old and older-old adults on EBPM, $F(1, 58) = .859$, $p = .36$, $\eta_p^2 = .02$. This indicates that both groups performed similarly on EBPM. Similarly, although younger-old adults performed better than older-old adults on TBPM, the difference was not significant; $F(1, 58) = 3.753$, $p = .06$, $\eta_p^2 = .06$. The lenient scoring criterion, however, revealed better performance for younger-old compared to the older-old group on TBPM $F(1, 58) = 8.234$, $p = .006$, $\eta_p^2 = .12$ with a medium effect size, but not on EBPM, $F(1, 58) = 1.097$, $p =.30$, $\eta_p^2 = .02$. This indicates that the younger-old adults (M = 7.24, SD = 2.65) remembered more TBPM tasks compared to the older-adults (M = 5.23, SD = 2.76) following the lenient criterion. In contrast, both performed similarly on EBPM. Also, the younger-old adult group (M = 4.67, SD = .48) and the older-old adults (M = 4.50, SD = .51) did not differ on their self-reported ratings of levels of vividness in imagery, $F(1, 58) = 1.7.6$, $p =.20$, $\eta_p^2 = .03$.

3.9.2. Effect of Imagery on PM Performance

3.9.2.1. Strict Criterion

The effect of imagery perspective on PM performance was examined in terms of accuracy of response; more specifically the PM task cues that elicited a correct response. The means and standard deviation of accurate responses were calculated. Summary results are displayed in Table 3.3 below.

Table 3.3

Means and Standard Deviations of Correct Responses on the Encoding Conditions on PM Task by the Younger-Old and Older-Old Groups

Task	EBPM			TBPM		
Encode	Verbal Encoding M(SD)	Field-Imagery M(SD)	Observer-imagery M(SD)	Verbal M(SD)	Field-imagery M(SD)	Observer-imagery M(SD)
Group						
Older-old	1.83(1.66)	1.63(1.35)	1.93(1.62)	1.07(1.08)	1.27(1.39)	1.97(1.25)
Younger-old	2.03(1.43)	2.10(1.49)	2.23(1.55)	1.63(1.25)	2.03(1.43)	2.00(1.17)

The above data were subjected to a group (younger-old vs. older-old) x encode (observer imagery vs. field imagery vs. verbal) x task (EBPM vs. TBPM) mixed repeated ANOVA analysis. A summary of the results is presented in Table 3.4.

Table 3.4

Mixed Repeated ANOVA Result on the Effect of Group and Encoding Strategy on PM Tasks Performance

	Sum of Squares	df	Mean Square	*F*	*p*	η_p^2
Task	8.100	1	8.100	4.226*	0.04	0.068
Group	13.61	1	13.611	2.265	0.14	0.038
Task ✻ Group	0.400	1	0.400	0.209	0.65	0.003
Encoding	9.706	2	4.853	5.671**	0.004	0.087
Encoding ✻ Group	3.039	2	1.519	1.776	0.17	0.027
Task ✻ Encoding	3.817	2	1.908	2.177	0.12	0.036
Task ✻ Encoding ✻ Group	1.817	2	0.908	1.036	0.36	0.017

Note. *$p<.05$, **$p<.01$.

Mixed ANOVA analysis shows a significant main effect of encoding, $F(2,58) = 5.671$, $p = .004$, $\eta_p^2 = .09$, with medium effect size and better performance after observer-imagery (M =2.03, SD =1.22) compared to field-imagery (M = 1.76, SD =1.14), and verbal encoding (M = 1.64, SD =1.07). No significant difference was observed between verbal encoding and field imagery (p>.05). The effect of task was also significant, $F(1,58) = 4.226$, $p = .04$, $\eta_p^2 = .07$, with medium effect size and numerically better performance for EBPM (M = 1.96, SD =1.34) compared to TBPM (M = 1.67, SD =.93). The effect of group was not significant, $F(1, 58) = 2.265$, $p = .14$, $\eta_p^2 = .04$. The interaction between encoding*group was also not significant, $F(2,58) = 1.776$, $p = .17$, $\eta_p^2 = .03$. No significant interaction was observed between encoding*task, $F(2,58) = 2.117$, $p = .12$, $\eta_p^2 = .036$. Group*Task interaction effect was also not significant, $F(1,58) = .209$, $p = .649$, $\eta_p^2 = .004$. Similarly, no significant interaction was observed between group*imagery*task, $F(2,58) = 1.036$, $p = .357$, $\eta_p^2 = .02$. Due to lack of a significant interaction effects following strict criterion, we employed the lenient scoring criterion to explore potential benefit of imagery for both groups on PM performance.

3.9.2.2. Lenient Criterion

The effect of imagery techniques on PM performance was examined using lenient scoring criterion, more specifically the PM task cues that elicited less strict accuracy of responses ("correct" plus "little early" plus "little late"). The means and standard deviation of responses were calculated. Summary results are presented in Table 3.5 below.

Table 3.5

Mean of Lenient Scores on PM Tasks by Younger-Old and Older-Old Adults

Task	EBPM			TBPM		
Encode	Verbal M(SD)	Field-Imagery M(SD)	Observer-imagery M(SD)	Verbal M(SD)	Field-imagery M(SD)	Observer-imagery M(SD)
Group						
Older-old	2.03(1.50)	1.80(1.32)	1.93(1.62)	1.47(1.11)	1.47(1.33)	2.30(1.21)
Younger-old	2.40(1.33)	2.20(1.47)	2.40(1.45)	2.10(1.09)	2.43(1.28)	2.71(1.28)

The above data was subjected to a group (younger-old vs. older-old) x encoding (observer vs. field vs. verbal) x task (EBPM vs. TBPM) mixed repeated ANOVA. A summary of results is displayed in Table 3.6.

Table 3.6

Mixed Repeated ANOVA Result on the Effect of Group and Encoding Strategy on PM Tasks

	Sum of Squares	df	Mean Square	*F*	*p*	η_p^2
Task	0.784	1	0.784	0.360	0.55	0.006
Group	22.10	1	22.102	4.882*	0.03	0.078
Task ✻ Group	2.704	1	2.704	1.243	0.27	0.021
Encoding	13.760	2	6.880	7.444**	< .001	0.112
Encoding ✻ Group	2.167	2	1.083	1.172	0.31	0.018
Task ✻ Encoding	6.165	2	3.082	3.184*	0.045	0.052
Task ✻ Encoding ✻ Group	0.558	2	0.279	0.288	0.75	0.005

Note. *p<.05, **p<.01.

Table 3.6 illustrates a significant main effect of encoding, $F(2,58) = 7.444$, p <.001, η_p^2 = .11 with medium effect size and better performance for observer-imagery (M =2.40, SD =1.12) compared to field imagery (M = 1.98, SD =1.06) and verbal encoding (M = 2.00, SD =.97). No significant difference was observed between verbal encoding and field imagery (p>.05). The effect of group was also significant, $F(1, 58) = 4.882$, p =.03, η_p^2 = .08 with medium effect size and numerically worst performance for older-old adults (M = 1.88, SD =.89) compared to younger-old adults (M = 2.37, SD =.85). The effect of task was not significant, $F(1,58) = .360$, p =.55, η_p^2= .01. The interaction encoding*group was also not significant, $F(2,58) = 1.172$, p =.31, η_p^2 = .02. No significant interaction was observed between either group*task: $F(1,58) = 1.243$, p =.27, η_p^2= .02, or between group*encoding*task, $F(2,58) = .288$, p =.75, η_p^2= .005.

However, the encoding*task interaction was significant, $F(2,58) = 3.184$, p =.045, η_p^2 = .05. Post-hoc Bonferroni interaction analyses were conducted to explore further this interaction between imagery and tasks. Means and standard deviations of results are summarised in Table 3.7.

Table 3.7

Mean and Standard Deviation of Encoding and PM Tasks

	EBPM M(SD)	TBPM M(SD)
Verbal	2.22(1.42)	1.78(1.14)
Field	2.00(1.38)	1.95(1.38)
Observer	2.30(1.45)	2.50(1.25)

The interaction is displayed in Figure 6 below.

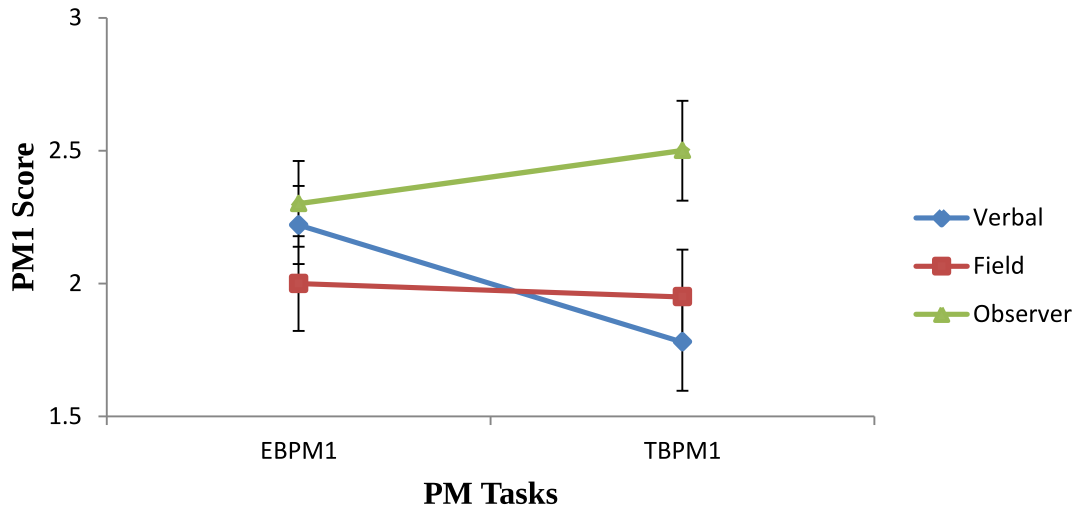

Figure 6. Interaction between Imagery and PM Task

Post-hoc Bonferroni analysis reveals that observer imagery (M =2.50, SD =1.25) is a better enhancer of TBPM compared to field imagery (M = 1.195, SD = 1.38), p =.01 and verbal encoding (M = 1.78, SD = 1.14), p =.001. However, no significant difference was observed between observer imagery, field imagery and verbal encoding on EBPM.

3.9.3. Role of EF in PM Performance

A one-way ANOVA test analysis was conducted to determine if differences exist between the younger-old and older-old group on task shifting, sustained attention and SVWM measures. The performance of the two groups is summarized in Table 3.8 below.

Table 3.8

Summary of the Means and Standard Deviations of Scores on Visual Working Memory, Task Switching and Sustained Attention Task by two Groups of Older Adults

	Older-Old n= 30	Younger-Old n=30			
Variable	M(SD)	M(SD)	*F*	*P*	η_p^2
SVWM Test					
Corsi Span					
Forward	4.76(.63)	4.67(.80)	.270	.61	.01
Backward	4.87(.90)	5.08(.72)	1.061	.31	.02
EF Tests					
Plus-Minus Task					
Plus-minus switch cost	21.92(15.85)	30.62(19.27)	3.647	.06	.06
Plus-minus switch errors	2.67(5.30)	2.70(5.23)	6.015	.98	.00
SART					
Commission error	6.67(4.26)	7.47(4.49)	.502	.48	.01
Omission error	3.87(4.54)	2.20(3.85)	2.350	.13	.04
SART total error	10.53(7.03)	9.67(6.26)	.254	.62	.004
SART reaction time (RT)	.475(.090)	.436(.08)	3.070	.09	.05

Note. p >.05, SART = Sustained Attention to Response Task,

From Table 3.8 above, no significant difference was observed between the two groups on tests of task shifting, sustained attention and SVWM, all *ps* >.05.

3.9.4. Relationship between EF and PM Performance (Strict Criterion)

We ran an exploratory correlation analysis to investigate whether PM performance (EBPM vs. TBPM) was related to measures of EF and SVWM for each group of younger-old and older-old. The role of demographic characteristics in PM performance of the groups was also investigated. The results of the correlations are reported in Table 3.9. Due to a large number of correlations, we used a more conservative alpha of .01.

Table 3.9

Correlations between Demographic Characteristics, EF, and SVWM for EBPM and TBPM Tasks Among Older-Old and Younger-Old Adults

	Older-old-adults n = 30				Younger-old-adults n = 30			
	EBPM	*p*	TBPM	*p*	EBPM	*p*	TBPM	*p*
Demographics								
Age	-0.22	.24	-.170	.37	-.209	.27	-.314	.09
Years of education	.178	.35	-.055	.77	.035	.86	.067	.73
MOCA	.182	.34	.282	.13	.561***	.001	.392	.03
SVWM Test								
Corsi Span								
Forward	.462*	.01	.507***	.004	.173	.36	-.113	.55
Backward	.360	.05	.273	.15	.352	.06	.194	.31
EF Tests								
Plus-Minus Task								
Plus-minus switch cost	-.128	.50	-.041	.83	.106	.58	.237	.21
Plus-minus errors	-.150	.43	.030	.87	.039	.84	.030	.88
SART								
Commission error	.034	.86	.116	.54	-.407	.03	-.277	.14
Omission error	-.109	.57	-.098	.45	-.305	.10	-.215	.25
SART total error	-.201	.29	-.072	.71	-.371	.04	-.326	.08
SART RT	-.257	.17	-.496***	.005	.036	.85	1.017	.93
Vividness rating	-.191	.31	-.244	.19	-.070	.71	-.185	.33

Note. SART- Sustained Attention to Response Task; MOCA = Montreal Cognitive Assessment Test; RT = Reaction Time in Milliseconds.

*p<.01, **P<.005.

Table 3.9 shows that at the .01 level of significance, within the older-old adult group, the Corsi Block-Tapping test (forward) correlates significantly positively with EBPM (r = .462, p =.01) and TBPM (r = .507, p =.004). This indicates that better performance on

Corsi forward span is associated with better performance on EBPM and TBPM for the older-adult group. The SART RT (ms) was also significantly associated with TBPM (*r* = .496, *p* =.005), indicating that faster reaction time is associated with better TBPM performance for older adults. Overall, Corsi forward span and SART RT were strongly associated with TBPM, *p*<.005 in the older adult group.

Within the younger-old-adult group, MOCA correlated strongly with EBPM (r = .561, *p*=.001) and moderately with TBPM (*r* = .392, *p* =.03). This indicates that better cognitive function is associated with better PM performance for younger-old adults. Also, SART commission error (r = -.407, *p* =.03) and SART-total-error (*r* = -.371, *p* =.04) correlated moderately with EBPM. The negative correlation indicates that fewer errors in attention play a role in better EBPM performance for younger-old-adults.

3.9.5. Relationship between EF and PM1 Performance (Lenient Criterion)

To examine further the role of EF in the PM performance of older adults, we conducted additional correlational analyses using the lenient scoring criterion. Because of a large number of correlations, we used a more conservative alpha of .01. Summaries of correlation results are reported in Table 3.10 below.

