Imaging the Effects of Cognitive Rehabilitation Interventions: Developing Paradigms for the Assessment and Rehabilitation of Prospective Memory

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Abstract

Prospective memory (PM), the ability to remember to carry out future intentions and goals following a delay filled with other unrelated tasks is often compromised following brain injury and other psychological and psychiatric disorders affecting the frontal lobes. It has long been acknowledged that patients with frontal lobe lesions can show relatively intact performance in laboratory settings yet their everyday functioning in multitasking situations requiring PM may be severely impaired (Mesulam 1986). The last 15 years has seen a marked expansion into research and theoretical models of prospective memory and its neural basis with the findings from recent neuroimaging studies suggesting that Brodmann's area 10 plays an important role in PM (Burgess et al., 2011).

The aim of this thesis was to develop paradigms for assessing prospective memory that could be used to measure the behavioural and functional changes in the brain following brief cognitive rehabilitation interventions with the first part of the thesis (Chapters 2-4) investigating the convergent and ecological validity of computerised assessment measures of PM in a group of young and older neurologically healthy individuals, as well as in individuals with acquired brain injury. The second part of the thesis (Chapters 5 and 6) investigated the behavioural and neural changes associated with a brief PM intervention developed from the principles of Goal Management Training (Robertson 1996; Levine et al., 2000; 2012) and Implementation Intentions (Gollwitzer 1993; 1996).

Chapter 1 provides a brief overview of the assessment and rehabilitation of PM. Chapter 2 assessed age related changes in performance on the computerised PM tests and a modified version of the Hotel Test (Manly et al., 2002) in a group of young and older neurologically healthy individuals. Both the computerised tasks and the modified Hotel Test (mHT) were found to be sensitive to the effects of ageing. Chapter 3 investigated the effects of a brief break filled with an unrelated task on performance on computerised PM tasks. A brief break was found to have a negative effect on performance with the amount of performance decay correlating with self-reported memory functioning. Chapter 4 assessed the convergent and ecological validity of the computerised PM tasks and their sensitivity to brain injury. The tasks were found to have good convergent validity with the mHT and the CAMPROMPT. The informant- and self-ratings of everyday memory and goal management functioning correlated with task performance in the ABI sample. Chapter 5 investigated whether brief intervention aimed at reducing PM lapses would be successful in improving performance on computerised PM task compared with a control training intervention. Chapter 6 investigated the functional changes in brain activation associated with this brief training. Significant behavioural improvements on the computerised PM tasks were seen following brief training with some evidence of transfer of the effect to a novel task. Significant changes in neural activations within Brodmann's area 10 were seen following brief training in the trained group compared to the control group. The findings have implications for the assessment and rehabilitation of individuals with PM problems and are discussed in relation to cognitive theories of PM.

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Conference Presentations with peer-reviewed publications

BAYLAN, S., Grosbras, M-H, Crabbe, F., Evans, J. (2013). Measuring the Effect of Brief Goal Management Training in Brain Imaging Environment. *Brain Impairment* 14 (2): 293-294.

BAYLAN, S., Evans, J. (2012). Can brief Goal Management Training improve performance on simple computerised prospective memory tasks?: A randomised study. *Brain Impairment* 13 (1): 139-140.

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Posters with peer-reviewed publications

BAYLAN, S., Scott, F., Wood, A., Evans, J. (2012). Assessment of Prospective Memory: a Comparison of Simple Computerised Tasks, and the Modified Hotel Test in the Prediction of Everyday Difficulties. *Brain Injury* 26 (4-5): 470.

BAYLAN, S.M., Evans, J.J. (2011). Oops, It Slipped My Mind: Improving the Assessment of Prospective Memory Using Two-Phase Computerised Tasks. *Brain Impairment* 12, S1: 10.

BAYLAN, S.M., Evans, J.J. (2011). Performance on Simple Computerised Prospective Memory Tasks Predicts Self- Reported Everyday Functioning, *Brain Impairment* 12, S1.

BAYLAN, S.M., Evans, J.J. (2010). Clock Checking as a Marker of Goal Maintenance in a Multi-Element Prospective Remembering Task. *Frontiers in Human Neuroscience. Conference Abstract: The 20th Annual Rotman Research Institute Conference, The frontal lobes*.

Other publications & presentations related to thesis

BAYLAN, S., Scott, F., Wood, A., Jansari, A., Evans, J. (2012). Striving for an ecologically Valid Assessment of Prospective Memory. *Brain Impairment*.

Scott, F., BAYLAN, S., Wood, A., Evans J. (2012). An Investigation into the Ecological Validity of Virtual Reality Measures of Planning and Prospective Memory in Adults with Acquired Brain Injury. *Brain Injury* 26, 4-5: 663.

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Declaration

I declare that this thesis, submitted to the University of Glasgow for the degree of Doctor of Philosophy, is the result of my own research, except where otherwise acknowledged, and that this thesis has not been submitted for a higher degree to any other university or institution.

List Abbreviations

ABI	Acquired Brain Injury
ACS	Activity Card Sort
ADL	Activities of daily living
ANOVA	Analysis of variance
ANCOVA	Analysis of co-variance
APS	Problem solving group
BA	Brodmann area
BADS	Behavioural Assessment of the Dysexecutive Syndrome
BIRT	Brain Injury Rehabilitation Trust
BL	Baseline condition
BOLD	Blood oxygen level dependent
CAMPROMPT	Cambridge Prospective Memory Test
CFQ	Cognitive Failures Questionnaire
DEX	Dysexecutive Questionnaire
EF	Executive Functioning (higher level cognitive functions typically associated with the frontal lobes
EI	Education intervention
ETG	Early training group
FEP	Frontal Executive Program
fMRI	Functional Magnetic Resonance Imaging
FWE	Family wise error
GMT	Goal Management Training
GMTii	Goal Management Training with Implementation Intentions Training
GMQ	Goal Management Questionnaire
JEF[@]	Jansari assessment of Executive Functions
IADL	Instrumental activities of daily living
ISI	Inter stimulus interval
LTG	Late training group
MCI	Mild cognitive impairment
MET	Multiple Errands Test
mHT	Modified Hotel Test
ms	milliseconds

MS	Multiple Sclerosis
MST	Motor skills training
OG	Ongoing condition
OGI	Occupational Goal intervention
PET	Positron emission tomography
PFC	Prefontal Cortex
PM	Prospective Memory
PRMQ	Prospective and Retrospective Memory Questionnaire
PTA	Post traumatic amnesia
RBMT	Rivermead Behavioural Memory Test
RTI-E	Routine Task Inventory – Expanded
rCBD	regional cerebral blood flow
RNL	Reintegration to Normal Living Index
RM	Retrospective memory
SAS	Supervisory Attentional System
SART	Sustained attention to Response Task
SDMT	Symbol digits modalities test
SET	Six Elements Test
SI	Stimulus independent
SIGN	Scottish Intercollegiate Guidelines Network
SO	Stimulus oriented
SRLT	Stimulated Real Life Test
SVC	Small volume correction
TAU	Treatment as usual
TBI	Traumatic brain injury
TE	Echo time
TR	Repetition time
WCST	Wisconsin card sorting test
WTAR	Wechsler Test of Adult Reading

Chapter 1

General Introduction

The central topics of this thesis are assessment and rehabilitation of prospective memory in adults with and without acquired brain injury.

The first part of this introductory chapter will provide an overview to the theory and assessment of prospective memory (PM). The beginning of this chapter will define key terms and describe theories of memory and action relevant to understanding prospective memory functioning. This will be followed by an overview of the neural correlates of PM and the methods used for assessing prospective memory, focussing on tests that allow clinicians and researchers to make predictions about prospective memory functioning in everyday life and to understand prospective memory processes at a theoretical level.

The second part of this chapter will provide a short overview of the rehabilitation of prospective memory focussing on interventions aimed at reducing the effects of prospective memory impairment on everyday functioning. This chapter ends with a summary of the aims of the thesis.

Part I: Theory and Assessment of Prospective Memory

1.1 Prospective Memory in the Context of Executive Functions

Executive or frontal lobe functions are complex cognitive processes underlying many goal-directed behaviours that are necessary for independent everyday living and social functioning. They cannot be described in terms of any single behaviour but rather as a broad concept including several cognitive skills (Evans 2009) or functional domains (Stuss 2008). They encompass decision-making, abstract thinking, planning and the ability to carry out plans (WHO International classification of function). Executive functions (EF) enable an individual to make plans and decisions for the future, problem solve, execute their planned actions at the appropriate moment and monitor their behaviour, particularly in novel and non-routine situations or in situations where the usually performed, routine behaviour is no longer appropriate. Executive functions tend to be associated with the frontal lobes of the brain. Damage to this brain region often results in deficits in one or more of the functions in the EF domain.