Table 3.10

Correlations between Demographic Characteristics, EF, and SVWM for EBPM1 and TBPM1 Tasks Among Older-Old and Younger-Old Adults

	Older-old-adults				Younger-old-adults			
	EBPM1	*p*	TBPM1	*p*	EBPM1	*p*	TBPM1	*p*
Demographics								
Age	-.194	.31	-.191	.31	-.135	.48	-.266	.16
Years of education	.254	.18	-.153	.42	.136	.48	.129	.50
MOCA	.261	.16	.180	.34	.611***	<.001	.157	.41
SVWM Test								
Corsi Span								
Forward	.558***	.001	.475*	.008	.221	.24	-.241	.20
Backward	.408	.03	.253	.18	.353	.06	-.130	.50
EF Tests								
Plus-Minus Task								
Plus-minus switch cost	-.225	.23	-.107	.57	.111	.56	.097	.61
Plus-minus errors	-.197	.30	-.112	.56	-.096	.61	-.065	.73
SART								
Commission error	.109	.57	.100	.60	-.423	.02	-.125	.51
Omission error	-.169	.37	-.001	.10	-.234	.21	-.113	.55
SART total error	-.173	.36	-.045	.81	-.361	.05	-.169	.37
SART RT	-.339	.07	-.543***	.002	.083	.66	-.024	.90
Vividness rating	-.209	.27	.210	.27	-.054	.78	-.190	.32

Note. SART- Sustained Attention to Response Task; MOCA = Montreal Cognitive Assessment Test; RT = Reaction Time in Milliseconds

*p<.01, **P<.005.

Table 3.10 shows that within the older-old adult group, the Corsi block-tapping test (forward) correlates significantly positively with EBPM (r = .558, p =.001) and TBPM (r = .475, p =.008). This indicates that better performance on Corsi forward span is associated with better performance on EBPM and TBPM for the older-adult group. A moderate positive correlation was also observed between Corsi span (backward) and EBPM (r = .408, p =.03). The SART RT (ms) was also significantly associated with TBPM (r = -.543, p =.002), indicating that better reaction time is associated with better TBPM performance for older adults. Overall, Corsi Span forward and SART RT were strongly associated with TBPM, p<.005

Within the younger-old-adult group, MOCA correlated strongly with EBPM (r = .611, p<.001). This indicates that better cognitive function is associated with EBPM. Also, SART commission error (r = -.423, p =.02) and SART-total-error (r = -.361, p =.05) correlated moderately with EBPM. The negative correlation indicates that fewer errors in sustained attention enhances the EBPM performance for younger adults.

3.10. Discussion

The current study provided interesting and new information on the effects of different imagery perspectives on PM performance in two groups of older adults (younger-old vs. older old). We also explored the role of SVWM and EF in PM performance for the two groups of younger-old and older-old adults. We expected that PM performance would be poorer for the older-old group compared to a younger-old group based on literature suggesting that PM performance declines with age. We also expected performance to be poorer on TBPM compared to EBPM since TBPM requires self-initiated processes. In addition, significant correlations between PM and both SVWM and EF was expected since SVWM and EF have been found to play a role in PM performance. In order to capture PM task performance two scoring criteria were used for the analyses. The scoring criteria were based on the assumption that participants were still able to remember PM tasks despite being a little early or little late in their responses. The discussion is therefore in two parts; strict criterion and lenient criterion.

3.10.1. PM Performance

The first goal of this study was to determine if differences exist in the PM performance of two groups of older adults (younger-old vs. older old) and to investigate whether the use of different types of imagery at encoding enhances TBPM and EBPM performance compared to verbal encoding. The first question that this study sought to answer was 'do older-old adults perform significantly worse than younger-old on PM tasks ? And is this difficulty evident on TBPM or EBPM or both?'

3.10.1.1. Strict Criterion

In terms of PM performance using a naturalistic task, consistent with previous literature, an age deficit for both EBPM and TBPM was not observed. The younger-old adults performed similarly to the older-old adults on both PM tasks (Henry et al., 2004; Rendell & Thomson, 1999) showing that older adults generally show similar or better PM performance on naturalistic tasks. Our result, however, contradicts current laboratory findings on PM performance in an older adult population (e.g., Kvavilashvili et al., 2009; Schnitzspahn & Kliegel, 2009).

Unlike previous laboratory studies (e.g., Kliegel & Jager, 2006a; Kvavilashvili et al., 2009; Mantyla & Nilsson, 1997; Schnitzspahn & Kliegel, 2009; Zeintl et al., 2007) we did not find an age-related decline in both EBPM and TBPM. Indeed, in naturalistic conditions, older participants appear to be able to compensate for any age-related decline in cognitive function observed in laboratory settings. The similarity in performance between the two groups in the current study could not be due to the use of aids by the older-old adults since none was available in the current study compared to previous studies that made use of external aids. For instance, unlike the current study where none of the participants made use of aids, few participants in the Rendell and Thomson (1999) study reported using aids with older participants reporting less use compared to younger participants. It is also important to note that our participants are a high cognitive functioning group as demonstrated on the MOCA (average score of 27.73 for younger old and 27.43 for older-old) with a high level of education (average score of 15.17 for younger old and 15.20 for older-old). This might have accounted for the lack of difference in PM performance between the two groups.

However, all participants performed significantly worse on TBPM compared to EBPM. Similar to previous literature poorer performance on TBPM compared to EBPM was expected because time-based tasks place a higher demand on executive control such as sustained attention to support retrieval (Einstein et al., 2005; Maylor et al., 2002; McDaniel & Einstein, 2000; McDaniel et al., 1999; McFarland & Glisky, 2009). In support of the multi-process theory of PM (Einstein & McDaniel, 2007; Einstein et al., 2000), the result suggests that participants were significantly slower in switching from an ongoing activity to perform TBPM task (Craik & Kerr, 1996). This response time cost implies that executive resources that would decrease response time to the TBPM tasks were instead deployed to performing an ongoing activity (Einstein & McDaniel, 2010). In contrast, a more automatic process supported EBPM retrieval due to the presence of the retrieval cue (Einstein & McDaniel, 2005; Einstein & McDaniel, 2010).

Second, an effect of imagery was observed such that observer imagery was better than both field imagery and verbal encoding. In contrast, no significant difference emerged between field imagery and verbal encoding although the former was better. The strength of observer imagery over the field and verbal mirrors the findings of Libby et al. (2007) who discovered that registered voters who were instructed to visualize themselves voting from observer perspective subsequently developed a stronger pro-voting mindset than those instructed to picture themselves voting from the field perspective and consequently reported that they were more likely to vote. This suggests that observing oneself as the type of person who would perform an intention increases the likelihood of remembering to perform the intention (Libby et al., 2007).

Contrary to prior literature showing that older adults have difficulty engaging in imagery (Addis et al., 2008; Levine, Svoboda, et al., 2002; Rendell et al., 2012), we found that both younger-old and older-old were able to make use of the different types of imagery and the verbal encoding but the effect on both EBPM and TBPM was not observed. The benefit of imagery was expected for both groups based on the theoretical assumption that mentally simulating PM task and cue strengthens the link between then thereby facilitating PM remembering (Paraskevaides et al., 2010). However, the lack of an imagery effect on PM for both younger-old and older-old suggests that the link between imagery and PM performance in older adults might be more complex than simply reinforcing the relationship between the cue and the action to be performed. These results support the work of Altgassen et al. (2015) and Altgassen et al. (2016) which failed to observe any differential effect of imagery on EBPM and TBPM tasks. It also mirrors the work of Terrett et al. (2016) who despite finding a significant bivariate correlation between episodic future thinking and PM, failed to observe a unique relationship between imagery and PM performance. Terrett et al. (2016) suggested that the age-related decline in attentional resources (Craik & Rose, 2012) might have decreased the mental capacity of older adults to efficiently utilize imagery while performing PM tasks. However, it should be noted that unlike the aforementioned research we specified a specific type of imagery (either field or observer perspective). When one considers that a field perspective is the more commonly adopted one and that we failed to observe any beneficial effects of this type of imagery, our findings suggest that adopting an observer imagery perspective is a more effective type of imagery for PM tasks.

3.10.1.2. Lenient

The lenient criterion result revealed a significant difference between the two groups with poorer PM performance in the older-old group compared to the younger-old group. This is similar to previous findings (e.g., Rendell & Thomson, 1999; Schnitzspahn & Kliegel, 2009) which confirmed a decline within older adults on both EBPM and TBPM. It however contradicts the work of Kvavilashvili et al. (2009) who observed age effects in a TBPM task but not in EBPM task. Likewise, the current study could not provide support for previous studies using only EBPM (e.g., Kliegel & Jager, 2006a; Mantyla & Nilsson, 1997; Zeintl et al., 2007) that found an age-related decline in PM performance in the EBPM task. In line with Schnitzspahn and Kliegel's (2009) suggestion that it is difficult to determine if both EBPM and TBPM performance are consistently susceptible to age effects within older adults, our result is similar to findings comparing old adults with young adults, in which results with EBPM tasks were also mixed (West & Craik, 2001). Further, we did not observe any difference in performance on both EBPM and TBPM task for all the participants. Similarly, no significant interaction was observed between age group and PM tasks. These would suggest that an age difference in PM performance between younger-old and older-old adults is evident for both EBPM and TBPM.

Contrary to the strict criterion, when a lenient criterion was employed, the benefit of imagery on PM tasks was observed, such that observer imagery was a better enhancer of PM tasks on TBPM compared to field and verbal. Observer imagery also improved EBPM performance compared to field and verbal, although this did not reach significance. The benefit of observer imagery for TBPM provides support for the work of Burgess et al. (2005) who showed that imagery increases the likelihood of enacting a planned action. Thus, in contrast with previous research which found benefit for imagery in EBPM (Leitz et al., 2009; Paraskevaides et al., 2010), our participants showed better TBPM responses following imagery. The use of alcohol in previous study might have accounted for the differences in findings. Paraskevaides et al. found benefit of imagery on EBPM in the alcohol group but Leitz et al. failed to do so. Rather Leitz found benefit for imagery on EBPM in the control group. These findings argued against the possibility of the influence of alcohol in the benefit of imagery on EBPM. It is possible that the use of observer imagery at encoding frees up cognitive resources while performing an ongoing task thereby enabling spontaneous time monitoring and efficient execution of TBPM tasks. This suggests that although older adults might have difficulty engaging in imagery (Rendell et al., 2012), nevertheless, they were able to effectively apply it to enhance their TBPM performance in this study. Since time-based tasks rely on self-initiated time monitoring (McDaniel & Einstein, 2000; McDaniel, Guynn, Einstein, & Breneiser, 2004), imagery might lead to pre-experiencing the specific visuospatial time at which the TBPM task was to be performed. This, in turn, strengthens the link between the time monitoring and TBPM task, thereby facilitating easy TBPM remembrance (Paraskevaides et al., 2010). This means that efficient use of observer imagery for TBPM task might increase attentional resources which is beneficial for younger-old and older-old adults' TBPM performance (Altgassen et al., 2015; McDaniel & Einstein, 2000). EBPM rely on external cues in the environment to trigger the retrieval of intention unlike TBPM (McDaniel et al., 2004). This indicates that the cues in the VW environment might have spontaneously trigger PM remembrance, thereby limiting the benefit of imagery.

Future studies could include a vivid description of imagery experience to assess possible age-related differences in participants' ability to imagine future events, which could be related to planning and PM performance (Burgess et al., 2005). However, analysis of subjective ratings of vividness following imagery revealed the absence of a significant difference between the two groups of younger-old and older-old adults on the vividness of imagery in the current study. One limitation of the use of vividness in the current study was that we used a global score of vividness rating for both field and observer imagery. This was because we were more interested in finding age differences in overall vividness. Future studies could split the level of vividness rating for both field and observer imagery in order to determine if differences might exist between them for both groups of older adults. The current result is mixed with the findings of Schnitzspahn and Kliegel (2009) who observed that 60- to 75-year-olds benefited from imagery plus implementation intentions although 76-to-90-year old did not. Considering that, our participants were between the ages of 59-79 it is possible that the benefit of imagery for PM remembering may be influenced by the methodology employed (e.g. tasks demand and characteristics of individuals carrying out the task).

We also discovered that imagining PM tasks to be performed in the future, through a third person perspective (*Seeing yourself in the image, as well as your surroundings*), enhanced remembering for future intentions for all participants. This finding indicates that the use of this third-person imagery person might be a more effective strategy to improve TBPM – in both TBI patients as well as older adults.

Taken together, the present study shows that older-old adults benefit as much as younger-old adults do from observer imagery strategy. This finding is important since observer imagery alone might be a beneficial strategy to enhance PM functioning in older adults (Altgassen et al., 2015). PM impairment is evident following ageing. Therefore, encouraging older adults to make effective use of observer imagery will help to attenuate difficulties in TBPM performance (Altgassen et al., 2016; Altgassen et al., 2015; Paraskevaides et al., 2010).

3.10.2. Role of EF in PM Performance

The second goal of our research was to determine whether there was a relationship between SVWM, EF and PM performance in both younger-old and older-old adults. If so, is EF strongly associated with TBPM compared to EBPM? Analysis revealed similar correlations for both lenient and strict criteria, so we merged the discussion for the purpose of simplicity and avoidance of repetition.

An analysis of performance on EF and SVWM measures did not reveal any significant differences between the younger-old and older-old adults. This indicates that not all executive or WM processes might be sensitive to age (Verhaeghen & Cerella, 2002). An exploratory correlational analysis showed that SVWM as indexed by the Corsi Span forward and attentional reaction time indexed by SART measure played a significant role in PM performance for older-old adults but not younger-old adults.

Within the older-adult group, Corsi forward span was strongly positively associated with performance on both EBPM and TBPM. In the backward test, a positive correlation was observed with EBPM although it did not reach significance. This suggests that active spatial attention plays a role in maintaining PM intentions within immediate visual memory. The need to perform well on PM tasks might have motivated the older-old adults to maintain the PM intention in short-term visual memory while performing other ongoing tasks. Therefore, the capacity and efficiency of SVWM is likely an important determinant of PM ability, as well as age-related changes in PM depending on scoring criterion (Rose et al., 2010).

SART reaction time was also strongly negatively associated with TBPM indicating that the probable poor performance on TBPM was due to slow response to TBPM tasks. The role of reaction time in TBPM suggests that adults' TBPM performance is indexed by how quickly older-adults respond to TBPM tasks when the time is due. This suggests that older adults' poor TBPM performance using the lenient scoring criterion might be due to the slow speed of processing. This means that processing speed might have played a role in age-related TBPM decline. This is in line with previous findings (Salthouse et al., 2004) and corroborates the processing-speed theory of adult age differences by (Salthouse, 1996) which suggests that the speed at which older-adults process cognitive information is fundamental for older-adults' PM performance (Schnitzspahn et al., 2013).

Within the younger-old adults, none of the SVWM and EF measures were significantly associated with PM performance. MOCA an index of cognitive function was the only test that correlated strongly with performance on EBPM. However, the SART commission error and SART total error were moderately related to performance on EBPM for the younger-old groups. This suggests that when younger-old adults sustain attention and make fewer errors, they are able to maintain PM intentions and the reverse is true. The apparent lack of the role of SVWM and EF in younger-old adults might be that the younger-old adults made less use of cognitive resources to successfully monitor finishing one task and moving on to another (Scullin, McDaniel, & Shelton, 2013). In this case, the cues might have spontaneously triggered PM initiation and performance thereby reducing the amount of controlled cognitive resources needed to perform EBPM tasks (Burkard et al., 2014).

Overall, task shifting as indexed by the Plus-minus tasks was the only aspect of EF that did not play a role in PM performance for both younger-old and older-old adults. The simple nature of the Plus-Minus task might have affected performance since all the participants were performing similarly with fewer errors (70% of older-old adults did not make any error compared to 63.3% of younger-old adults with no errors). Taken together, the findings on the role of EF in PM in the current study are mixed. This could be due to the use of particular measures focusing on some aspect of EF (e.g. attention, shifting). In summary, the result indicates that SVWM and EF indexed by visual memory capacity and speed of processing plays an important role in PM function for older-old adults.

3.10.3. Summary Discussion

Following from our findings in the previous study on the effect of encoding on PM performance in the TBI population, which revealed that enactment encoding enhances EBPM performance but not TBPM, this study investigated the effect of imagery perspective on PM performance, especially TBPM within older adult groups. The use of older adults was based on previous literature that indicates that ageing is associated with difficulties in completing TBPM tasks.