The ability to carry out plans is necessary for independent and purposeful functioning. Everyday life frequently involves multi-tasking, the management of multiple goals and tasks that need to be remembered to be carried out but cannot be executed immediately, such as remembering to take medication, collect a parcel from the post office, renew a car tax disk before the current one expires, pass a message onto someone or to remember to buy something from the shops later on. A key cognitive component that is critical for multitasking and successful realisation of these intended actions is prospective memory (PM).

Prospective memory refers to the cognitive processes required to support the fulfilment of an intention to perform a specific action in the future (Ellis and Kvavilashvili, 2001) and involves a range of executive processes, such as planning, disruption of an ongoing activity and initiation of an action (Shum et al., 2002). Intentions that utilise PM cannot be carried out at the point that they are formed, for a variety of reasons (e.g. logistic, social etc.) but their content has to be stored and retrieved for action at an appropriate moment in the future; either at or after X amount of time has lapsed (e.g. at 11am, I will need to remember to phone the dentist), when an appropriate event occurs (e.g. I will need to remember to give photos to Mary when she comes to visit) or following a particular activity (I will need to remember to ask John about X at the end of this meeting). Delayed intentions therefore require maintenance while performing other unrelated tasks, which prevent the continuous rehearsal of these intentions.

Many of our intended actions are ill structured (e.g. I must remember to buy some envelopes soon or I intend to finish this project in two months), lacking a direct cue to remind us to carry out the intended action or requiring the completion of multiple intended actions in the correct sequence at various time points).

1.2 Prospective Memory: Cognitive Processes and Theoretical Considerations

Several different models have been proposed to explain how prospective remembering operates. They all describe a multi-faceted system but vary in the procedural or situational aspects of PM that they try to explain. Those trying to explain the stages of PM generally propose a delay between forming and acting upon an intention (retention of an intention), the need to interrupt ongoing activity in order to complete the intention (initiation) and the absence of reminders to prompt retrieval (execution). Essentially, prospective memory is needed for any event that cannot be completed immediately but needs to be retained to be performed at some point in the future, after engagement in other activities. Therefore, the list of situations that require PM is endless, extending far beyond the most commonly used examples of remembering to attend an appointment or remembering to post a letter.

Burgess, Scott and Frith (2003) provide a useful starting point for the theoretical consideration of the characteristics of typical situations involving prospective memory (Table 1.1) that are useful in understanding the PM mechanism and in separating it from working memory paradigms.

Table 1.1: Features of a typical situation involving prospective memory (adapted from Burgess, Scott and Frith, 2003).

1. There is an intention (novel or routine), or multiple intentions to carry out a mental or physical act
2. The intended act cannot be performed immediately after the intention to do it has been created.
3. The intended act (or thought) is to be performed in a particular circumstance. This is known as the "retrieval context" (Ellis, Kvavilashvili and Milne, 1999). In event-based studies, the retrieval context is signalled by a cue (the "intention cue", or "PM target"). In time-based tasks this is either at a particular time, or following a given duration, and with activity-based PM tasks this is after or during a particular ongoing activity or another task.
4. The delay period between creating the intention and occurrence of the appropriate time to act (the "retention interval") is filled with activity known as the "ongoing task".
5. Performance of the ongoing task prevents continuous, conscious rehearsal of the intention over the entire delay period. Typically this is because the activity is too demanding of competing cognitive resources (e.g. attention), or the delay period is too long. This is a feature which distinguishes a prospective memory paradigm from e.g. some "working memory" or vigilance paradigms.
6. The intention cue (or retrieval context) does not interfere with, or directly interrupt, performance of the ongoing task. Intention enactment is therefore self-initiated, and the participant has to recognise the PM cue or retrieval context for themselves (e.g. rather than receiving a clear interrupt or instruction from an external source).
7. In many situations involving prospective memory no immediate feedback is given to the participant regarding errors or other aspects of their performance.

1.2.1 Stages of Prospective Remembering

Einstein and McDaniel (1990) described two different types of PM - time and event based PM, and later an activity based PM (Einstein and McDaniel, 1996). Time based PM requires performing the intention at a specific time (e.g. at 5pm) or after a period of time has elapsed (e.g. after two weeks). The early work of Ellis (1988) had divided PM into 'pulses' and 'steps' similar to time based PM with pulses being tasks that have to be completed at a specific time (e.g. at 5pm) and carry a greater personal importance, and steps being tasks that can be completed within a wider time frame (e.g. sometime tomorrow). Pulses may require restructuring of daily activities and thus people may be more likely to use reminders for pulses than for steps. Event based PM requires the intention to be carried out in response to an external cue or an event. Activity based PM is similar to event based PM but the external cue coincides with the end of an ongoing activity (e.g. switching off the oven after cooking) and does not require the interruption of the activity. The focus of this thesis will be on event based PM.

Later Ellis provided a framework (Figure 1.1 adapted from Ellis 1996) describing the cognitive processes required for the successful 'realization of delayed intentions' by expanding the two stage model proposed by Einstein and McDaniel (1990) into a five stage model of prospective memory involving (1) intention formation, (2) retention, (3) initiation, (4) execution and (5) evaluation (Ellis, 1996).

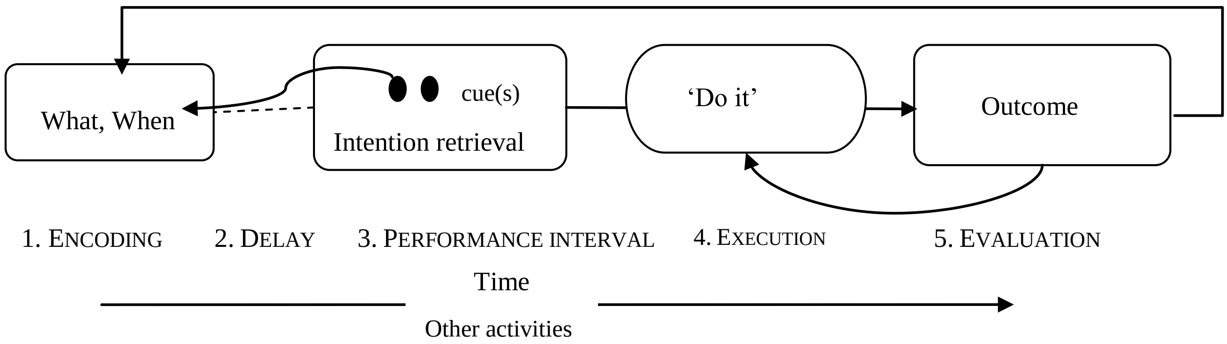

Figure 1.1: Adapted from Ellis (1996).

The Ellis model suggests that (1) unless the intention can be completed immediately, one must either actively rehearse the intention in working memory or encode it in such a way that it is likely to be remembered at an appropriate moment in the future. This requires both the ***content*** (what needs to be remembered) and ***timing*** (when the intention needs to be done) to be remembered. This stage is also known as the retrospective component of PM as described by Einstein and McDaniel. Because the newly formed intention cannot be acted upon immediately the intention must be stored and retained during the delay period also referred to as the ***retention interval*** (2) for later use. Intentions that are well-specified have been shown to be interfered less by other ongoing tasks during the delay period than intentions that are more ill-specified (Hicks, Marsh and Cook, 2005). This thesis will partly examine the extent to which other tasks performed during the retention interval will affect subsequent execution of the intended actions. Roche, Moody, Szabo, Fleming and Shum (2007) suggested that forgetting to act on the intention is more likely with longer retention intervals. (3) The intention must then be retrieved at the appropriate time (e.g. 3pm or after 20mins) or in response to a particular event or cue (e.g. post box when having to remember to post a letter) during the ***performance interval*** (3). This interval can be either short or narrow as suggested by Ellis (1988) and the retrieval can be either self- or environmentally cued. Once the intention has been retrieved it can be executed and the outcome evaluated as the task having been completed. ***Execution*** (4) often requires inhibitory control as ongoing activity may need to be interrupted in order to carry out the intended action. The ***evaluation phase*** (5) requires remembering that the intention has been carried out (e.g.

morning medication has been taken), being incomplete or re-encoded if repetition of the same intention is necessary later (e.g. medication needs to be taken again in the evening). With incomplete intentions, the progress must be monitored (e.g. intending to buy bread and milk on the way home but the store has run out of milk, one has to remember to stop at another store on the way home). Roche (2007) has suggested that patients with TBI experience most difficulties with the encoding, performance interval, and execution phases of prospective remembering.

Ellis also acknowledged that other factors such as motivation, task complexity and familiarity can affect prospective memory. Time based PM tasks task that are given in a way that carry a high personal importance have been shown to result in superior performance compared with intentions that have low personal importance (Kliegel et al., 2001). However, personal importance has been shown to have no effect on performance on event based PM tasks. A later study (Kliegel et al., 2004) however suggested that those event based PM tasks that required more demanding monitoring process and thus higher personal importance resulted in better PM than event based PM tasks with more automatic processing requirements.

Similar to Ellis' (1996) model Glisky (1996) described a PM model that involves four components: (1) forming and organizing an intention, (2) remembering the intention over a delay period, (3) monitoring when and how to execute the intention, and (4) performing the intention and remembering that it has been carried out.

More general models of action are also useful in understanding prospective memory difficulties as they provide a broader framework for understanding deficits and allow for PM processes to be set in the context of everyday actions, of which PM tasks are an important component.

1.2.2 Goal Management Theory

The goal management theory falls within the general executive functions domain and argues that the prefrontal cortex (PFC) is central to organisation and goal management. It is based around the idea that behaviour is organised around a list of goals and sub-goals and makes a distinction between ‘‘active’’ or ‘‘voluntary’’ and ‘‘passive’’ or ‘‘automatic’’ control of behaviour. It argues that individuals have to compare their ongoing behaviour against these lists in order to maintain behaviours directed at achieving their goals. The theory emphasises the importance of the prefrontal cortex in goal formulation, goal selection and goal monitoring (Turner and Levine, 2004). Duncan et al., (1996) introduced the notion of goal neglect, after noting that goal neglect was common in patients with frontal lesions in situations that were novel or that had multiple simultaneous requirements. These patients showed an impairment in their ability to achieve their goal despite being able to understand, state and hold in mind their goals thus showing a discrepancy between their knowledge and behaviour suggesting that the knowledge held on their 'goal list' failed to guide behaviour in an appropriate manner or to activate appropriate behaviour to resolve this discrepancy. They also noted that prompting was effective in reducing goal neglect. This thesis will seek to examine whether older adults and individuals with ABI experience a greater level of goal neglect compared to neurologically healthy individuals in a task requiring holding in mind goals and subgoals.

1.2.3 The Supervisory Attentional System Model

The Supervisory Attentional System (SAS) model of Norman and Shallice (1986), later updated by Shallice and Burgess (1996) (Figure 1.2), is another general theory of how action is controlled. Nevertheless, this model is useful in understanding PM failures and the PM assessment and rehabilitation framework as it proposes that processes in the model involve areas of the prefrontal cortex.

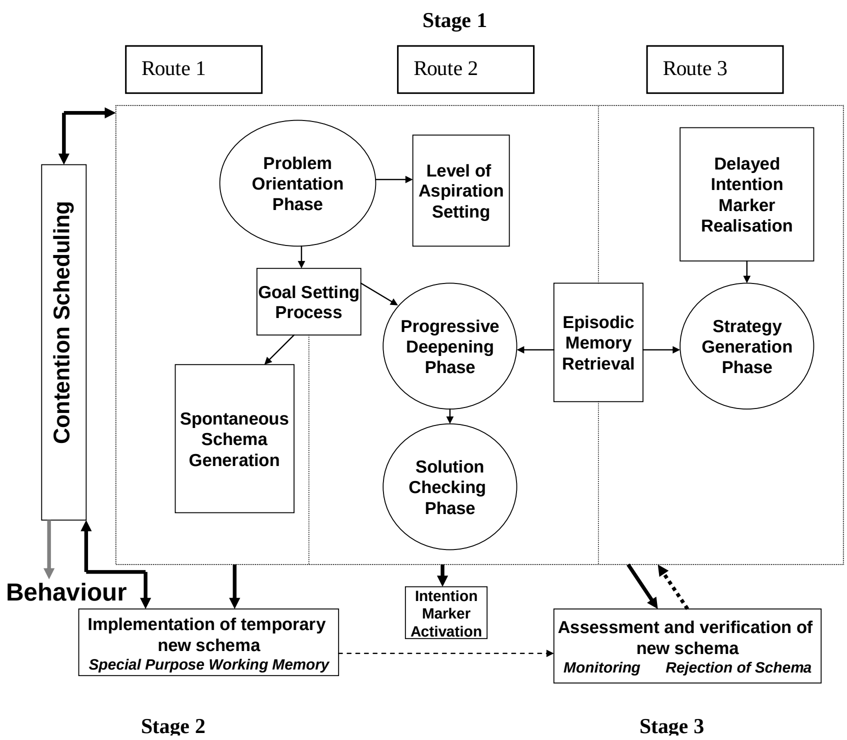

Figure 1.2: SAS model adapted from Shallice and Burgess (1996).

The SAS makes a distinction between the cognitive processes required in novel and routine situations. It suggests that in routine situations actions and intentions can be carried out relatively automatically by a system called ‘contention scheduling’, which draws upon a previously learned schemata and this does not require the use of SAS. They propose that tasks require additional cognitive resources only when they are new, require planning (e.g. when deviation from normal routine is required), or are technically difficult in that no pre-existing schema exists, and therefore a new schema must be formed, implemented and monitored through a Supervisory Attentional System. Importantly, there is an emphasis on the requirement to switch between the two systems and to stop to assess current state in order to achieve the required action.

Formation of the new schema can happen spontaneously, through a problem solving process or through intention generation and realisation (routes 1, 2 and 3 of SAS). The two latter processes require identifying the problem (problem orientation) and setting the goal(s). This provides a quantifiable measure for assessing the outcome of the action. The problem solving process approach involves deeper multiphase processing of the problem than the spontaneous problem solving approach. Based on this model, one would expect that people with impaired PM would show greater impairment on novel tasks since their poor PM would interfere with the later stages of strategy generation, implementation and monitoring but would be less impaired when relatively automatic resources are needed. Further, route 3 is believed to be important in multielement tasks requiring PM given that patients with frontal lesions have been found to show impaired performance on these (Shallice and Burgess 1991).

The use of episodic memory is known to help with identifying a solution to a problem that may require PM through drawing on past experience in dealing with a related but different problem. Patients with TBI are less likely to use episodic memory in problem solving situations compared with healthy individuals, particularly in situations that are low in frequency (Dritshel et al., 1998).

The implementing stage (stage 2) requires a special purpose working memory which stores the temporary schema. It is unclear whether patients’ difficulties may be partly attributable to problems with reduction in working memory ability or greater interference effect from ongoing other activities given that patients difficulties are more pronounced in novel situations compared with in situations that are routine and well rehearsed.

The intention marker activation is related to triggering of an intention created at an earlier stage and could be viewed somewhat similar to cue detection in the Ellis (1996) PM model. This activation will act to interrupt ongoing behaviour when the non-routine intention needs to be acted upon in the future.

The assessment and verification stage (stage 3) of the model is concerned with monitoring of performance. Some patients show difficulties in monitoring and have a tendency to perseverate on a task, break rules or be easily distracted (Burgess et al., 2000).

1.2.4 Stuss Model of Frontal Lobe Functioning

Stuss, Shallice, Alexander and Picton (1995) expanded the original SAS model (Norman and Shallice, 1986) following a review of published literature on attentional impairments following focal frontal lesions. They identified at least four categories of frontal lobe functioning (Energization, Executive, Emotion/Behavioral Regulation and Metacognition) of which each associated with a different PFC region supporting the idea of multiple basic frontal processes. Energization deficits are suggested to be associated with superior medial "(dorsomedial, BA24, 9, and 6)" deficits, Executive functions deficits in the monitoring domain with right lateral deficits "(BA44, 45, 46, 9, 9/46, and 47/12)" and in the Task setting domain in left lateral areas). Emotion and behaviour regulation covers deficits to ventromedial cortex areas "(32, 25, 24, 14, 13, 12, 11)" and results in integration difficulties of the motivational, reward/risk, emotional, and social aspects of behaviors. Perhaps the process most relevant to PM in addition to the Executive category according to the Stuss revamped attentional framework is Metacognition, which is necessary for accomplishing complex, novel tasks with damage to area 10 causing impairments in these integrative/gateway functions (Burgess et al., 2005).