The first aim was to explore the difference in performance on both event-based and time-based PM in two groups of older adults: younger old (59-69 years) and older adults (70-79 years). In addition, this study for the first time investigated whether engaging in field-imagery or observer-imagery enhances PM in younger-old and older-old adults in a naturalistic environment using the VW. Key findings to emerge from our study indicate that following the strict criterion, a significant effect of PM tasks was observed with better performance for EBPM compared to TBPM. Observer imagery enhanced PM performance compared to field and verbal encoding for all the participants. However, no significant age effect in PM performance was observed. Similarly, encoding did not interact with either the type of PM task or the age group.

In the lenient criterion, an age deficit on PM specifically time-based task emerged with worse TBPM performance for older-old compared to younger-old adults. Observer imagery also enhanced TBPM performance for all the participants. This indicates that observer imagery benefits TBPM for both groups of older adults. Test of SVWM and EF revealed that short-term visual memory capacity and speed of processing played a role in PM performance for older-old adults but not younger-old adults. Younger adults however potentially made fewer errors in EBPM performance due to better sustained attention.

Taken together, the findings are consistent with the meta-analysis of Uttl (2008)) which suggest that PM declines (especially TBPM) with ageing but the magnitude of age decline varies by PM subdomain (e.g., working memory, speed of processing, sustained attention, how PM is measured and scored [strict PM score, lenient PM score]) as well as location (laboratory vs. natural). Effective use of observer imagery, however, attenuates the age-related decline in PM such that its benefit was observed in TBPM but not in EBPM. Future research should explore the effect of enactment and imagery on PM performance in a virtual reality environment in order to determine the most efficient mechanism by which naturally occurring PM could be improved in the naturalistic environment.

CHAPTER FOUR

GENERAL DISCUSSION

4.1. Overview

The primary aim of my research programme was to identify and explore the efficacy of some of the factors (e.g. enactment, imagery) that could potentially enhance correct PM performance in TBI patients and older adults. The beneficial effects of these variables were explored in the VW task.

In this Chapter, I briefly outline some of the theoretical foundations for the current studies. Summaries of findings from Study 1 and Study 2 are also discussed. Implications of the findings in relation to theories and rehabilitation strategies in both TBI patients and older adults are also discussed. Limitations and directions for further research are also addressed.

4.2. Summary of Theoretical Background

As we go about our daily activities in life, we usually plan for the future and often defer an intended intention until the appropriate moment to perform it. In the literature, this is generally referred to as prospective remembering or PM (Einstein & McDaniel, 1990). Generally, PM involves key processes including the formation of future intentions (encoding), keeping the intention in mind during the delayed period, and performing the intention at the right moment (Ellis, 1996). Practically, difficulties sometimes emerge when the moment arrives for a PM task to be remembered (Einstein & McDaniel, 1996; Einstein et al., 1995). Research suggests that impairment in PM is prevalent following TBI and in ageing due to deficits/ or deterioration in frontal lobe

EFs (Cabeza & Dennis, 2012; Cabeza et al., 2016; Levine, Cabeza, et al., 2002; Levine, Katz, et al., 2002). As discussed earlier, PM task is thought to involve a number of EF processes such as planning and encoding of intention and action, retaining an intention, interrupting an ongoing activity, initiation and execution of intended action, strategy use and evaluation of outcome (Ellis, 1996; Shum et al., 2002).

Several other processes are believed to also affect PM performance. The strength of the association between the retrieval cue and its intended action has, for example, been identified as one of the key factors in PM performance (McDaniel & Einstein, 2000). To this end, McDaniel and Einstein (2000) proposed a multiprocess framework according to which "PM retrieval could be accomplished either by controlled monitoring of the environment for a target event or by a more reflexive process that spontaneously responds to the presence of a target event" (Einstein et al., 2005, p. 327). This suggests that the reliance on a more automatic process or the use of conscious mental resources could be mediated by the characteristics or nature of the specific task. For instance, prospective remembering could be automatic when there is a strong association between the PM cue and the intended action (Marsh et al., 2003), or when the ongoing task facilitates processing of the target event (Kliegel, Martin, et al., 2004). Considering the demands of daily life and the infinite number of PM tasks that must be performed while engaged in multiple activities of daily living, strategies that enhance the automaticity of PM performance are needed, especially for older adults and TBI patients. TBI patients and older adults have significant and frequent PM failures that hinder their daily functioning (Altgassen et al., 2010; Altgassen et al., 2015; Bisiacchi et al., 2008; Henry et al., 2004; Henry, Phillips, et al., 2007; Ihle et al., 2013; Kliegel et al., 2008; Mioni, Bertucci, et al., 2017; Mioni, McClintock, et al., 2014; Mioni et al., 2013; Mioni et al., 2015; Schmitter-Edgecombe & Wright, 2004; Shum, Levin, et al., 2011). TBI and age-related deficits are more evident in TBPM tasks due to low environmental support with high self-initiated activity (Maylor, 1996). In contrast, deficits are less evident in EBPM tasks due to the availability of greater environmental support with less requirement for self-initiated activity (Maylor, 1996).

Following from Atance and O'Neill's (2001) article which suggested that the use of imagery or enactment during the encoding of a PM task is essential in mobilizing cognitive resources to enhance PM task remembering, we studied the benefit of enactment encoding (in TBI) and imagery encoding (in older adults) on PM performance. Research on the benefit of imagery on PM performance indicated the possibility of enhanced performance in older adults (Altgassen et al., 2015). Similarly, the potential benefit of enactment on PM performance in younger and older adults has been reported (e.g., Pereira et al., 2015; Pereira et al., 2012). However, to the best of our knowledge, virtually no research on the benefit of enactment on PM in the TBI population has been reported. Similarly, the effect of various types of imagery on PM performance in healthy older adults has not been studied. To this end, the aim of the current study was to explore PM deficits in in both the TBI and healthy older adult populations and to identify strategies that could be used to enhance their PM performance in daily life.

4.3. Summary and Discussion of the Experimental Studies

4.3.1. Study 1: Supporting everyday activity following TBI: An investigation of PM performance

The aim of Study 1 was to examine differences in PM performance between TBI and HC and whether the use of enactment at encoding could be advantageous for PM performance for both TBI and HC in a more naturalistic, yet still laboratory-based PM paradigm (this allowed for effective experimental control). Furthermore, this experiment was designed to observe whether EF and quality of life measures and social inference play a role in PM performance for both TBI and HC.

It was anticipated, in line with the PM literature that TBI patients consistently present with PM deficit compared to HC that the HC group would perform significantly better than the TBI group on both EBPM and TBPM. Furthermore, the use of enactment encoding was expected to be advantageous for PM performance compared to verbal encoding. As expected, it was observed that HC outperformed TBI on EBPM functioning. In contrast, both groups performed similarly on TBPM. PM performance was significantly improved when physical enactment was used during encoding compared to verbal encoding. However, enactment facilitated the improvement of EBPM but worsened TBPM. A discussed in Chapter 2, the absence of a benefit of enactment for TBPM tasks might be due to difficulties in enacting an action at a particular time on the clock. We also speculated that time-based cue might not have been integrated into TBPM tasks during enactment. Interestingly, no significant interaction was observed between group, encoding, and PM tasks (EBPM, TBPM). The brain regions involved in motoric movement (motor cortex) during enactment might not have been affected in our TBI group since they were able to enact PM task requirements. It also possible that enactment makes use of different processes independent of injury status. Detailing what these processes are might require a neuro-imaging study in order to identify brain regions that might be activated, alongside the motor cortex, during enactment encoding and if these regions were intact following TBI related brain atrophy. However, as discussed earlier, enactment enhances EBPM remembering irrespective of individuals' clinical presentation such that it strengthens the link between an action (post letter) and retrieval cue (post office) thereby allowing reliance on spontaneous retrieval processes and removing the need for substantial attentional processing (Einstein & McDaniel, 2005, 2010). It is also possible that enactment creates a memory trace of an EBPM intention that makes available more mental resources for cue detection and PM remembering.

It was also anticipated that EFs, QoL functioning and social perception would be associated with PM performance, especially TBPM since it places more demand on cognitive resources associated with PM. The results revealed that although TBI patients presented with deficits in digit span, it was their level of sustained attention that played a role in PM performance. In contrast to our expectation, sustained attention was associated with EBPM performance of the TBI group. Although a deficit in sustained attention was associated with better EBPM performance, it was suggested that enactment encoding might have attenuated the observed deficit thereby enhancing EBPM performance.

QoL and social perception measures were also expected to play a role in PM performance for both the TBI and HC group respectively. The results revealed that negative evaluation of others' emotion, indexed by TASIT, enhanced PM performance in the TBI group. This suggests that attaching negative emotion to PM cues strengthens the link between the retrieval cue and PM target thereby enhancing performance. It is thought that emotion PM cues could benefit PM performance either by increasing the saliency of the cue, boosting monitoring effort, or enhancing PM remembrance compared to non-emotion PM cues (May et al., 2012; Murphy & Isaacowitz, 2008). Current evidence suggests that participants show better long-term memory for emotional than for neutral information (e.g., Altgassen et al., 2017; Denburg, Buchanan, Tranel, & Adolphs, 2003; Grühn, Smith, & Baltes, 2005). Similarly, emotionally valenced cues have been found to increase PM performance across both younger and older adults (Altgassen et al., 2010). It is possible that emotion cues might be more meaningful to the individual and therefore mobilize cognitive attentional resources (e.g., inability to remember to take medication might be linked to fear of loss of independence) to enhance PM functioning (Kensinger, Piguet, Krendl, & Corkin, 2005). This is consistent with Marsh, Hicks, and Cook (2008) suggestion that the emotional context of PM encoding and retrieval merit critical attention in PM research.

4.3.2. Study 2: Benefit of visual imagery perspectives on prospective memory performance in older adults

Based on the findings in Study 1 (conducted in Ghana), that suggested that sustained attention plays a role in the EBPM performance of TBI patients, we wanted to take a further look at the impact of sustained attention, in relation to executive processes, on PM functioning in the TBI population in the UK. However, as explained in Chapter 3, due to difficulty in recruiting TBI patients in England, we had to look for a different population who might present with a pattern of impairment that shares some similarities with a TBI population. Ageing is associated with decrements in attention and with difficulties in completing TBPM tasks similar to TBI. Moreover, older adults present with EF deficits that are broadly similar to those experienced by many TBI patients. Consequently, we decided to investigate the relationship between sustained attention and TBPM in younger-old and older-old healthy adults. We also investigated the potentially beneficial effects of different types of imagery on PM performance in older adults. As in Study 1, we used the same relatively naturalistic, yet laboratory-based PM task environment i.e., the VW. It was expected that, based on previous literature suggesting an age-related decline in PM performance, younger-old adults would perform significantly better than older-old adults on PM functioning. In addition, the use of different imagery techniques (field perspective imagery and observer perspective imagery) was expected to be advantageous for PM performance compared to verbal encoding. Further, it was hypothesised that sustained attention and task shifting (EFs) and SVWM would play a role in both older-old and younger-old adults' PM performance. Two scoring criteria (i.e., a strict criterion [PM accuracy] and a lenient criterion [little-late, accuracy, little-early] were used for the analysis of PM performance, based on the assumption that older adults might be slower in retrieving PM performance.

When the strict criterion was used, all participants performed significantly better on EBPM compared to TBPM tasks. In addition, observer imagery enhanced PM performance relative to field imagery and verbal encoding for all participants. However, an age-related deficit was not observed. Interestingly, there was no significant interaction between encoding and PM tasks for the groups. Measuring PM performance within a defined score may have limited the potential benefit of encoding in PM performance for both groups of older adults.

Following the lenient criterion, younger-old adults performed significantly better than older-old adults on PM tasks. Observer imagery was also observed to enhance TBPM performance for both younger-old and older-old adults. Furthermore, both strict and lenient criteria revealed that short-term visual memory capacity and speed of processing played a significant role in the PM performance of older-old adults. In the younger-old adults, sustained attention was observed to potentially enhance EBPM performance. The above findings have both theoretical and clinical implications.

4.4. Implications

4.4.1. Theoretical implication

Our research findings are in line with a multiprocess view of PM that might be referred to as the "level of activation" required to successfully complete a PM task (Guynn et al., 1998, p. 296). According to the multiprocess view, PM tasks can be initiated by relatively spontaneous processes or by relatively strategic, effortful processes depending on the task (TBPM tasks usually require effortful processes). However, TBI and age-related deficits in PM tasks are thought to be a result of the need to use strategic monitoring rather than spontaneous processes to successfully accomplish a PM task (Altgassen et al., 2015; Mioni et al., 2013). This suggests that efficient encoding of PM intentions might free up more cognitive resources to perform other tasks, which would be beneficial for TBI patients and older adults' PM performance (Altgassen et al., 2015; McDaniel & Einstein, 2000). The multiprocess view of PM functioning suggests that PM representations exist at a certain level of activation and the use of efficient encoding strategies further increases the level of activation of that representation (Einstein & McDaniel, 1996; Ellis, 1996; Guynn et al., 1998; Mäntylä, 1996). Thus, the use of effective encoding strategies should increase the link between the target action and the retrieval cue (Einstein & McDaniel, 1996; McDaniel & Einstein, 1993). This suggests that efficient encoding strategies may be able to activate the association between the PM retrieval cue and PM target and thereby enhance PM remembering. Support for this view comes from the finding that the use of enactment encoding enhances EBPM in both the TBI and HC group in Study 1.

In addition, the use of observer imagery enhanced TBPM in both younger-old and older-old adults in Study 2. Thus, the use of enactment (in TBI) and observer imagery (in older adults) increases the likelihood that the activation level of PM representation will be sufficient to support EBPM and TBPM remembering. Enactment benefited EBPM but not TBPM in Study 1 possibly due to the difficulty of enacting time on the clock. In Study 2, observer imagery benefited TBPM but not EBPM. EBPM tasks are cued by an external event that serves as a prompt and tends to be salient (compared to a time-related cue) and therefore retrieved more spontaneously (Faytell et al., 2015). This might explain why there was no benefit of imagery at encoding EBPM i.e., it did not affect cue saliency. Our findings suggest that enactment benefits EBPM while imagery benefits TBPM. Further research that combines observer imagery technique and enactment in one study might be needed to further explain these findings.

Our results provide support for the neuropsychological model of PM (McDaniel et al., 1999) which was based on Moscovitch (1994) neuropsychological account of associative memory. Moscovitch (1994), as cited in Guynn et al. (1998, p. 296), proposed that hippocampal components are actively involved in the encoding process of PM such that they integrate the relationship between the retrieval cue and the PM task, thereby creating a single memory trace. To remember a PM task, the hippocampal system must spontaneously initiate the memory trace for the task in the presence of the retrieval cue. To do this, there must be a strong interactive ecphory (a term coined by Semon, 1904, cited in Tulving, 1983) between the cue and target PM task in order to initiate response and vice versa. This model has implications for PM performance. For instance, at encoding, a memory trace is created between the target cue (e.g., bank) and the PM action (e.g. deposit cheque) such that the PM action is spontaneously initiated and executed in the presence of the cue (Guynn et al., 1998).

The hippocampal components are thought to automatically initiate the memory trace for the cue and the PM action so that the PM task can be remembered and performed (Guynn et al., 1998). This model suggests that efficient encoding strategies (i.e., enactment and observer imagery) benefit PM performance by strengthening the link between the cue and the PM task (Guynn et al., 1998). Thus, efficient encoding can free up resources for cue monitoring and PM task recognition during the delay interval (Brewer & Marsh, 2010).

Overall, our findings have contributed to existing knowledge by identifying the benefits of enactment and observer imagery in enhancing naturalistic PM performance for a TBI and other potential clinical populations, healthy young and older adults, and possibly those suffering the onset of dementia. The effects of enactment and observer imagery on PM performance could also be due to several cognitive factors (Faytell et al., 2015). First, enactment and observer imagery might have served as an elaboration strategy that led to deeper encoding (Altgassen et al., 2016; Faytell et al., 2015).

Unlike verbal encoding where the to-be-remembered information may have induced rote rehearsal, elaborative rehearsal further strengthens the relationship between the cue and PM task through the mobilization of attentional memory resources (Craik & Lockhart, 1972). Thus, enacting an intention or mentally visualizing oneself performing a future intention from a third person perspective may have strengthened the link between the cue and the PM action such that the cue facilitates retrieval of the intended action when the specific visuospatial environment is encountered (Altgassen et al., 2016; Altgassen et al., 2015; Paraskevaides et al., 2010; Schacter, Benoit, & Szpunar, 2017). It is also possible that the use of a observer perspective could create a sense of dèja vu plus (which literally means “already experienced or seen”(Barr, 2011,

p. 9). Thus, the act of visualising oneself performing a future action in response to a cue could deepen encoding such that in the presence of a cue, one could spontaneously felt a sense of having experienced the phenomenon before and therefore remember what to do, thereby leading to enhanced PM performance. The benefit of observer visualization is similar to earlier research by Grilli and McFarland (2011) who observed that visualising a future event from a personal perspective improved PM performance significantly compared to rote-rehearsal.

The role of short-term visual memory capacity and speed of processing in PM performance in the current study is also consistent with the conclusion that EF processes, supported by the PFC, are involved in PM performance (Burgess et al., 2007; Burgess et al., 2011; Okuda et al., 2007; Simons et al., 2006). However, the exact nature of the relationship between EF and PM could not be determined in the current study since most of the EF measures did not fully account for the performance observed in PM. It is possible that the processes involved PM are complex (Barr, 2011). As mentioned earlier, PM tasks place a greater demand on self-initiated EF processes such as planning and encoding of intention and action, retaining an intention, interrupting an ongoing activity, initiation and execution of intended action, strategy use and evaluation of outcome (Ellis, 1996; Shum et al., 2002). These complex interactions are thought to be localised in the PFC and the hippocampus (Shallice, 1996).

In line with the role of speed of processing in PM performance, Salthouse's (1996) theory of adult age differences in cognition on processing speed suggested that ageing is associated with decreased speed of cognitive processing and execution. According to Salthouse (1996), time-constraints imposed on the processing of information are detrimental to older adults and this might have accounted for the ease with which they are diagnosed with disorders of cognitive impairment. Thus, older adults' cognitive performance is degraded when processing must occur within a limited time period since they are unable to execute relevant operations on time. Also, due to the attentional resources allocated to an ongoing task, they might forget what was earlier encoded and therefore find it difficult to remember to perform PM tasks especially TBPM (Salthouse, 1996). This is where the benefit of observer imagery in attenuating the difficulties associated with PM becomes important.

4.4.2. Clinical Implication

Our findings have both practical and clinical implications. The findings from Study 1 suggest that the use of an enactment encoding strategy can improve performance on computerised PM tasks in both TBI and healthy individuals, with the possibility of transferring this effect to very similar tasks in an everyday environment. This indicates the potential value of focusing on training TBI patients to enact event-based tasks that they intend to perform in future. This strategy of directly targeting improving PM ability is in contrast to several current PM rehabilitation strategies which focus primarily on teaching compensatory strategies (e.g., using diaries, making list of things-to-do; Mioni, Bertucci, et al., 2017). Cockburn (1996) argues that compensatory strategies could be adopted relatively easily by healthy individuals who might discover the need, with advancing age or increasing workload, to supplement internal resources with external aids. However, there is little evidence to suggest that TBI patients with impaired PM would spontaneously adopt strategies to reduce their PM difficulty (Cockburn, 1996).

The potential value of pursuing an enactment strategy in rehabilitation contexts is further supported by the fact that enactment benefited both TBI and HC equally on

PM performance. This supports the work of Koriat et al. (1990) which indicated the substantial advantage of enactment over verbal encoding in PM encoding among student participants. It is also possible that that encouraging TBI patient to attach emotional cues to PM tasks could also improve PM remembering as evidenced by the relationship between emotional evaluation and PM performance in our TBI participants. Future research is needed to further investigate this finding.

The findings from Study 2 suggest that encouraging older adults to use observer imagery might enhance their PM performance in everyday life. Further research might be needed to explore further the benefit of this strategy for clinical groups with PM deficits, especially TBI patients. It might be possible to teach older adults, especially for those whom medication adherence is important, to use observer imagery in order to improve performance on important tasks at home or other social settings. For instance, in order to remember to take medication at 12 pm, older adults could be instructed to imagine themselves performing the PM task (i.e., taking medication) from an observer perspective while engaged in morning routines (e.g., breakfast). Following Salthouse's(1996) suggestion, it is important to allow older adults sufficient time to perform PM tasks due to their slower speed of processing. In this way, the extent to which older adults are quickly diagnosed with PM impairment is reduced thereby improving their quality of life.

4.5. Limitations and Further Work

Several possible scenarios might have affected the outcome and interpretation of our results. First, although we used a relatively naturalistic task (i.e. the VW) for our study, the task was completed in a laboratory setting in order to limit the effects of potential confounds. This suggests that findings may be more relevant for a laboratory environment compared to an everyday setting. As such, our findings in the VW might be considered more artificial in comparison to what pertains in the real world. Our results, however, suggest that the use of enactment and imagery encoding strengthens the link between PM cues and PM targets thereby enhancing PM performance for both clinical and non-clinical populations. For this reason, the most effective encoding strategy should involve the use of enactment for EBPM tasks and observer imagery for TBPM tasks in a natural setting. For instance, Jane might want to give John a message when she meets him on campus and remember to take her medication at 12:30 pm. Our data indicate that enacting the processes of meeting John and delivering a message would increase the likelihood that the presence of John will trigger the memory to deliver a message. Similarly, visually imaging taking medication when the time is 12:30 pm from a third-person perspective (observer imagery) would also increase the likelihood of monitoring the clock and remembering to take the medication when the time is due.

It is important to note that the VW is a promising task that partially addresses the observed discrepancy between performance on a laboratory task and performance in a real-life situation (Burgess et al., 2006; Chaytor & Schmitter-Edgecombe, 2003; McDaniel & Einstein, 2007; Mioni, Bertucci, et al., 2017; Mioni et al., 2015; Mioni & Stablum, 2013). A growing body of research has focused on the development of virtual environment tasks that simulate real-life activities to test PM performance and pointed out the importance of using tasks that better recreate real-life activities (Kinsella et al., 2009; Knight & Titov, 2009; Knight et al., 2006; Mioni, Bertucci, et al., 2017; Mioni et al., 2013; Mioni et al., 2015; Potvin et al., 2011; Rendell & Henry, 2009; Rendell & Thomson, 1999; Rose et al., 2015).

Furthermore, the VW includes, within the same task, parallel versions of EBPM and TBPM tasks, which allows researchers to investigate differences between needing to notice an environmental cue versus needing to monitor time and thus the effect of variations in self-initiated retrieval (Mioni et al., 2013). The VW also includes regular (routine/habitual) and irregular (PM) tasks that have relatively low and high demands on the RM component and allows researchers to investigate the contribution of RM in PM, although we did not collect data on RM since the VW was still undergoing further development at the time of testing. This, however, has been rectified with more recent versions of VW that include a test at the end of each virtual day of the memory for the content of the PM tasks (Mioni, Bertucci, et al., 2017). Future research could consider using this feature of more recent versions of the VW together with enactment and imagery encoding strategies. In addition, although rating scales of PM may have issues with validity, including them in the evaluation of PM performance could bridge our understanding between PM impairment, activity limitation in the real world and quality of life. Future study could consider the role of subjective rating of PM in addition to ecologically valid measures.

Another possible limitation of the current study is that although it was easy to observe enactment at encoding, the use of imagery presents a challenge of establishing whether participants effectively engaged in imagery as required by the instructions. Although the inclusion of the vividness of experience was expected to gauge the extent of imagery usage, it is limited in function by its self-reported nature. However, as discussed in Chapter 3, the absence of a significant difference between older-old and younger- old adults in their ratings of the vividness of their imagery and the absence of a significant correlation between errors in attention and PM performance indicate the possibility that participants engaged in efficient imagery. Future research could split vividness rating for both field and observer imagery in order to determine if differences in vividness exist between them for both groups of older adults. It was also possible that participants may have switched unknowingly when alternating between field and observer imagery perspective. Two alternate days were assigned to each technique to minimise the effect of contamination, but this technique may not have fully reduced the risk. Future research could employ fMRI scanning or electroencephalogram to detect the brain regions involved when we engage in imagery and indeed in different types of imagery. This will enable future research to elucidate the benefit of observer imagery for PM performance.

Another question that arose during this research was whether the benefits of enactment and imagery could be extended to other clinical populations, especially patients with severe amnesia or Alzheimer's disease and other neurological disorders. In order for these strategies to become widely accepted, as an effective form of treatment for PM difficulties, further research is needed in a more naturalistic environment where PM demands are often unpredictable and no-one is available to give instructions on the need to use encoding strategies and if possible provide prompts in situations where spontaneous initiation is not achieved.

One other potential limitation of the study involving the TBI participants was that, due to limited availability of fMRI scanners and the huge cost involved in obtaining a brain scan (in Ghana where the first study was conducted), most of the TBI patients had no scan reports. This made it difficult to determine the exact location of their injury. The findings from Study 1 therefore need to be interpreted with caution. Similarly, all of these patients were already in the community post several years of injury (6 to 33 months). Thus, they might have recovered an aspect of brain function and reduced EF deficits due to neural plasticity. This might explain the absence of a difference between the HC and TBI on almost all measures of EF function.

4.6. Conclusions

Research in PM has generated much interest, although it is still in its infancy. As theoretical and practical knowledge of the processes involved in PM increases, strategies to attenuate PM deficits should become easier to develop and integrate into improving rehabilitation programmes. This is important because PM difficulties are common following ageing and TBI and thus there is a need to identify effective strategies that will help reduce PM difficulties and improve capacity for independent living. The findings of the present studies indicate that TBPM and EBPM are impaired following normal ageing while EBPM is impaired following TBI. Notwithstanding, these studies have demonstrated that the use of enactment and imagery at encoding enhances PM performance in both clinical and non-clinical populations. Indeed, they reveal that enactment benefits EBPM performance for both TBI and HC while observer imagery benefits TBPM performance for both younger-old and older-old adults. Furthermore, the findings suggest that enactment and observer imagery offer potential for the rehabilitation of PM. The use of enactment and observer imagery have practical utility, given that they are brief and do not require any physical materials but only a simple instruction. Future studies could compare the relative benefit of both enactment and imagery in PM performance for both TBI and older adults in a more naturalistic environmental setting. It appears then that they can have a positive impact on PM performance of healthy younger and older adults, and TBI patients and as such have the potential be a valuable technique for increasing functional independence.

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Appendices

Appendix 1: Ethics

Appendix 1.1. Information Sheet and Consent Form for Study 1

University of Reading

School of Psychology and Clinical Language Sciences
Whiteknights
Reading RG6 6AL

Title: Supporting Everyday Activity Following TBI: An Investigation of Prospective Memory Performance

Information Sheet

Supervisor: Prof. J. A. Ellis	Email: j.a.ellis@reading.ac.uk	Phone:01183786415
Supervisor: Dr. Arpita Bose	Email: a.bose@reading.ac.uk	
Student: Emmanuel Sarku	e.k.sarku@pgr.reading.ac.uk	

We would be grateful if you could assist us by participating in our study which aims to identify some of the factors that lead to improving memory for everyday future intentions. Your participation will take approximately 45minutes to 1hr, during which time you will play a simulated board game of everyday future intentions on a desktop computer, using the mouse to interact with the software and move around the board with the simulated roll of a dice. You are required to do some virtual everyday tasks when a particular event occurs in the game (e.g., take favourite children's book when you visit a school) or when a particular time square is passed (e.g., phone plumber at 4pm). You will be given the opportunity to perform these tasks even if late. You will be given pre-game instructions and then a practice virtual day to ensure you understand all features of the game.
All data gathered from this experiment will be kept confidential and securely stored using only an anonymous number to identify it. Information which links the number to your name will be stored securely and separately from the data we collect. All data gathered from the study will be destroyed after 5 years from the completion of the study.

Taking part in this study is voluntary and you may withdraw from the study at any point without having given a reason. Please feel free to ask any questions you have regarding your participation in the study.

This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

www.reading.ac.uk

University of Reading

School of Psychology and Clinical Language Sciences
Whitenights
Reading RG6 6AL

<u>Title:</u> Supporting Everyday Activity following TBI: An Investigation of Prospective Memory Performance

<u>CONSENT FORM</u>

I, ……………………………………………………………… agree to participate in the study on Supporting everyday activity following TBI: An investigation of prospective memory performance. The study is being conducted by Emmanuel Sarku and supervised by Prof. J. A. Ellis and Dr. Arpita Bose at the School of Psychology and Clinical Language Sciences of The University of Reading. I have seen and read a copy of the Participants Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. I understand that all personal information will remain confidential to the Investigator and arrangements for the storage and eventual disposal of any identifiable material have been made clear to me. I understand that participation in this study is voluntary and that I can withdraw at any time without having to give an explanation.

I am happy to proceed with my participation.

Signature --

Name (in capitals) --

Date --

www.reading.ac.uk

Appendix 1.2. Information Sheet and Consent Form for Study 2

University of Reading

School of Psychology and Clinical Languag
Sciences
Whitenights
Reading RG6 6AL

Title: Benefit of Visual Imagery perspectives on Prospective Memory Performance in Older Adults

Information Sheet

Supervisor: Prof. J. A. Ellis	Email: j.a.ellis@reading.ac.uk	Phone:01183786415
Co-Supervisor: Dr. Arpita Bose	Email: a.bose@reading.ac.uk	
Research Student: Emmanuel Sarku	e.k.sarku@pgr.reading.ac.uk	

We would be grateful if you could assist us by participating in our study which aims examine the how imagining a task affect memory for everyday future intentions.
Your participation will take approximately 45minutes to 1hr, during which time you will play a simulated board game of everyday future intentions on a laptop computer, using your hand to interact with the software and move around the board with the simulated roll of a dice. You are required to do some virtual everyday tasks when a particular event occurs in the game (e.g., take favourite children's book when you visit a school) or when a particular time square is passed (e.g., phone plumber at 4pm). You will be given the opportunity to perform these tasks even if late. You will be given pre-game instructions and then a practice virtual day to ensure you understand all features of the game. You will also be tested on some simple executive function tasks

All data gathered from this experiment will be kept confidential and securely stored using only an anonymous number to identify it. Information which links the number to your name will be stored securely and separately from the data we collect. All data gathered from the study will be destroyed after 5 years from the completion of the study.

Taking part in this study is voluntary and you may withdraw from the study at any point without having given a reason. Please feel free to ask any questions you have regarding your participation in the study.

This application has been reviewed by the University Research Ethics Committee and has been given a favourable ethical opinion for conduct.