1.2.5 The Gateway Theory

The Gateway Theory proposed by Burgess et al., (2005; 2006b) is an addition to the SAS model (Shallice & Burgess, 1996) and makes a dissociation between stimulus oriented (SO) and stimulus independent (SI) processing providing a more detailed component for the maintenance of intentions. SI processing is where attention is directed towards future goals or internal thoughts (e.g. day dreaming) rather than the environment. By contrast, stimulus-oriented (SO) attending operates when attention is focused towards current external sensory or physical stimuli (Burgess et al., 2007).

Initial evidence for the model came from brain imaging studies showing differential patterns of activation when participants were performing tasks either in response to an external stimuli or 'in their head' (Gilbert et al., 2005). The theory proposes that Brodmann area 10 in the prefrontal cortex acts as a gateway (Figure 1.3) that controls the flow of information between the central representations and outputs of current internal processing (SI) and inputs from currently available external stimuli (SO). This is seen as being equivalent to the adjustment of the position of the 'gates', in order to determine the focus and level of further processing of information by the cognitive system. The operation of the gateway is needed mostly in ill-structured situations that require self-initiation and thus switching between SI and SO approaches. By contrast, the need for the operation of the gateway system will be minimal in well-specified and/or familiar situations. A typical prospective memory task is likely to require both SO and SI processing as one has to hold in mind an intention to do something later (SI, this is likely to rely more heavily on self-generated or maintained thoughts where the current thoughts are not closely linked to or determined by the current ongoing task) whilst performing other tasks (often referred to as the ongoing task) during the retention interval requires attending to the external world (SO processing).

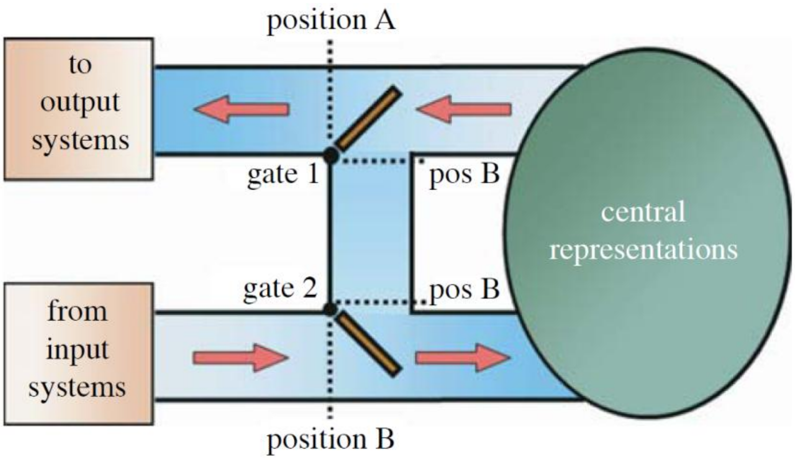

Figure 1.3: 'The Gateway Hypothesis' Burgess et al., (2007)

If both gates at position A, then they suggest that there is no interaction with the external world (stimulus independent thought performed 'in the head') and is believed to be supported by the lateral BA10. On the other hand, if both open at position B, the full attention given to the external world (i.e. fully focused on current ongoing task) with brain activation focusing on anterior medial BA10 regions. And if one gate is at position B and one gate shut then one operates on an autopilot and is likely to be utilising contention scheduling (not fully engaged with the external world). The degree to which the gate is open determines the level of interaction between the external and internal worlds or the switching (‘dynamic moment by moment swinging of the gates’) between current ongoing activity and future intentions stored in the brain for later use associated with lateral BA10 activation (Burgess et al., 2007, Gilbert et al., 2005). Failure in the gate control mechanism or switching between internal and external thoughts may be one way of explaining the PM difficulties following brain injury where patients fail to interrupt their current ongoing behaviour in order to switch to a new task such as remembering to switch tasks in the Hotel Test (Manly et al., 2002).

1.2.6 Multiprocess Theory of PM

The Multiprocess theory of PM (McDaniel and Einstein, 2000; 2007; Einstein and McDaniel 2005) proposes a distinction between monitoring and spontaneous intention retrieval processes. Monitoring is proposed to rely on conscious or more effortful process in some ways similar to that of the problem solving part of the SAS model whereas spontaneous retrieval or the experience of an intention ‘popping into’ mind is proposed to rely on more automatic processes in some ways similar to the contention scheduling part of the Shallice and Burgess (1996) model. The Multiprocess Theory suggests that reliance on a monitoring or spontaneous retrieval process depends on the characteristics of both the PM task and the ongoing task. They also suggest that there is a general bias to rely on spontaneous retrieval but it would not be feasible to rely entirely on the monitoring process given that this utilises working memory resources heavily as people often have multiple, simultaneous PM intentions with the delay period between task formation and execution often being long. They further propose that situations with focal cues (cue that overlaps or is directly linked to information relevant to performing the ongoing task and the specific target event that need to be performed) can be processed automatically through a spontaneous retrieval process system where as non-focal cues (the action that needs to be remembered cannot be directly extracted from the current ongoing activity) require strategic monitoring that has a higher self initiation demand compared with spontaneous retrieval.

1.3 Neural Correlates of Prospective Memory

Evidence from both lesion and neuroimaging studies suggest that the prefrontal cortex plays a part in prospective memory.

Studies investigating PM in healthy individuals using brain imaging technology suggest that the frontal lobes, in particular Brodmann's area 10, play an important role in prospective remembering. Using Positron Emission Technology (PET), Okuda, Fujii, Toshikatsu, Yamadori, et al., (1998) were the first to show that tasks that require prospective remembering activate Brodmann's area 10 in healthy individuals. Later PET studies (Burgess et al., 2001; Burgess et al., 2003; Okuda, Fujii, Ohtake, Tsukiura, Yamadori, Frith, et al., 2007) have also found BA 10 activation during tasks requiring prospective remembering but not on tasks with similar cognitive load. A similar pattern of BA 10 activation has also been found using fMRI (den Ouden et al., 2005) with lateral BA10 showing an increase in activation and medial BA10 decrease in activation (Simons et al., 2006). This pattern of activation has been found regardless of whether or not the intention is acted upon (Burgess, Quayle and Frith, 2001) and regardless of whether the intended action is performed in response to visual stimuli or in imagery (Gilbert, Frith and Burgess, 2005).

Using a human lesion study approach, Burgess et al., (2000) identified a specific brain region where damage was associated with poor performance on ill-structured multitasking situations in the laboratory: rostral prefrontal cortex (RLPFC). The Rostral prefrontal cortex (RLPFC) or Brodmann's area 10, also known as the 'Anterior prefrontal cortex' (anterior PFC), 'the frontal pole' or 'frontopolar cortex' (Burgess et al., 2005), is the single largest region in the human frontal lobes (Cristoff et al., 2001); and covers a much larger area of the brain in humans compared with other animals (Semendeferi et al., 2001). It is also believed to be the last area to achieve myelination (Fuster, 1997) which is in turn is believed to correlate with slowly developing higher cognitive functioning such as theory of mind. The evidence from behavioural studies support later developmental time course in childhood and adolescence with older children outperforming younger children on tasks requiring PM (Ward et al., 2005) The RLPFC also has a much higher number of dendritic spines cells than other brain area (Jacobs et al., 2001) making it a highly connection rich region with connections to deeper subramodal areas (Dumontheil, Burgess and Blakemore, 2008).

The first neuroimaging study investigating the neural basis of prospective memory was only published just over a decade ago (Okuda et al., 1998) and even at the time of starting work on this thesis, only a handful of studies utilising brain imaging methods existed. This thesis will therefore seek to provide further evidence for the involvement of the prefrontal cortex (PFC) in prospective memory using brain imaging methods.

The functions of BA 10 are not understood very well but RLPFC activations are not unique to PM. Activations within this area are often reported on a wide range of tasks and paradigms such as working memory, episodic memory, language and problem solving tasks (MacLeod et al., 1998; Gilbert et al., 2006) making theorising about its function more difficult. Brodmann's area 10 and its role in PM has received more research interest following case and group studies of patients with damage to this area showing impairment in PM functioning (Burgess et al., 2000; Shallice and Burgess, 1991; Uretzky and Gilboa, 2010). Contrast to wide range of paradigms eliciting activation in BA10, patients with damage to this area do not appear to show broad deficits affecting several different domains but rather a specific deficit in multitasking.

Functional imaging studies investigating prospective memory have shown consistent activation in medial and lateral rostral PFC suggesting that these two PFC regions work in concert in situations that place demands on prospective memory.

1.3.1 Specialisation within BA10

The findings from the early imaging studies (Burgess, Quayle and Frith, 2001; Burgess, Scott and Frith, 2003; Okuda et al., 1998) suggested that performance on event based PM paradigms, relative to ongoing task alone, typically show changes in the blood-oxygen-level-dependent (BOLD) signal or increases in regional cerebral blood flow (rCBF) within the rostral prefrontal cortex (approximately BA10). This pattern of activation appears relatively independent from the type of stimuli used, level of difficulty in detecting the PM cue, the nature of the ongoing task or whether PM targets are actually encountered (Burgess et al., 2001, 2003; Simons et al., 2006). Later studies (Gilbert et al., 2009; Hashimoto et al., 2010; Haynes et al., 2007; Poppenk et al., 2010; Reynolds et al., 2009) also support this view as activations in lateral aspects of rostral PFC are typically seen where participants are required to maintain an intention over a delay period while fully occupied with another task. Activations during ongoing or (most) control conditions, on the other hand, tend to be higher in medial regions compared to PM conditions requiring the maintenance of an intention (Burgess et al., 2001, 2003; Hashimoto et al., 2010; Okuda et al., 2007; Simons et al., 2006). Gilbert, Frith and Burgess (2005) suggested that these regions correspond to stimulus independent and stimulus oriented attending proposed by the Gateway theory. They found Medial Rostral PFC (Area 10) activation in the condition where people were using externally displayed stimuli i.e. stimulus-oriented attending compared with when they were asked to do the same task 'in their head', in the absence of external stimuli. By contrast, they found Lateral BA 10 activation at the points where the subjects switched between either condition regardless of the direction of the switch. Small changes in task instruction can also produce differences in participants' approach to the task, their subsequent performance and patterns of activation in rostral PFC (Gilbert et al., 2009).

The results obtained so far, would suggest that lateral and medial rostral PFC regions support a system that works together (Burgess et al., 2007), with anterior medial area 10 activations or changes in the haemodynamic response (environmental attending) being accompanied with lateral area 10 activation (the need to 'bear the PM intention in mind').

This raises a question of whether intentions carried out in response to an event share the same neural basis as intentions carried out at a given time or after a certain amount of time has passed. Okuda et al. (2007) investigated the neural basis of time and event based PM using PET. In their first study participants were required to clench both hands when a given time had passed (time based PM task) while performing another task or in response to seeing the number seven (event based PM task). Decrease in medial BA 10 activation bilaterally was seen during event based PM task in line with Burgess et al., (2003) where as lateral activation was seen in the time based task relative to the event based task. In their second experiment, where participants had a clock available to them in order to remove additional time monitoring requirements, medial aspects of BA10, right superior frontal gyrus (BA9/10) and right anterior cingulate gyrus (BA32/10) showed greater activation during time based tasks compared to event based tasks where as lateral left superior frontal showed greater activation during event based task in relation to time based task. These findings would suggest that the lateral BA10 is involved in event based PM and the medial BA10 in time based PM regardless of whether self initiated time monitoring is required.

1.3.2 Other Brain Regions Relevant to Prospective Memory

In addition to rostral PFC activations typically seen during tasks requiring prospective memory, areas in the posterior prefrontal regions and non-frontal regions are also commonly activated. Activations are frequently seen in BA 7 and 40 (precuneus, parietal lobe), and the anterior cingulate (BA 32) during performance of PM tasks (Burgess et al., 2001; den Ouden et al., 2005; Eschen et al., 2007; Gilbert et al., 2009; Hashimoto et al., 2010; Okuda et al., 1998, 2007, 2011; Poppenk et al., 2010; Reynolds et al., 2009; Simons et al., 2006). It is generally agreed that several neural networks sustain processes that are critical at one stage or another of a PM task but it is not yet understood if and what role these co-activations play in specific subcomponents of a PM task (e.g., maintenance of intention over time, monitoring, switching between ongoing and PM activity, etc.) and the successful completion of intended actions.

1.4 Clinical Relevance of Prospective Memory

Prospective memory failures are the most frequent type of memory failures in daily life reported by the general population (Winograd 1988; Smith, Della Sala, Logie, Maylor 2000) with memory problems in general being the most commonly reported symptom one year after a traumatic brain injury (TBI) (Dikman et al., 2010). Executive functions including prospective memory are often compromised in individuals with altered brain functioning, such as traumatic brain injury, stroke, dementia, multiple sclerosis, as well as following psychological and psychiatric disorders and autism (Altgassen, Williams, Bölte and Kliegel (2009). It is likely that when people talk of “absent mindedness” or having a “poor memory”, they often mean poor prospective memory (Baddeley, 1997).

Luria (1973) described patients with frontal lobe lesions who had impairment in their ability to translate verbal intentions into action. Although, clinical case reports of PM deficits (Ackerly and Benton 1947; Brickner 1936; Eslinger and Damasio 1985; Penfield and Evans 1935) have been around for quite some time but they have only received greater research attention during the last 15 years.

Prospective memory failures are commonly reported in many real-life multi-tasking situations that support independent living, such as meal preparation, shopping, driving management of finances and remembering to do something at a certain time (e.g. attending appointments or remembering to watch a particular TV program). A recent review of studies on medication adherence (Zogg et al., 2012) suggests that prospective memory is an important component of medication adherence with deficits in PM being associated with poorer adherence. The reasons for PM lapses can be many fold because several cognitive processes play a part in PM and following an injury to the brain, more than one PM process may be affected in many individuals.

Understanding impairments in other cognitive domains through neuropsychological assessment may aid in understanding why PM lapses may be occurring and can be useful in informing the rehabilitation process. For example, an individual showing impaired performance on tests of delayed recall may experience prospective memory failures due to their difficulty in remembering the content of their intentions (retrospective component) thus they may require external reminders to compensate for the deficit. On the other hand, individuals with executive deficits may fail to interrupt their ongoing activities, to ensure they execute their intentions at the appropriate moment (Fish, Wilson, and Manly, 2010) and thus a cognitive rehabilitation intervention aimed to support stopping or a prompting device may be more appropriate. It is also important to bear in mind that normal performance on traditional neuropsychological assessments including tests of frontal lobe functioning does not always equate to good functioning in real life. Several cases of apparent disorganization of planned behaviour in real life have been reported in the literature despite normal intellectual ability and performance on a wide range of formal clinical tests of memory, language, motor skills, perception and problem-solving (Shallice and Burgess 1991; Knight et al., 2002; see also Burgess, Alderman, Volle, Benoit, and Gilbert, 2009).

1.5 Assessment of Prospective Memory – Challenges in the Assessment of PM

Despite the fact that most common memory complaints are failures of prospective memory and the fact that they are frequently reported in a range of psychological and psychiatric disorders, this aspect of memory functioning is not often systematically assessed in clinical practice. For neuropsychological assessment to be of value, it is ought to be able to predict functioning in everyday life (i.e. to be ecologically valid) or determine which abilities should be addressed during rehabilitation and/or be able to assess the effects of rehabilitation interventions.

Ecological validity is “the functional and predictive relationship between a patient’s performance on a set of neuropsychological tests and their behaviour in a variety of real world settings” (Sbordone, 1996 p. 228). The ecological validity of assessment tools is important in clinical practice in general but particularly when the assessment process is trying to determine whether the individual is likely to be able to return to work, manage their finances or live independently.

In the past, many neuropsychological tests were developed to assess whether an impairment is present or not (Chaytor and Schmitter-Edgecombe, 2003), and were not designed to provide information about real life impairments. It is now recognised that performance on traditional tests designed to assess frontal lobe or executive functioning does not always seem to predict everyday functioning (Burgess, Alderman, Volle, Benoit and Gilbert, 2009). People with executive deficits may show relatively normal performance on neuropsychological assessments commonly employed in an office or laboratory setting, and yet they may struggle to perform activities such as shopping or taking medication in their daily lives.

Repeated assessment of functioning is common in clinical practice to assess change over time or following attendance on a rehabilitation program. This creates a challenge for the development of ecologically valid tests that allow repeated assessment of functioning without compromising the validity or reliability of the results.