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School of Psychology and Clinical Langu
Sciences
Whitenights
Reading RG6 6AL

Title: Benefit of Visual Imagery Perspectives on Prospective Memory Performance in Older Adults

CONSENT FORM

I, ……………………………………………………………… agree to participate in the study on the benefit of visual imagery perspectives on prospective memory performance in older adults. The study is being conducted by Emmanuel Sarku and supervised by Prof. J. A. Ellis and Dr. Arpita Bose at the School of Psychology and Clinical Language Sciences of The University of Reading. I have seen and read a copy of the Participants Information Sheet and have been given the opportunity to ask questions about the study and these have been answered to my satisfaction. I understand that all personal information will remain confidential to the Investigator and arrangements for the storage and eventual disposal of any identifiable material have been made clear to me. I understand that participation in this study is voluntary and that I can withdraw at any time without having to give an explanation.

I am happy to proceed with my participation.

Signature --

Name (in capitals) --

Date --

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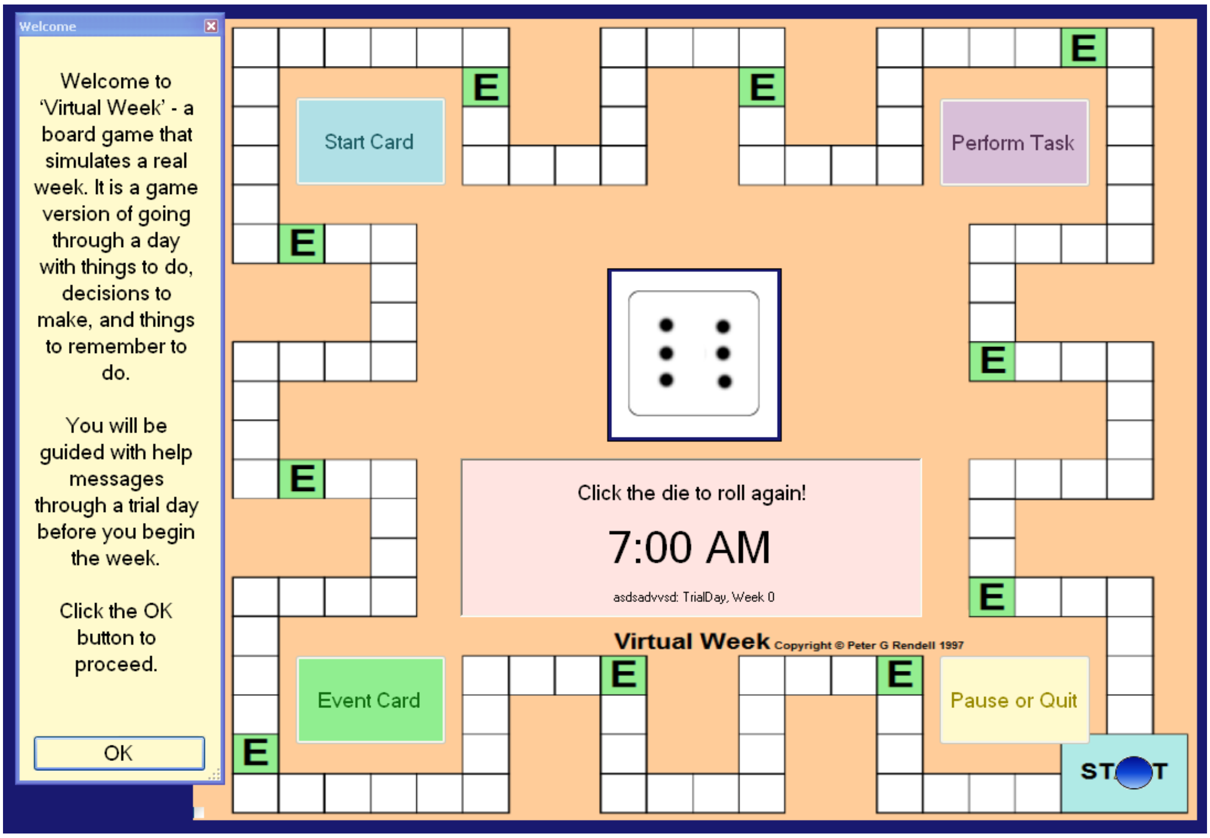
Appendix 2. Measures

Appendix 2.1. Virtual Week

Welcome to ‘Virtual Week’ – it is a board game that simulates a real week. It is a game version of going through a day with things to do, decisions to make, and things to remember to do.



Virtual Week Copyright © Peter G Rendell 1997

You will move around the board on the roll of the computer dice. As you move around the board and pass green E squares, you will select Event Cards that will describe an activity relevant to the time of day (e.g. **visit school**). Each circuit of the board represents one day, the first Event Cards cover morning activities and the last ones cover evening activities (e.g. **breakfast, dinner**). These cards will give you three options for daily activities. You will be required simply to indicate your choice of one activity. Choose the option you are most likely to do in normal life even if nothing fits exactly (e.g. **You go to a special relatives day at your nephews school. During visit you have a choice; *help with an art lesson on making puppets, help with science***

activity on climate, help supervise a sport activity with your nephew's class). Depending on the activity you choose, you will have to roll an odd, even number, or a particular number, to continue.

In addition you will be given some extra tasks to remember to do as you move around the board. Each task will need to be carried out at a set time when the future events occur (Even if you are late to remember a task, still perform the task by first selecting the ‘Perform Task button and then selecting the correct task). Each day you will get four extra tasks to perform: 2 at start of day and 2 during day.

1) On one day you will be asked to read tasks silently and look away from the computer and say it aloud. E.g. **Take favourite children's book out of your bag when you visit a school.**

2) On another day you will be asked to read tasks silently and get away from the computer to allow for extra space and mime the task. E.g., **phoning the plumber at 5:00 pm** (e.g., pretend to be engaged in an activity, pause, check time on clock, assume it is 5:00pm, dial an imaginary number and pretend to talk to plumber).

Now we are going to do a practice virtual day and you will be guided with help messages on this practice before you begin the week. **After practice you will be able to start the week.**

You can now start the trial day…………………………………………………………

End of trial

Did you find any of the actions difficult to understand or mime?

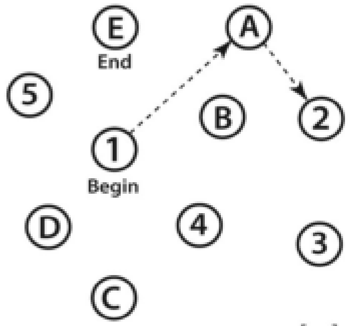
Are you comfortable to start the week?

Appendix 2.2. MOCA

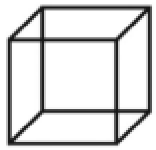
MONTREAL COGNITIVE ASSESSMENT (MOCA)
Version 7.1 Original Version

NAME :
Education : Date of birth :
Sex : DATE :

VISUOSPATIAL / EXECUTIVE



[ ]



Copy cube

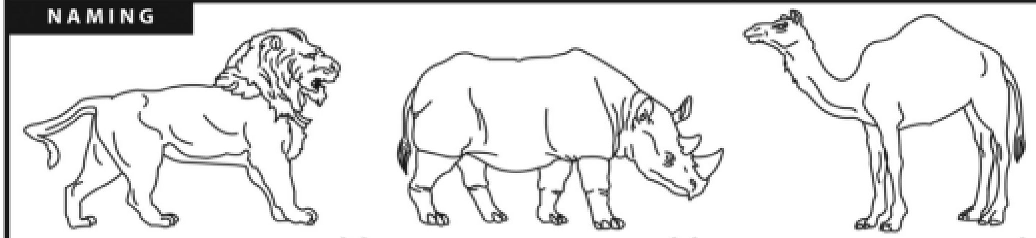
[ ]

Draw CLOCK (Ten past eleven)
(3 points)

[ ] Contour [ ] Numbers [ ] Hands

POINTS ___/5

NAMING



[ ] [ ] [ ] ___/3

MEMORY Read list of words, subject must repeat them. Do 2 trials, even if 1st trial is successful. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 ___/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] F B A C M N A A J K L B A F A K D E A A A J A M O F A A B ___/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** ___/3

LANGUAGE Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] ___/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] ____ (N ≥ 11 words) ___/1

ABSTRACTION Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler ___/2

DELAYED RECALL	Has to recall words WITH NO CUE	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only	___/5
Optional	Category cue							
	Multiple choice cue							

ORIENTATION [ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City ___/6

 www.mocatest.org Normal ≥26 / 30 TOTAL ___/30
Add 1 point if ≤ 12 yr edu

Administered by: ________________

Appendix 2.3. National Adult Reading Test (NART)

The NART-R is administered by giving the subject the list of 61* words and asking him to read each word aloud: *"I want you to read slowly down this list of words starting here [indicate "DEBT" *] and continuing down this column and on to the next. I must warn you that there are many words that you probably won't recognize, in fact most people don't know them, so just guess at these, O.K.? Go ahead."*

The subject should be encouraged to guess, and all responses should be reinforced ("good", "that's fine", etc.). The subject may change a response if he wishes to do so, but if more than one version is given the subject must decide which is his/her final choice. No time limit is imposed. If the subject becomes frustrated, encourage him to continue to the end. At the end of the task, if the subject wants more information, the examiner should feel free to tell the subject the correct pronunciation and/or meaning of each word (definitions are shown below). If a subject asks for feedback in the middle of the task, simply tell him that you have to wait until he reaches the end of the task.

The examiner indicates on the scoring form whether or not each word was pronounced correctly. It is OK to stop the subject and ask him to slow down if he is reading the words too quickly. Subjects should not be penalized for minor variations from the exact pronunciation: because of the irregular, non-phonetic, spelling of the words, it should be obvious when the subject is not familiar with the written form of the target word. At the end of the task, sum the number of errors and the number of correct items. It is very important the subject attempt all of the items. If the subject refuses to complete the entire task, do not score the task.

Word Card

CHORD	SUPERFLUOUS
ACHE	SIMILE
DEPOT	BANAL
AISLE	QUADRUPED
BOUQUET	CELLIST
PSALM	FACADE
CAPON	ZEALOT
DENY	DRACHM
NAUSEA	AEON
DEBT	PLACEBO
COURTEOUS	ABSTEMIOUS
RAREFY	DETENTE

EQUIVOCAL

NAIVE

CATACOMB

GAOLED

THYME

HEIR

RADIX

ASSIGNATE

HIATUS

SUBTLE

PROCREATE

GIST

GOUGE

IDYLL

PUERPERAL

AVER

GAUCHE

TOPIARY

LEVIATHAN

BEATIFY

PRELATE

SIDEREAL

DEMESNE

SYNCOPE

LABILE

CAMPANILE

Appendix 2.4. Trail Making Test

Trail Making Test (TMT) Parts A & B

Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

Step 1: Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.

Step 2: Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).

Step 3: Time the patient as he or she follows the "trail" made by the numbers on the test.

Step 4: Record the time.

Step 5: Repeat the procedure for Trail Making Test Part B.

Scoring:

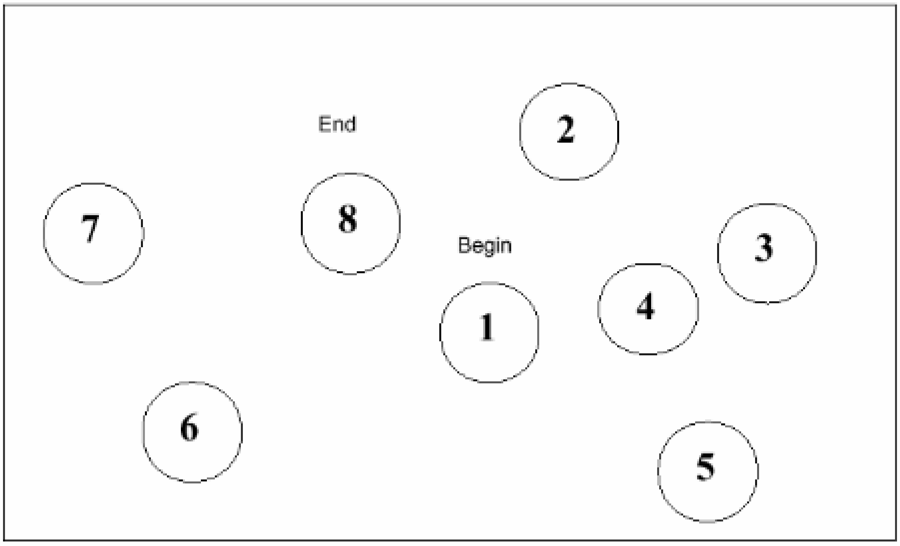
Results for both TMT A and B are reported as the number of seconds required to complete the task; therefore, higher scores reveal greater impairment.

	Average	**Deficient**	**Rule of Thumb**
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 3 minutes

Sources:

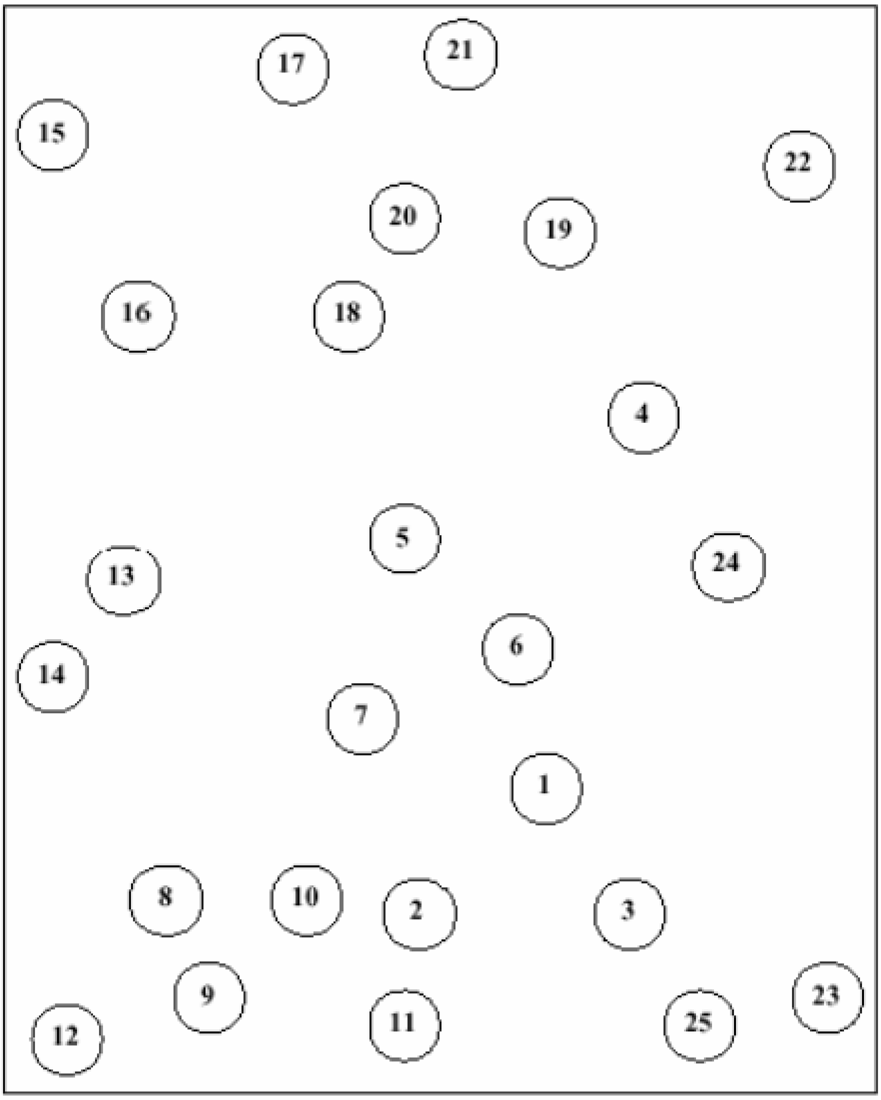
- Corrigan JD, Hinkeldey MS. Relationships between parts A and B of the Trail Making Test. *J Clin Psychol*. 1987;43(4):402–409.
- Gaudino EA, Geisler MW, Squires NK. Construct validity in the Trail Making Test: what makes Part B harder? *J Clin Exp Neuropsychol*. 1995;17(4):529-535.
- Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment*. 4th ed. New York: Oxford University Press; 2004.
- Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958;8:271-276.

Trail Making Test Part A – *SAMPLE*

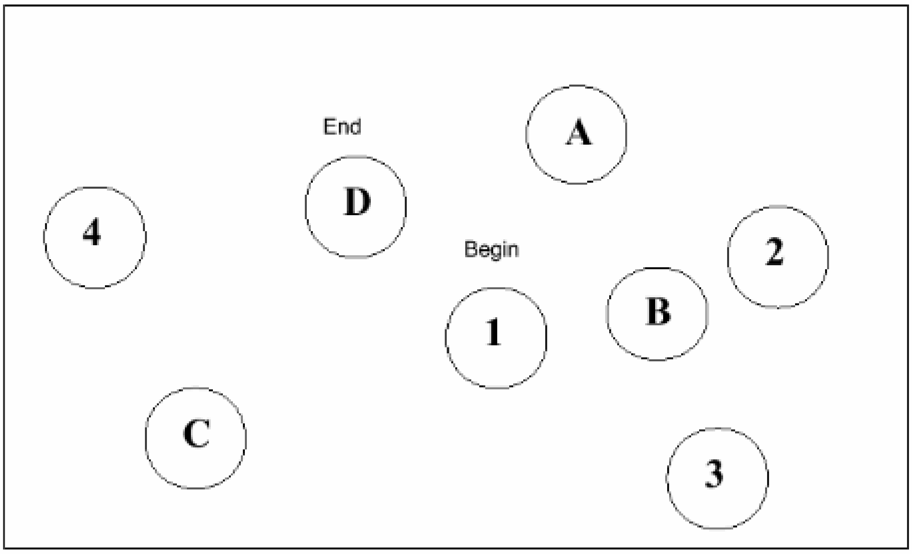


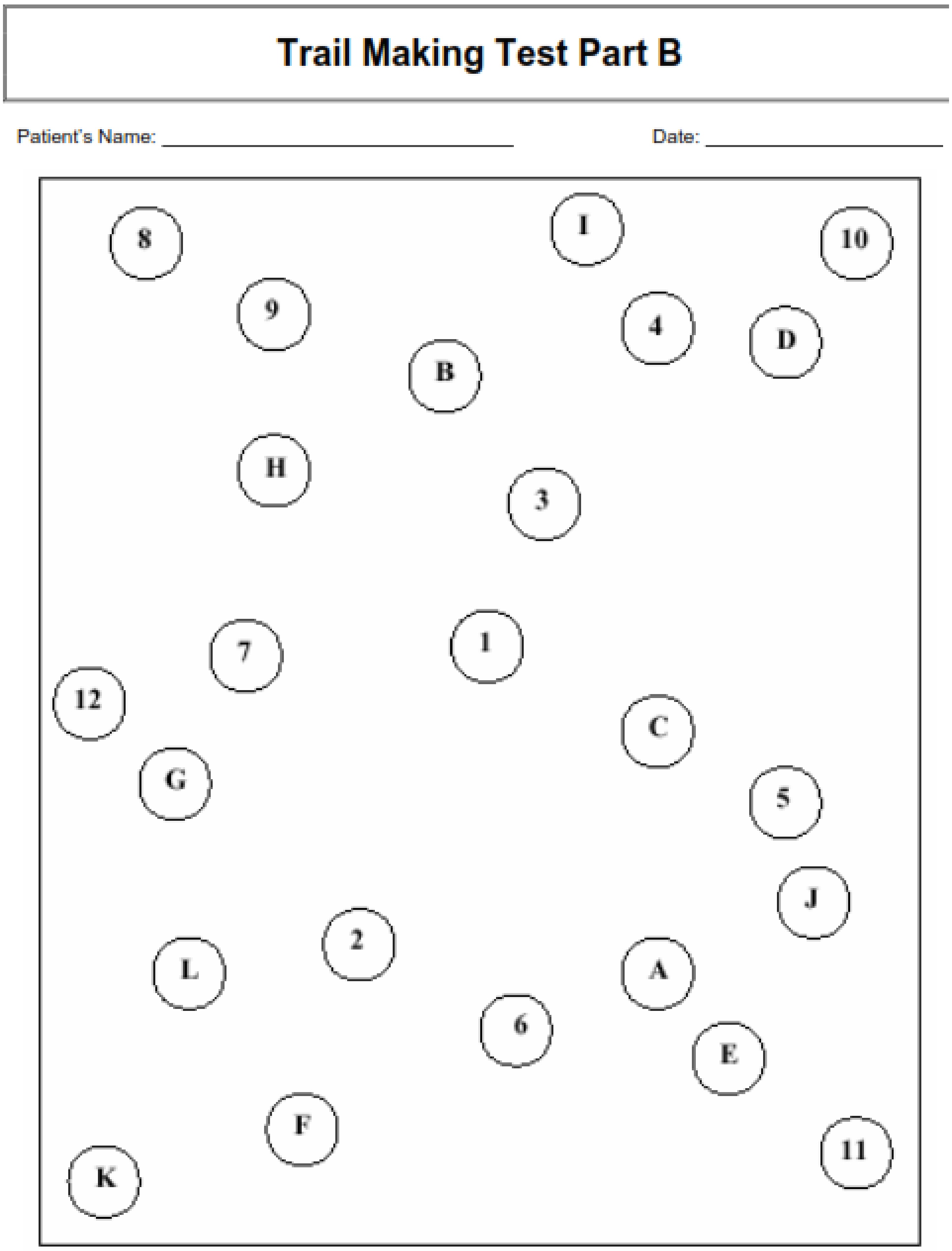
Trail Making Test Part A

Patient's Name: ______________________________ Date: ____________________



Trail Making Test Part B – *SAMPLE*





The computer version of the TMT by PEBL® was administered in our study.

Appendix 2.5. Verbal Fluency Task

Verbal fluency (FAS)

Ask the participant to tell you as many words as they can think of beginning with the letters F and A (ordinarily the participant would also be asked to think of words beginning with 'S' but we will not have time for this today).

Take each letter in turn and allow the participant 1 minute for each one.

Make it clear to the participant that they should avoid giving you numbers and proper nouns (e.g. names of people or countries). Also ask them not to produce words that have the same prefix as words they have already produced (e.g. avoid friend, friendly, friendship, friendless, etc.).

Record participant's words below.

F	A
subtotal:	subtotal:

TOTAL (subtotals combined) =

Appendix 2.6. Stroop Interference Task

The stroop is a computer based test. Instructions are as follows;

You are about to take part in a study in which you will be asked to determine the colour that written words appear in. sometimes the words will be actual colour names. When this happens, try not to respond with the written word colour name but only with the colour of the word. You will need to respond to the 1(red), 2(blue), 3(green), 4 (yellow) keys on top of the key board.

Before we begin, take a moment to lean the mapping between colours and the keyboard markers. Press the markers with numbers 1-4 consecutively to practice the response and space bar to begin test (1minute)

……………………………………………………………………………………………
…….Practice is complete. Now you will be tested for real. Remember to answer as quickly and accurately as possible.

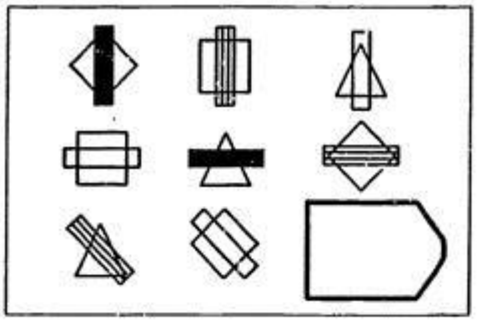
Press any key to begin.

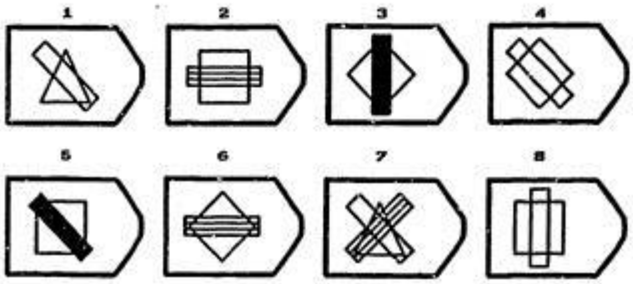
……………………………………………………………………………………………
……..

You may now take a short break. When you resume, remember to answer as quickly and accurately as possible.

Press any key to continue………………

Appendix 2.7. Cattell Cultural Fair Test-Sample





When the participant has filled in his/her name, etc., on the answer sheet, say:

Put down your pencil and I'll tell you a little bit about what you are going to do. In this booklet, there four tests which are like four different games or puzzles. There are no words in them-only drawings. Each of the tests has some examples for you to practice on so that you can see how to do it. First, we'll look at the examples together and then you'll be asked to go ahead on your own. Some of the questions at the end of each tests may be quite hard to do but try as many as you can. Even when you're not sure mark the answer you think you might be right, rather than none. It's perfectly all right to guess if you don't know the answer. You don't lose point for wrong guesses, and you might guess right.

Please don't turn any page until I tell you. You are to mark all your answers on the answer sheet that you've been given and not in the test booklet. Now read the instructions on the answer sheet and see if you understand them. (pause)

Verbatim instructions for Scale 2

FORM A

Test1: now open the booklet to the first page, Test 1. At the top of the page are three examples. Look at the first example. (point) Notice that the first three boxes have black lines that keep getting longer. Then there is a dotted empty box (point), followed by five more boxes. (point) Of the five, choose the one that would be right to put into the empty box. (point) For this example, the correct answer has been given to you. It is <u>1.</u> Look at your answer sheet. Notice that under test 1, in the first example, the box under the 1 has been filled in. that shows 1 is the correct answer of the five you have to choose from.

Look at the second example. See how the little curved lines bend to the left, then to the right, then to the left. What will it do at the next step? (wait for an answer) Yes, it will bend to the right. Number 3 is correct. Pick up your pencil and in the second example on the answer sheet, fill in the box under 3.

Now, the third example. See how the black part moves. It begins at the top and moves around the circle. Look at the five choices for the right answer. (pause) Which one is it? (wait for an answer) Yes, its number 1. Mark it on your answer sheet by filling in the box under 1.

You can see that none of the other choices in all three examples would have been quite right. When I tell you to start, go on and do the rest yourself. Begin with the first row just below the line and work through this page to the bottom of the next. (point to both pages). in each row choose just one of the five boxes on the right that fits correctly in the empty box. Then mark it on the answer sheet. You might not have time to finish them all, but work as quickly and carefully as you can. You are allowed to change your answer if you change your mind, but be sure to erase carefully.

Ready? Go!

After exactly 3 minutes say

Stop! Pencil down

TEST 2

Now turn to Test 2. (Check that the booklet is turned to the right page.) Look at the first example. (Pause) There are five figures in a row. Four are the same and one is different. In this row, which one is different in some way from all the others? (pause) The fourth one is different, so the box under 4 has been filled in on the answer sheet. Why is that one different? (Permit an answer)

Let’s do the second example now. Which one is the different one here? (permit and answer) Yes it is the first one. Its black and all the others are white. Of course the others are different sizes but they are all white so you cant pick out one of those. On your answer sheet fill in the box under 1 in the second example.

When I tell you to start, I want you to choose one picture in each row which does not belong with the others. Remember, only one picture in each row is different in some way from all the others. Work quickly and carefully to try to finish as many as you can on the two pages before I tell you to stop. Ready? Go!

After exactly 4 minutes say

Stop! Pencil down.

TEST 3

Turn to test 3. Look at the first example. (Pause and check) there are four small boxes in the large square (point) at the left. One of them is doted and empty. Which one of this five boxes over here (point) is the correct one to fill in the dotted and empty box? (pause for answer) Yes, it's the third. If we put that one in the empty box, it would look right. Do you see on your answer sheet that the box under the 3 has been filled in?

Now look at the second example. (Pause and check) Which one shall we put in the empty box to make it look right? (Permit an answer) Yes, it's 1, isn't it? Mark this on your answer sheet.

Let's take the third example. You choose the right answer. Which is it? (Pause for answer) Yes, it's 4. Mark it on your answer sheet.

When I say 'Go,' start with number 1, here, just below the line. (Point) Look first at the large square with the four boxes. (Point) Then look at the row of five boxes and pick out the one box that would look right in the dotted empty box. See what number it is and on your answer sheet, fill in the little box under that number. Do both pages. Work as carefully and as fast as you can. Ready? Go!

After exactly 3 minutes say

Stop! Pencils down

TEST 4. Turn to Test 4. Look at the first example. (Point) In the box at the top that's by itself (Point, check) you see that there is a circle, and in the circle there are a dot and a square. (Pause, check) The dot is inside the circle, but outside the square. Now look over here at the five boxes on the right. (Point) We must find one where we can do just the same thing: put a dot inside the circle but outside the square.

What about the first one? No, because any dot in the circle would be in the square too. Would the second do? (Permit answer) No—because a dot in the circle would also be in the square. The third? Yes, you see the dot is inside the circle but outside the square. The dot was put in for you to show you that answer 3 would be right. (Pause) It is the only one where we can do the same as in the separate box on the left, here. (Point) So the box under the 3 has been filled in for the first example on your answer sheet.

Look at the second example. In the separate box at the left (Point), the dot is inside the egg-shaped figure, but under the line. Now we have to find another box where we can do just the same. Which one is it? (Pause) Yes, the second. That's the only right one. Fill in box 2 for the second example on your answer sheet.

Now look at the third example. (Pause) This time one dot must be in both squares at once, but outside the circle. In the first box over here (Point), you could not put a dot in both squares at once, could you? (Pause) In the second box, the dot could go in both squares, but it would be inside the circle, so it won't do. What about the third? (Pause) Yes, the third is the only one where we can put the dot in both squares, but outside the circle. Mark the answer on your answer sheet.

When I say, ‘Go!’ start at the first one under the line. (Point) Look carefully at the separate box to see just where the dot is. Then find the box where you could do just the same, and mark that number on your answer sheet. Please do not make any dots or marks on the test booklet.

You will have almost as much time for this one page as you had for the two pages in the last test. See how many you can do. Ready? Go!

After exactly 2½ minutes say

Stop! Pencil down.

FORM B

Open your booklet to the first page, Test 1.

TEST 1

Look at the first example. You see that the line leans over more and more as we go from one box to the next. (Point) Now we must choose from these five boxes over here on the right (Point), the one that ought to go into the dotted empty box. (Pause) Yes, it’s the first one, number <u>1</u> leaning right over, so on your answer sheet the box under the <u>1</u> has been filled in.

Now look at the second example. We have a black square and a white square; then a black square. What will the next one be? (Permit an answer) Yes, it will be white. Which is the right box over here? (Point to row) Yes, number <u>5</u>. It would look right in the empty box. Fill in the correct box on your answer sheet.

Now, the third example. Do you see that the hand turns more – and more – and more? Which one of these five over here ought to be in the dotted empty box? (Permit an answer) Yes, it’s the third one. None of the others is quite right. Fill in the box under the <u>3</u>.

When I tell you to start, go on and do the others yourself. Start with the row just under the line. Decide which one will look right in the empty box, and mark that number as your answer on the answer sheet. You might not have time to finish them all, but work as quickly and carefully as you can. You are allowed to change your answer if you change your mind, but not after I tell you to stop. Ready? Go!