Drawing on the theoretical models such as the SAS and empirical evidence it is known that people experience most difficulty in remembering to complete intentions in novel and unstructured situations. Novelty is therefore necessary for the accurate measurement of the PM functioning and also creates a need to have parallel versions of tests or multiple tests that may look very different but produce similar results (i.e. tests that have convergent validity). Very few studies exist that have systematically assessed the convergent validity different PM assessments. Studies focussing on the assessment of PM presented in this thesis will assess the convergent validity of seemingly very different tests of prospective memory to determine whether or not they produce similar results and are likely to assess the same underlying cognitive ability. Novelty is also important when a clinician is trying to assess the effectiveness of rehabilitation interventions in improving a specific cognitive function, rather than just measuring the effects of practicing a task.

Structure is another challenge in the assessment of PM. Many traditional neuropsychological tests bear little resemblance to the ill-structured, often overlapping activities that characterise modern living and therefore, may serve to mask an existing impairment (Bennett, 2001). Many of the intentions we create lack detail as to when they should be completed (e.g. remember to phone the dentist). By contrast, many of the standard cognitive tests have a single explicit goal prompted by the examiner and well defined instructions (e.g. when you see x, I would like you to do Y) thus these are more likely to load onto the contention scheduling part of the SAS model as opposed to the problem solving part of the SAS as there is no need to structure or prioritise tasks.

1.5.1 Clinical Tests of Prospective Memory

Only a small number of neuropsychological tests designed to be sensitive to PM deficits and ecologically valid have been developed, standardised and validated.

The Behavioural Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson et al., 1996; Wilson et al., 2003) was developed for the clinical assessment of dysexecutive difficulties and to have a better ecological validity than standard neuropsychological tests. The BADS provides a measure of multitasking behaviour and was derived from the Six Elements Test (SET; (Shallice and Burgess, 1991) that originally developed for the assessment of PM in a laboratory setting. The SET requires six simple open ended tasks to be attempted within a given time but the completion of all tasks would take much longer than the time available thus requiring patients to switch between tasks. Patients have a tendency to spend more time on individual tasks and attempt a fewer number of subtasks than healthy controls (Shallice and Burgess, 1991). The BADS is widely used in the clinical practice and poses relatively good ecological validity as measured by the Dysexecutive Questionnaire (DEX) but is limited in its ability to predict everyday functioning (Wood and Liossi, 2006) and has a limited range of scores to provide a good understanding of multitasking difficulties.

The Rivermead Behavioural Memory Test (RBMT; Wilson, Cockburn, and Baddeley, 1985) is a well established test of everyday memory functioning with the current version including prospective memory items embedded within other memory tasks (RBMT-3, Wilson, Greenfield, Clare, Baddeley, Cockburn, Watson, Tate, Sopena, Nannery and Crawford 2008). Both current parallel versions of the test also possess good ecological validity with the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000) ($r = -.43$ and $r = -.44$). A disadvantage of the RBMT is that there are too few tasks (remembering to deliver a message, to ask for the return of a belonging and to ask the date of an appointment) to form a good picture of an individual’s PM functioning and to generate a range in performance needed for empirical studies. More recently the original RBMT subtests were expanded into the Cambridge Prospective Memory Test (CAMPROMPT, Wilson et al., 2005). Although the CAMPROMPT shares a modest correlation with the RBMT ($r = .38$) and self-reported everyday memory failures (Wilson 2004), convincing evidence that it predicts everyday PM performance is to date lacking.

1.5.2 Multi-element and Process Based Tests of Prospective Memory

The successful completion of PM tasks relies on a prospective memory component (being able to retrieve the intended action/plan at the right time and/or place e.g. phone the dentist at 9am tomorrow morning) and a retrospective component (being able to remember the content of this intention e.g. who to phone). In real life, our intentions are often embedded in an environment more akin to multitasking and often multiple intentions need to be retained in mind at any given time with each having to be remembered to be completed at a different point in the future This may imply that to be ecologically valid, tests of PM should also be set in situations of similar complexity to everyday life. Several paradigms that aim to closely reflect everyday multitasking environment have now been devised. Many of these tests are yet to be validated or standardised for clinical use. These multitasking tests differ from most dual-tasks or task-switching paradigms in that only one subtask is attempted at any given time and switching between task often has to be self-initiated without the appearance of a cue (unlike most task-switching paradigms). Tests such as the Six Element Test (SET), the Multiple Errands Test (MET), the Greenwich test, or the Hotel Test (Shallice and Burgess, 1991; Burgess, Alderman, Evans, Emslie, and Wilson, 1998; Burgess et al., 2000; Manly et al., 2002 respectively) are examples of these.

Shallice and Burgess (1991) were the first to formally identify and quantify the deficits in planning and intentionality (i.e. goal directed behaviour) experienced by patients with prefrontal lesions, who were otherwise unimpaired on tests of executive function. They did this by creating two relatively ill-structured tests: the Six Element Test (SET) suited for use in the laboratory described earlier and the Multiple Errands Test (MET), a shopping task, carried out in a pedestrian precinct. Performance on these tests was shown to be a good predictor of planning and multitasking difficulties in everyday life. The MET requires participants to complete eight tasks where they are to organise their own behaviour around a set of rules rather than follow step by step instructions given by the experimenter. Six of the given tasks are simple (e.g., buy a brown loaf, buy a packet of throat pastilles), one requires them to be at a certain place 15 min after starting and one requires four sets of information to be obtained and written down. The tasks are to be completed in as little time and with as little money as possible. No task order or detailed instructions on how to approach these tasks are provided other than rules that state that participants are not to use anything not bought on the street (other than a watch) and that no shop should be entered other than to buy something. Tests carried out outside the laboratory such as MET can be better at detecting PM difficulties but are less controlled, more difficult and time consuming to administer particularly in clinical practice than tests carried out in the laboratory.

Alderman, Burgess, Knight and Henman (2003) created a simplified version of the Multiple Errands Test (SV-MET) in order to increase its sensitivity and clinical utility. The SV-MET was administered to 46 neurologically healthy individuals and 50 patients with brain injury. The majority of the patients had their injury classed as 'severe'. Many of them passed traditional tests of executive function (Cognitive Estimates, Verbal Fluency and Modified Wisconsin Card Sorting Test) yet showed below normal performance on the SV-MET and experienced dysexecutive difficulties in daily life. Alderman et al., (2003) found that patients committed a greater number of task failures and rule breaks (particularly social ones) than healthy controls and that those rule breaking were more likely to show executive difficulties in real life where as those failing to achieve tasks were more likely to experience negative affect. The Hotel Test (HT), that is similar in nature to the SET. The HT requires participants to do some of each of the five different subtasks and complete a time based prospective memory task at two set times during a period of 15 minutes. Their overall goal is to try and do some of each of the subtasks. Because it is not possible to complete all these tasks within this time limit subjects should switch between tasks and keep track of their intensions. The HT has been shown to be problematic for patients with real life dysexecutive impairment (Manly et al., 2002) and more recently for those with frontal lobe lesions compared with patients with non frontal lesions (Roca et al., 2011).

The last few years have seen an increase in the development of complex multi-element tests of PM such as the Executive Secretarial Task (EST; Lamberts, Evans and Spikman, 2010) and the Virtual Week (Rendel and Craik, 2000). Many of these tasks such as the JEF© (formerly JAAM©; Jansari et al., 2004), the library task (Renison et al., 2012) and the VMALL; Rand et al., (2009) utilise virtual reality methodology. This is now seen as a more ecologically valid and controlled way of assessing PM in a research context compared with standard laboratory based tabletop tasks. Recent years have also seen a move towards more precise PM assessment in that many of these tasks have further attempted to fractionate performance by trying to measure PM component processes in the context of a complex, dynamic multitasking environment more akin to everyday life. Together these findings would appear to support the view that multitasking tests are better at capturing real life difficulties compared with traditional tests.

Complex multitasking tests such as the MET require several executive functions and can be useful in demonstrating that an impairment exists but tasks such as the Greenwich test has attempted to go further by breaking tasks into subcomponent such as planning, rule following and PM in addition to an overall test score. Using a lesion study approach, Burgess et al. (2000), showed that patients with left prefrontal lesions failed to do what they intended to do, despite being able to learn the task rules, form a plan, remember what they had done, and say what they should have done. In other words, suggesting that their impairment was mainly in the PM subdomain of multitasking. Contrary to this, lesions in the right dorsolateral frontal areas were associated with planning deficits. And lesions in posterior medial brain regions, gave deficits in all measures except planning. Umeda et al. (2011) also identified right dorsolateral prefrontal cortex (BA9 and superior parts of BA10 and BA46); the right ventromedial prefrontal cortex (BA11 and inferior parts of BA10); and the left dorsomedial prefrontal cortex (BA9 and the superior parts of BA10) being areas contributing to PM performance using patients with focal damage to frontal or temporal lobe following TBI.

An opposite assessment approach to complex multielement tasks is the use of short and simple computerised tasks that have been used to assess PM in healthy individuals (Einstein and McDaniel 1990; Einstein, Smith, McDaniel, & Shaw, 1997; Burgess et al. 2001, 2003). These tasks try to imitate the demands of real life situations by asking subjects to maintain an intention while doing something else and then to retrieve it at the appropriate moment. In these tasks, participants are typically asked to perform some ongoing activity (e.g. rating the pleasantness of words) and instructed to perform an action whenever a target event occurs (e.g. a pre-determined word).These tasks claim to tap into the ‘purer’ PM processes, lack the complexity of the multitasking environment and lend themselves to brain imaging methods. Some of these tasks (Burgess et al., 2001, 2003) have been shown to activate regions in the PFC (Brodmann’s area 10) shown to commonly be damaged in individuals showing impairments in the PM component of multitasking (Burgess et al., 2000). Because of their simplicity they may be more sensitive in pinpointing deficits in different aspects or process of multitasking as opposed to complex tasks which can be failed for many reasons.

The ecological validity of these simple computerised PM tasks has not been investigated before. One aspect this thesis will be assessing is the ecological validity of these simple computerised tasks in neurologically healthy individuals and in individuals following injury to the brain. Their convergent validity with other complex multielement tasks such as the Hotel Test and CAMPROMPT will also be assessed. Further, their suitability of assessing the effects of brief cognitive interventions aimed at improving PM functioning will be assessed. If deemed suitable, they will then be used to measure behavioural and neural changes following a brief cognitive intervention in neurologically healthy individuals.

The process based approaches have the potential to help in the understanding of the neural correlates and processes involved in PM, inform both the neuropsychological assessment and the later rehabilitative efforts in individuals suffering from PM deficits.

1.5.3 Questionnaire Measures of Prospective Memory

Questionnaires, such as the Prospective and Retrospective Memory Questionnaire, PRMQ, (Smith et al., 2000), Prospective Memory Questionnaire (Hannon et al., 1995) and Comprehensive Assessment of Prospective memory, CAPM (Waugh 1999; Roche et al., 2007) are another way of assessing PM. They all use a Likert rating scale to gain a better understanding of an individual's memory functioning in real life in contrast to performance on tests completed in the laboratory. The PMQ was the first questionnaire developed to specifically assess PM. The PMQ consists of 52 items on four subscales (short-term habitual PM, long-term episodic PM, internally-cued PM, and techniques to remember). The CAPM has three scales measuring the frequency of PM failures (39 items), the perceived amount of concern about these memory failures (same 39 items) and the reasons associated with the success or failure of PM tasks (15 items). The PRMQ provides a measure of both individual's prospective (16 items) and retrospective memory (16 items) functioning in addition to an overall score and subscales measuring self and environmentally cued memory.

Although questionnaire measures of PM are fast, cheap and easy to administer they may be uninformative when given to individuals with brain injury unless patients own ratings are complemented and compared with ratings done by a significant other, as patients with severe injury may lack insight and not be aware of their own difficulties resulting in (over or) underestimation of their PM difficulties (Roche, Fleming and Shum, 2002). Lack of awareness of one's own PM difficulties may also be evident on performance on multi-element tasks of PM. Alderman, Burgess, Knight and Henman (2003) found that patients who performed poorly on the SV-MET also tended to rate themselves as having fewer executive problems in everyday life, when in fact the opposite was true. However, both own and significant other rated questionnaires have shortfalls in that they rely on subjective and often retrospective reports of functioning. Another reason why they may not always provide a full picture of real life dysfunction is that many do not take into account the environmental demand individuals have in their lives and the extent to which they can compensate for their deficits. In research, questionnaires are often employed as a measure of ecological validity with performance on tasks correlated with scores on the questionnaires.

This thesis aims to assess the usefulness of questionnaires in assessing the ecological validity of several different tests of prospective memory.

All of the assessment tools have the potential to inform the rehabilitation process in one way or another when used together with other clinically relevant information.

Part II Rehabilitation of Executive Dysfunction: Prospective Memory

1.6 Aims of Rehabilitation

Neuropsychological rehabilitation (NR) is concerned with the amelioration of cognitive, emotional, psychosocial, and behavioural deficits caused by an insult to the brain (Wilson, 2008). The main purposes of cognitive and neuropsychological rehabilitation is to enable people to return to their own most appropriate environment by reducing the impact that cognitive disabilities have on activities that need to be performed, help people to achieve their optimum physical, psychological, social, and vocational well-being and to maximise their independence in daily life (Wilson 2008; Cicerone et al., 2000; McLellan, 1991). For this reason, being able to use cognitive assessment tools that are good at predicting cognitive, psychosocial and emotional functioning in everyday life in the initial assessment process has value in informing the goal setting process for vocational, recreational, social and independent living rehabilitation goals, subsequent rehabilitation approaches and evaluation of any progress made.

It is now recognised that neuropsychological and cognitive rehabilitation can be of value as well as effective and beneficial for the overall recovery and quality of life after acquired brain injury (Cicerone et al., 2000; 2005; 2011; Rohling et al., 2009). However less is known about specific interventions aimed at enhancing cognitive functioning particularly in the executive function domain.

People who are given intensive rehabilitation have an improved likelihood of returning to work (Wilson, 2008). Cicerone's 2011 systematic review of the literature for TBI and stroke concluded that there is now substantial evidence to support interventions for attention, memory, executive function, and comprehensive-holistic neuropsychological rehabilitation. Based on the review, the use of metacognitive strategy training was recommended as a *Practice Standard*[1] for people with deficits in executive functioning after TBI. For memory, the use of compensatory strategy training was recommended as a P*ractice Option*[3] for those with mild memory impairment and errorless learning techniques

[1]. Practice Standards are based on at least 1, well-designed class I study with an adequate sample, with support from class II or class III evidence, that directly addresses the effectiveness of the treatment in question, providing substantive evidence of effectiveness to support a recommendation that the treatment be specifically considered for people with acquired neurocognitive impairments and disability (ANID)

[2]. Practice Guidelines are based on 1 or more class I studies with methodological limitations, or well-designed class II studies with adequate samples, that directly address the effectiveness of the treatment in question, providing evidence of probable effectiveness to support a recommendation that the treatment be specifically considered for people with ANID.

[3]. Practice Options are based on class II or III studies that directly address the effectiveness of the treatment in question, providing evidence of possible effectiveness to support a recommendation that the treatment be specifically considered for people with ANID.

for those with severe memory impairments after TBI. External aids, such as pagers, were also noted to benefit those with moderate to severe memory impairments after TBI. The review makes no distinction between different types of memory however, it was noted that the presence of a significant executive dysfunction appeared to limit the effectiveness of external aids and were recommended as a Practice *Guideline*[2] after TBI or Stroke.

Traumatic brain injury (TBI) and stroke are the two biggest causes of brain injury in adults. It is estimated that TBI affects an estimated 10 million people worldwide annually (Koechler et al., 2011) and around 15 million people each year are estimated to suffer a stroke (WHO, 2004). Due to advances in health care and medical treatment, more individuals are surviving their injuries, requiring cognitive rehabilitation services, and living with long-term disabilities. Strokes alone have a high economic cost associated with them, costing the UK economy just over £2.5 billion in health and social care costs (year 2006/07), with a quarter of a billion pounds in Scotland (BHF stroke statistics). Most of this cost (over 80%) comes from hospital and residential care, reflecting the long length of rehabilitation needed post stroke

1.7 Cognitive Rehabilitation Mechanisms

1.7.1 Restorative versus Compensatory Approaches

One theoretically important question in rehabilitation is whether to try to restore lost functioning or to try to compensate for deficits. Restorative approaches aim to directly improve impaired cognitive functions by strengthening or restoring lost or impaired functions. By contrast, compensatory approaches aim to find ways around the deficit through the use of alternative strategies that can be employed to carry out daily activities.