After exactly *3 minutes* say
Stop! Pencil down.

TEST 2

Turn to Test 2. Look at the first example. (Pause and check to see that all booklets are turned to the right page.) There are five figures in a row. Four are the same, but one is different in some way. Which one is different from all the others? (Permit an answer) Yes, it's the fourth, and it has been marked for you on your answer sheet.

Now look at the second example. Which is the different one here? (Permit an answer) Yes, it's the third one because that's the only one that is not the same size and shape as the others. When I tell you to start, choose one picture in each row that is different in some way from all the others. Work quickly and carefully to try to finish as many as you can on the two pages before I tell you to stop. Ready? Go!

After exactly *4 minutes* say
Stop! Pencils down.

TEST 3

Turn to Test 3. Look at the first example. There are four boxes in the large square at the left. One of them is dotted and empty. Which of these five boxes over here (Point) will be the right one to fill it? (Pause. Permit answer) Yes, it's <u>3</u>, and it has been marked for you. If we put that one in the empty box it would look right.

Now look at the second example. (Pause) Which one shall we put in the empty box to make it look right? (Permit an answer) Yes, it's the fourth. Fill in the box under <u>4</u> on your answer sheet.

In the third example, you choose the right answer. Which is it? (Pause) Yes, it's the fifth one, so mark the box under <u>5</u> on your answer sheet.

When I say 'Go,' start with number 1, here, just below the line. (Point) Look first at the large square with the four boxes. (Point) Then look at the row of five boxes and pick out the one box that would look right in the dotted empty box. See what number it is and, on your answer sheet, fill in the little box under that number. Do both pages. Work as carefully and as fast as you can. Ready? Go!

After exactly *3 minutes* say
Stop! Pencil down.

TEST 4

TEST 4. Turn to Test 4. Look at the first example. In TEST 4 the box at the top, that's by itself, separate from the others (Point; check), you see that there is a square, and in the square there are a dot and a circle. The dot is outside the circle, but inside the square. Now look over here at the five boxes on the right. (Point) We must find one where we could do just the same: put a dot inside the square, but outside the circle. What about the first one? No, because any dot inside the square would be in the circle too. Would the second do? (Permit answer) No, because a dot in the square would also be in the circle. But the third is all right. The dot was put in to show you that answer <u>3</u> is right. You see the dot is inside the square but outside the circle. (Pause) It's the only one where we can do the same as in the separate box, here. (Point) Now fill in the box under the <u>3</u> on your answer sheet.

Look at the second example. In the separate box at the left (Point), the dot is inside the egg-shaped figure, but over the line. Now we have to find another box where we can do just the same. Which one is it? (Pause) Yes, the second, and that's the only right one. Mark answer <u>2</u> for the second example on your answer sheet.

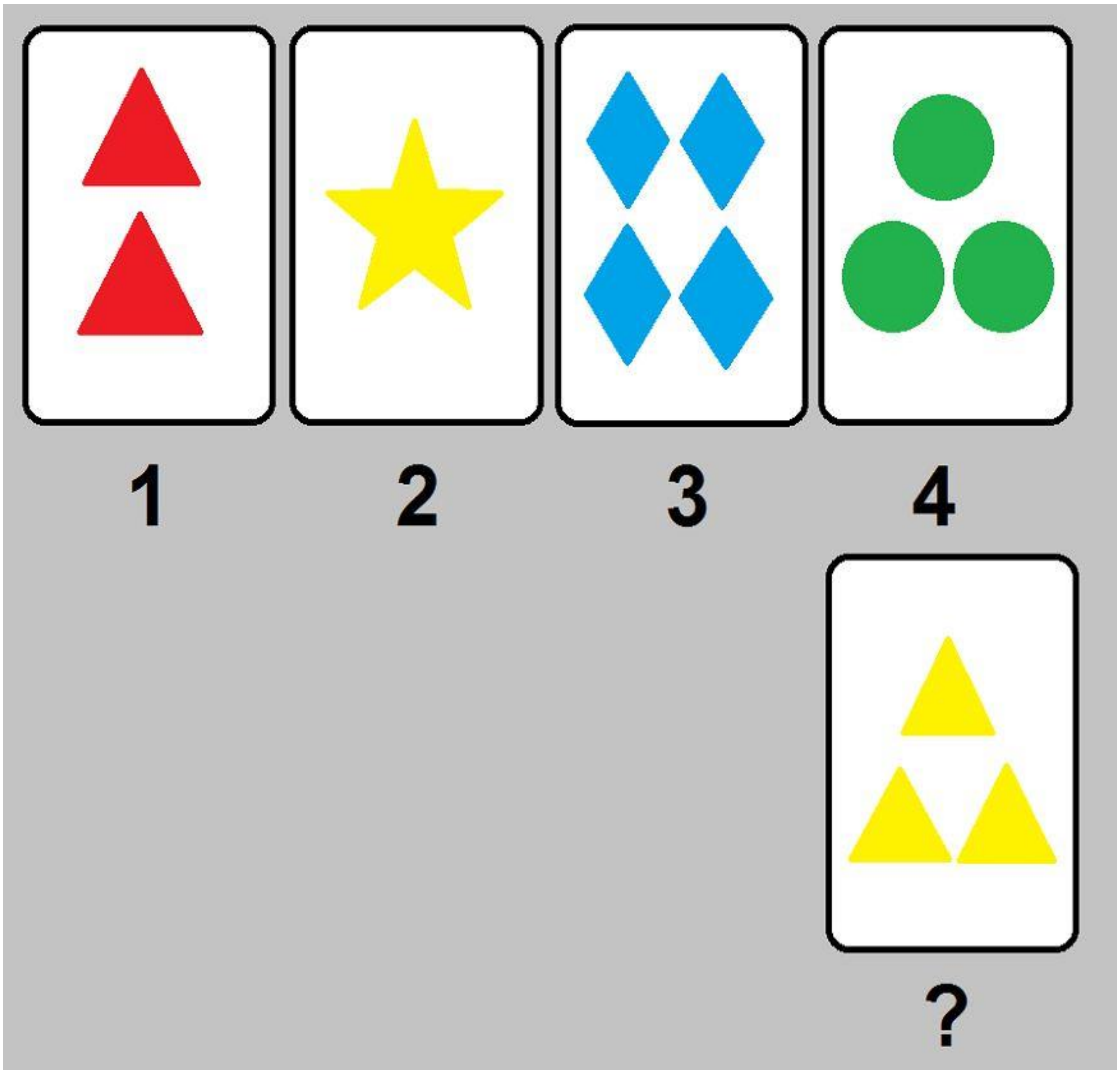
Now, the third example. (Pause) This time one dot must be in both squares at once, but outside the circle. In the first box over here (Point), you could not put a dot in both squares at once and outside the circle. The second one is just as bad. In the third box you could not put a dot in both squares at once, could you? But in the fourth box you can put a dot in both squares that is outside the circle. Mark answer <u>4</u> on your answer sheet.

When I say, 'Go!' start at the first one under the line. (Point) Look carefully where the dot is in the separate box. Then find the box where you could do just the same, and mark that as your answer on your answer sheet. Please do not make any marks on the test booklet.

You'll have almost as much time for this one page as you had for the two pages in the last test. See how many you can do. Ready? Go!

After exactly *2½ minutes* say
Stop! Pencil down.

Appendix 2.8. Wisconsin Card Sorting Test-sample



The WCST is a computer-based test. Instructions are as follows;

You are about to take part in an experiment in which you need to categorised cards based on the pictures appearing on them. To begin you will see four piles (press on mouse button to see the piles).

Each pile has a different number, colour and shape. You will see a series of cards and need to determine the pile each new card belongs in. the correct answer depends on a rule, but you will not know what the rule is. But we will tell you on each trial whether or not you were correct.

Finally the rule may change during the tasks so when it does you should figure out what the rule is as quickly as possible and change with it. Click mouse button to begin.

Appendix 2.9. Digit Span

Digit span test

	Column 1	Column 2
Forward test	(3) 2-6-5 (4) 1-5-2-3 (5) 2-4-7-6-1 (6) 4-2-1-9-3-7 (7) 3-6-4-8-5-2-9 (8) 7-5-8-2-9-6-1-3 (9) 5-8-6-4-2-7-3-9-1	(3) 2-8-1 (4) 1-9-5-2 (5) 5-2-1-4-3 (6) 8-5-3-1-4-7 (7) 6-8-1-4-7-2-5 (8) 2-8-5-9-7-3-1-4 (9) 4-2-5-8-1-3-9-7-6
Backward test	(2) 2-1 (3) 5-8-4 (4) 4-8-9-1 (5) 6-8-7-2-1 (6) 5-8-1-7-4-6 (7) 8-5-3-6-7-2-9 (8) 1-7-4-3-8-9-5-2	(2) 2-8 (3) 3-2-8 (4) 2-9-4-1 (5) 3-5-9-7-6 (6) 4-3-1-9-2-5 (7) 5-3-2-4-1-6-8 (8) 6-8-4-7-5-3-9-2
Maximal digit number for forward test ( ) + Maximal digit number for backward test ( ) = Total score ( )		

The two parts of Digit span-Digits forward and Digits Backward- are administered separately.

Digit Forward

Start with item 1. Say,

I am going to say some numbers. Listen carefully, and when I am through say them right after me.

The digits should be given at the rate of one per second. Let the pitch of voice drop on the last digit of each trial. Administer both trials of each item, even if the subject passes trial 1.

Discontinue after failure on both trials of any items.

Digit Backwards

Start with item 1. Say,

Now I am going to say some more numbers, but this time when I stop I want you to say them backwards. For example, if I say 7-1-9, what would you say?

Pause for the subject to respond

If the subject responds correctly (9-1-7), say,

That's right,

And proceed to item 1. As with digit forward, read the digits at the rate of one per second and administer both trials of each item, even if the subject passes trial 1.

However, if the subject fails the example, say,

No, you would say 9-1-7. Now try these numbers. Remember, you are to say them backwards. 3-4-8

Whether the subject succeeds or fails with the second example (3-4-8), proceed to item 1. Give no help on this second example or any of the items that follow.

Discontinue after failure on both trials of any item

Appendix 2.10. QOLIBRI

QOLIBRI - QUALITY OF LIFE AFTER BRAIN INJURY

In the first part of this questionnaire we would like to know **how satisfied** you are with different aspects of your life since your brain injury. For each question please choose the answer which is closest to how you feel now (includin the past week) and mark the box with an "X". If you have problems filling out the questionnaire, please ask for help

PART 1

A. These questions are about your thinking abilities now (including the past week).	Not at all	Slightly	Moderately	Quite	Very
1. How satisfied are you with your ability to concentrate, for example when reading or keeping track of a conversation?					
2. How satisfied are you with your ability to express yourself and understand others in a conversation?					
3. How satisfied are you with your ability to remember everyday things, for example where you have put things?					
4. How satisfied are you with your ability to plan and work out solutions to everyday practical problems, for example what to do when you lose your keys?					
5. How satisfied are you with your ability to make decisions?					
6. How satisfied are you with your ability to find your way around?					
7. How satisfied are you with your speed of thinking?					

B. These questions are about your emotions and view of yourself now (including the past week).	Not at all	Slightly	Moderately	Quite	Very
1. How satisfied are you with your level of energy?					
2. How satisfied are you with your level of motivation to do things?					
3. How satisfied are you with your self-esteem, how valuable you feel?					
4. How satisfied are you with the way you look?					
5. How satisfied are you with what you have achieved since your brain injury?					
6. How satisfied are you with the way you perceive yourself?					
7. How satisfied are you with the way you see your future?					

C. These questions are about your independence and how you function in daily life now (including the past week).	Not at all	Slightly	Moderately	Quite	Very
1. How satisfied are you with the extent of your independence from others?					
2. How satisfied are you with your ability to get out and about?					
3. How satisfied are you with your ability to carry out domestic activities, for example cooking or repairing things?					
4. How satisfied are you with your ability to run your personal finances?					
5. How satisfied are you with your participation in work or education?					
6. How satisfied are you with your participation in social and leisure activities, for example sports, hobbies, parties?					
7. How satisfied are you with the extent to which you are in charge of your own life?					

D. These questions are about your social relationships now (including the past week)

	Not at all	Slightly	Moderately	Quite	Very
1. How satisfied are you with your ability to feel affection towards others, for example your partner, family, friends?					
2. How satisfied are you with your relationships with members of your family?					
3. How satisfied are you with your relationships with your friends?					
4. How satisfied are you with your relationship with a partner or with not having a partner?					
5. How satisfied are you with your sex life?					
6. How satisfied are you with the attitudes of other people towards you?					

PART 2

In the second part we would like to know **how bothered** you feel by different problems. For each question please choose the answer which is closest to how you feel now (including the past week) and mark the box with an "X". If you have problems filling out the questionnaire, please ask for help.

E. These questions are about how bothered you are by your feelings now (including the past week).

	Not at all	Slightly	Moderately	Quite	Very
1. How bothered are you by feeling lonely, even when you are with other people?					
2. How bothered are you by feeling bored?					
3. How bothered are you by feeling anxious?					
4. How bothered are you by feeling sad or depressed?					
5. How bothered are you by feeling angry or aggressive?					

F. These questions are about how bothered you are by physical problems now (including the past week).

	Not at all	Slightly	Moderately	Quite	Very
1. How bothered are you by slowness and/or clumsiness of movement?					
2. How bothered are you by effects of any other injuries you sustained at the same time as your brain injury?					
3. How bothered are you by pain, including headaches?					
4. How bothered are you by problems with seeing or hearing?					
5. Overall, how bothered are you by the effects of your brain injury?					

Appendix 2.11. The Awareness of Social Inference Test (TASIT)

This test provides a systematic examination of social perception. It uses videos of vignettes to assess (1) emotion recognition, (2) the ability to understand when a conversational inference such as sarcasm is being made, and (3) the ability to differentiate between different kinds of counterfactual comments (lies and sarcasm)

Part 1: Emotion evaluation test

For this test you need (a) the video (A and B), (b) the 5 response cards and (c) the Summary sheet for Part 1(A or B).

Verbatim instructions are as follows:

“You will be shown some short scenes on the video. Each one lasts from 16 to 20 seconds. Please watch each scene carefully. If there are two people on the scene you will be asked to pay particular attention to one. After viewing the scene, you will be asked to point to the emotion from the selection provided, which in your opinion BEST describes the emotion or feeling of the nominated person in the scene.”

Present the practice Response Card

“The emotions you have to choose from are; Sad, Angry, Revolt, Neutral , Happy, Surprise and Anxious. Most of these are straightforward and easy to understand, but it might help if l clarify some of them. For example, look at the word ‘Revolt’. It means the same as ‘disgusted’ or feeling like you might be sick’. Now let’s look at ‘Anxious’. Here, the word ‘anxious’ means anything from feeling very worried about something, right up to feeling fearful or scared about something. Now, look at ‘neutral’. We know that there is really no such thing as neutral emotion. But we have included it for when you think the person in the scene wasn’t strongly showing any of the other emotions.”

“each time you will be asked to identify the DOMINANT or MAIN emotion of the person. If you think the emotion changed during the scene or there was mix of emotions, try to identify the STRONGEST or MOST PERSISTENT emotion present. If you feel there was no particular emotion present, choose the ‘neutral’ response. On occasions you may think there were two strong emotions present. If you find it difficult to choose between the two, point to both emotions, but point to your preference first. If you think the person is SAYING something different from what they are FEELING, answer the question based on what you think they are feeling”.

Ask the person if they have any question and repeat the relevant instructions as necessary. Then say: “are you ready”?

And start the tape, showing the practice Item. Stop the tape after this and prompt the person to select their response from the practice Response Card, saying

“What do you think s/he was feeling”.

If, after viewing the Practice Item, the person chooses “Happy”, record their response on the Summary Sheet and say:

“That’s right. She was clearly looking happy, so the correct response is ‘Happy’.

If they choose an emotion other than “Happy”, record their response and say:

“That’s right. She was clearly looking happy, so the correct response is ‘Happy’.

Ask them to tell you about why they chose another emotion and note their explanation. If they provide a complex convoluted explanation that suggests that they are trying to “psychoanalyse” the actor, instruct them to keep it simple and to choose the emotion that the person him/herself would say they were feeling.

Turn to response card 1 and proceed with item 1. Present Response Card 2 for item 2. Response card 3 for item 3, response card 4 for item 4 and then Response card 1 for item 5. Continue to cycle through the 4 cards for the remainder of the items. After showing each item, ask

“what do you think he (she) was feeling?”

And prompt the person to choose their response from the multiple-choice array on the Response Card, and then record their response on the summary sheet.

NB: prior to each two-person scene (identified in the second column of the summary sheet), cue the person to focus on the actor to whom the question for that item refers- e.g. focus on the woman.

Part 2: social inferences (minimal)

For this test you need (a) the video (A or B) (b) the Social Inference Response Card (c) the response form for Part 2 (A or B) and the summary sheet for part 2 (A or B).

Verbatim instructions are as follows:

"lasts You will be shown some short scenes on the video. Each one lasts from 16 to 20 seconds. Please watch each scene carefully. After viewing the scene, you will be asked to answer four simple questions.

Present the social inference Response card and point to question A.

"the first question will focus on what you think someone is *doing* to the other person, that is, what they are trying to make another person do, think or feel."

Point to Question B

"The second question will ask you what you think someone is trying to say to the other person- that is, what is the message they are trying to get across. Note that this may be different to the actual words they are using. For example, a person may say 'It's hot in here' to mean 'you should open the window'. Point to Question C. "the thid question will ask you what you think someone is *thinking, that is, what is their underlying belief, which may be different from what they are saying.* Point to question D. the fourth question will ask you what you think someone is *feeling* – that is, what is the emotion they are feeling, or how do they feel towards the other person or the situation.

"each time you only need to say 'yes' or 'no', or 'don't know'. If you really can't decide whether the answer is 'yes' or 'no', say 'don't know', but try your hardest to choose either 'yes' or 'no'.

Ask the person if they have any questions and repeat the relevant instructions, as necessary.

Remove the response card and say:

"are you ready?"

And start the tape showing practice item.

Stop the tape after this item and using the Response Form ask the person the four questions relating to that item, circling their response.

Make sure that they answer each of the four questions for the Practical Item. If they have difficulty answering one of the questions, prompt them to choose either "yes" or "no" and if they are unable to decide then prompt them to answer "DK".

Do not give any coaching or feedback on the Practice Item.

Ask all questions for each item.

On completion, transfer response to the Summary Sheet. Correct responses are indicated on summary sheet in bold type.

Part 3: Test of Social inference (ENRICHED)

For this test you will need (a) the video (A or B) (b) the Social inference Response Card (unless part 2 has been given immediately prior (c) the Response Form for part 3 (A or B).

Verbatim instructions are the same as those for Part 2: social inference (minimal above).

If part 3 is being given immediately following part 2, it is not necessary to repeat all the instructions or show the practice Item, as it is the same as those for part 2. Simply say:

"I am going to show you some more short scenes on the video. Again, please watch each scene carefully. After viewing each scene, you will be asked to answer four simple questions, just like you did for the last part of the tape. Ready?"

Ensure that all the questions are answered for each item.

QOLIBRI - QUALITY OF LIFE AFTER BRAIN INJURY

In the first part of this questionnaire we would like to know how satisfied you are with different aspects of your life since your brain injury. For each question please choose the answer which is closest to how you feel now (including the past week) and mark the box with an "X". If you have problems filling out the questionnaire, please ask for help.

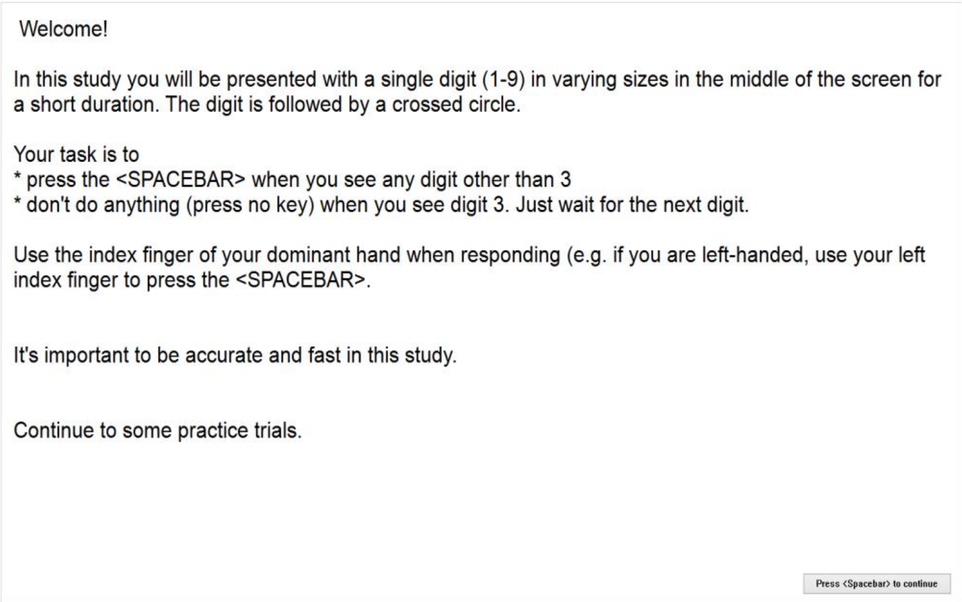
Appendix 2.12. Plus-Minus Task

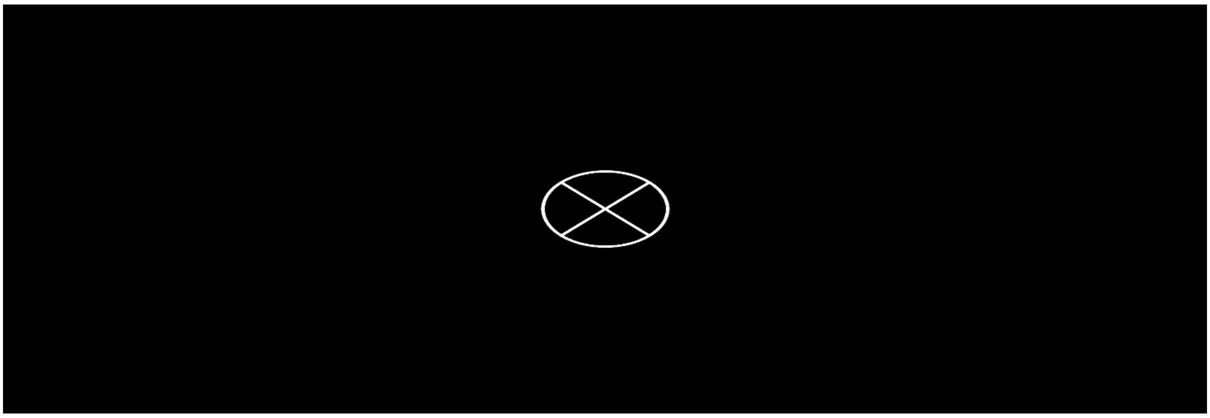
Please add 3 to numbers in list 1; please subtract 3 to numbers in list 2; please alternate between adding and subtracting 3 to numbers in list 3.

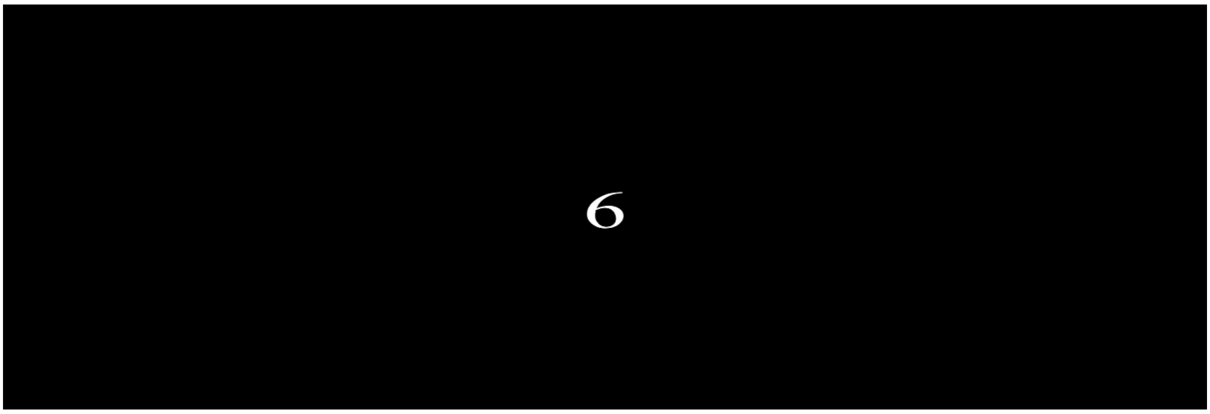
List 1	**List 2**	**List 3**
10_____	11_____	12_____
13_____	14_____	15_____
16_____	17_____	18_____
19_____	20_____	21_____
22_____	23_____	24_____
25_____	26_____	27_____
28_____	29_____	30_____
31_____	32_____	33_____
34_____	35_____	36_____
37_____	38_____	39_____
40_____	41_____	42_____
43_____	44_____	45_____
46_____	47_____	48_____
49_____	50_____	51_____
52_____	53_____	54_____
55_____	56_____	57_____
58_____	59_____	60_____
61_____	62_____	63_____
64_____	65_____	66_____
67_____	68_____	69_____
70_____	71_____	72_____
73_____	74_____	75_____
76_____	77_____	78_____
79_____	80_____	81_____
82_____	83_____	84_____
85_____	86_____	87_____
88_____	89_____	90_____
91_____	92_____	93_____
94_____	95_____	96_____
97_____	98_____	99_____

Appendix 2.13. Sustained attention to response task (SART)

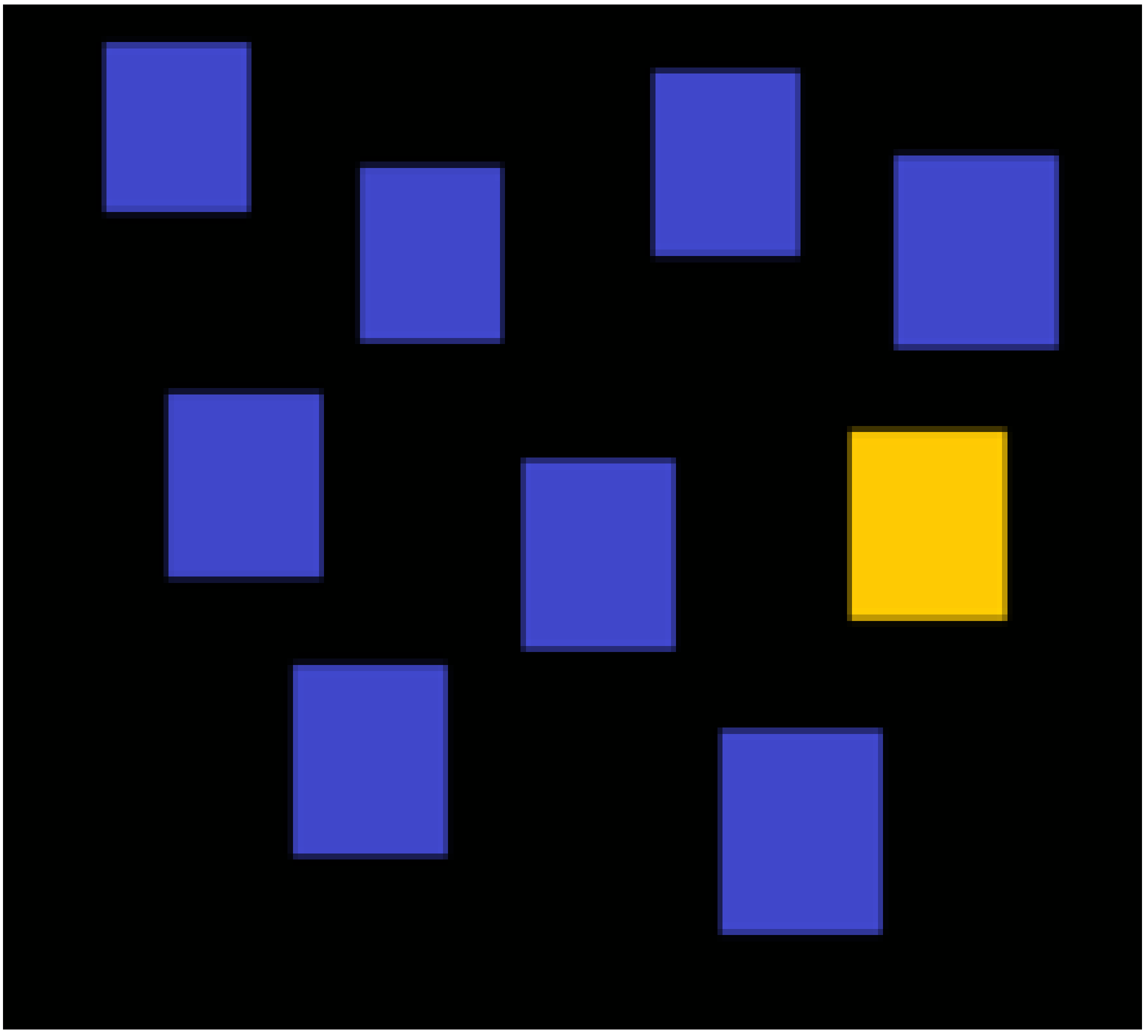
The SART is a computer based test.







Appendix 2.14. Corsi Block-Tapping Test



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This is an example of the computer version of the task. The yellow symbolizes the current block in the sequence.

Instructions:

You are about to take part in a test that measures your ability to remember a sequence of locations on the screen. You will see nine blue squares on the screen. On each trial, the squares will be lit up one at a time in sequence. Remember the sequence. When the sequence is finished, you need to click on each square IN THE SAME ORDER THEY WERE GIVEN. When you are done, click the button labeled DONE. If you cannot remember the order of squares, click them in as close the the original order as you can.
You will start with a sequence of two squares, and you will get two tries for each sequence length. The sequence will increase by one whenever you get at least one of the two sequences correct.
If you are correct, your next list will be one longer; Click the mouse button when you are ready to begin.

You will first perform three practice trials to become familiar with the test. They will not affect your score.

Appendix 2.15. Observer Visual Imagery

An illustration of what one might see when imagining ‘posting a letter ‘ using an Observer (third-person) visual imagery perspective.

Appendix 2.16. Field Visual Imagery

An illustration of what one might see when imagining ‘posting a letter ‘ using an Field (first-person) visual imagery perspective.

Appendix 2.17. Vividness of Imagery

After imagining (observer vs field) PM tasks on the VW task, the participants is asked to verbally respond to the following question, rate how vivid the image was using the five-point scale described below. If you do not have a visual image, rate vividness as ‘1’. Only use ‘5’ for images that are truly as lively and vivid as real seeing. Please note that there are no right or wrong answers to the questions, and that it is not necessarily desirable to experience imagery or, if you do, to have more vivid imagery.

Perfectly clear and vivid as real seeing	5
Clear and reasonably vivid	4
Moderately clear and lively	3
Vague and dim	2
No image at all, you only “know” that you are Thinking of the object	1