[1]. Practice Standards are based on at least 1, well-designed class I study with an adequate sample, with support from class II or class III evidence, that directly addresses the effectiveness of the treatment in question, providing substantive evidence of effectiveness to support a recommendation that the treatment be specifically considered for people with acquired neurocognitive impairments and disability (ANID)

[2]. Practice Guidelines are based on 1 or more class I studies with methodological limitations, or well-designed class II studies with adequate samples, that directly address the effectiveness of the treatment in question, providing evidence of probable effectiveness to support a recommendation that the treatment be specifically considered for people with ANID.

[3]. Practice Options are based on class II or III studies that directly address the effectiveness of the treatment in question, providing evidence of possible effectiveness to support a recommendation that the treatment be specifically considered for people with ANID.

1.7.1.1 Restorative Approaches

Restorative approaches tend to utilise intensive and repetitive “exercise-like” tasks that gradually increase in their difficulty or processing demand for a given function. Restorative approaches are based on a Hebbian theory (Hebb, 1949) suggesting that repetitive activity facilitates neuroplasticity. This argues that connections in the underlying neural circuitry are being strengthened with repeated use of a particular cognitive process which then leads to an increase in the ability to perform that task (Kolb, Cioe and William, 2011). Some have suggested that restitution can only occur if there is a sparing of a minimum proportion of cells or connections (Robertson and Murre, 1999) and if more than the critical proportion of cells is destroyed then compensatory approaches are needed to achieve improvement in function (Wilson, 2005). The benefit of restorative approaches is that if restoration in the underlying cognitive ability truly occurs, then all of the activities requiring this underlying cognitive skill should be likely to improve.

Sohlberg, White, Evans and Mateer (1992) assessed the usefulness of repeated prospective memory training in a patient following haemorrhagic brain injury. He was trained to carry out a two stage motor command (e.g. Close your eyes and clap your hands) after certain number of minutes had lapsed whilst performing another task. A watch was available for him to use. Following initial training, he was given PM tasks (e.g. taking medication or taking a dish out of the oven) to complete out with training sessions with the delay interval between being increased from one minute to six minutes greater than his current PM ability. Training was successful in increasing his PM retention interval from 5 minutes to 12 minutes. However, given that this improvement came about from over five months of training with 3 sessions per week and did not have great nor lasting generalization effect to tests of memory and to real life situations it cannot be said to have been effective in improving the underlying PM ability.

More recently Raskin and Sohlberg (2009) trialled a prospective memory training programme designed to increase the length of time that people were able to hold their intentions in mind demonstrating an improvement on neurospsychological measures and a standardised measure of prospective memory. Following training improvement was also seen on a generalisation measure of prospective memory in daily life.

Until very recently it has been impossible to determine whether ‘true’ restoration of function has occurred or whether behavioural improvements have become routine as there has been no window to see into the brain. Current brain imaging technologies now offer that window that may shed more light to the neural changes occurring in the brain following rehabilitation efforts although understanding of these changes is still in its infancy.

In 1999, Robertson indicated that there was no evidence for direct and lasting improvement of memory through restitution-oriented therapies and thus compensatory approaches to memory problems are the treatment of choice until such a time when evidence for restitution exists. However, Evans (2006) noted that this conclusion is largely based on the lack of evidence for the effectiveness of restitution based therapies rather than on evidence suggesting that restitution oriented therapies are ineffective.

1.7.1.2 Compensatory approaches

In contrast to restorative approaches, compensatory approaches do not aim to restore lost function but rather aim to use compensatory strategies or aids in order to deal with the impairment caused by the underlying brain pathology. Compensatory approaches, in particularly the use of external aids, are currently the most commonly used method of addressing PM deficits in clinical practice when the individual has sufficient environmental demands to need to remember to do something. Compensatory approaches can be divided roughly into two main types. They can be either *internal*, where a person learns to use mental strategies, or *external*, where a person adopts the use of passive or active aids.

Given that remembering future intentions is more difficult that remembering past events, even most neurologically healthy people rely on external memory aids that acts as cues to memory for remembering to do things.

Passive external aids such as calendars, diaries, lists, post-it notes, timetables and Dictaphones, rely heavily on the person remembering to use or check them which itself is a prospective memory task. Active aids such as Neuropage®, pagers, mobile phones and Google calendar, on the other hand, send the user active reminders that attract their attention and instruct them to carry out specified actions at the appropriate time making them more suited for those with more severe impairment. Research has generally found external aids to be effective in helping people with memory impairment complete everyday activities (Sohlberg et al., 2007) with active reminders being more effective than passive aids (Giles and Clarke-Wilson, 1993).

Although external aids are useful for specific prospective memory tasks (e.g., appointments), they are limited in their flexibility as some require pre-programming while others need to be frequently consulted and may not always available when the intention is formed or when the intended action must be performed. The use of external aids may be particularly difficult for prospective memory tasks that need to be performed after a relatively short period on the same day making recording of all PM actions that must be done each day rather time consuming (e.g. put the kettle on after having made a phone call). Consequently, internal cognitive strategies for improving prospective memory following mild to moderate brain injury may provide an avenue, which can be complementary to external compensatory strategies. More severe impairments are still likely to require the use of active external aids. For example patient R.P showed marked improvement in performance when external prompting was used rather when a passive aid was employed as a compensatory strategy (Evans, Emslie and Wilson 1998; Fish, Manly and Wilson, 2008).

A challenge in the use of internal strategies is the ability of treatment effect to translate to behavioural gains on real-world tasks. Traditionally compensatory strategies tended to be designed around important activities rather than around the impairment itself offering solutions at a task level. Recently, there has been a more towards designing interventions based on theoretical models of cognition

1.8 Cognitive strategies for improving prospective memory

Many of the theoretical models relevant to understanding the assessment of PM and PM processes in general are also relevant to understanding the rehabilitation of PM.

Most people receiving rehabilitation following brain injury have both cognitive and non-cognitive problems. Given that a typical patient in a rehabilitation centre will have several cognitive problems such as poor attention, memory, planning, and organisational difficulties together with some emotional problems such as anxiety, depression, they are likely to need more than one rehabilitation intervention to deal with their cognitive impairments as well as support for their family and dealing with issues connected with the continuation of their work or psychological well being.

Goal Management Training (GMT) is the most researched theoretically driven evidence based treatment approach for improving prospective memory. GMT's evidence base is slowly finding its way to clinical practice guidelines in Scotland[4] and reviews on the effectiveness of cognitive rehabilitation therapies for traumatic brain injury (Koechler, Wilhelm and Shoulson, 2011).

1.9 Goal Management Training

1.9.1 Theoretical framework of GMT

Goal management training (GMT), a structured, cognitive rehabilitation technique, was developed by Ian Robertson, Brian Levine and Tom Manly (Robertson, 1996; Levine, Manly and Robertson, 2012) to help patients with frontal lobe lesions to manage goals that they otherwise neglected in their day to day lives. GMT was developed around theories frontal lobe functioning and draws mainly on Duncan et al.'s (1996) theory of goal neglect. GMT consists of five stages (Figure 1.4) and works through getting individuals to think, review and monitor their goals more efficiently through a better cognitive strategy and using mental imagery. GMT may be the first theoretically driven rehabilitation intervention with a clinical evidence base designed for patients suffering from significant day-to-day impairment due to poor decision making, attentional slips, and judgement errors.

The failure to STOP and being aware of what one is doing is a main source of real-life executive problems for patients as well as for healthy adults (GMT information leaflet, 2012). Step 1 of GMT (Figure 1.4) encourages one to stop and think about what they are doing or going to be doing. The STOP concept is very simple yet powerful. Once STOPping is established patients learn how to DEFINE (step 2) their goal (in relation to other competing goals) by deciding what the task is and what would be a desirable outcome. Once the goal is selected, if necessary, this can be split into more easily manageable sub-goals by LISTing the required steps to achieve the overall goal in step 3 (i.e. what are the steps I need to take to achieve my goal?). Step 4 is concerned with LEARNing and reviewing the steps created earlier until they have been successfully learned (a). STOPping is then employed to monitor behaviour over time (Step 5) by comparing whether current progress matches with the desired goal (b). If these two don't match the whole process is repeated (c). GMT encourages the use of visual imagery through the use of the mental black board (step 5).

[4.] Scottish Intercollegiate Guidelines network (SIGN) guidelines (2013) recommend that Patients with TBI and deficits in executive functioning should be trained in meta-cognitive strategies relating to the management of difficulties with planning, problem solving and goal management in personally relevant functional situations.

The mental blackboard works as a sort of a ‘ to do list’ in the head that allows people to mentally write their intentions on it and periodically check it in order to prevent information being replaced, faded, rubbed off or pushed away by new material from their blackboard.

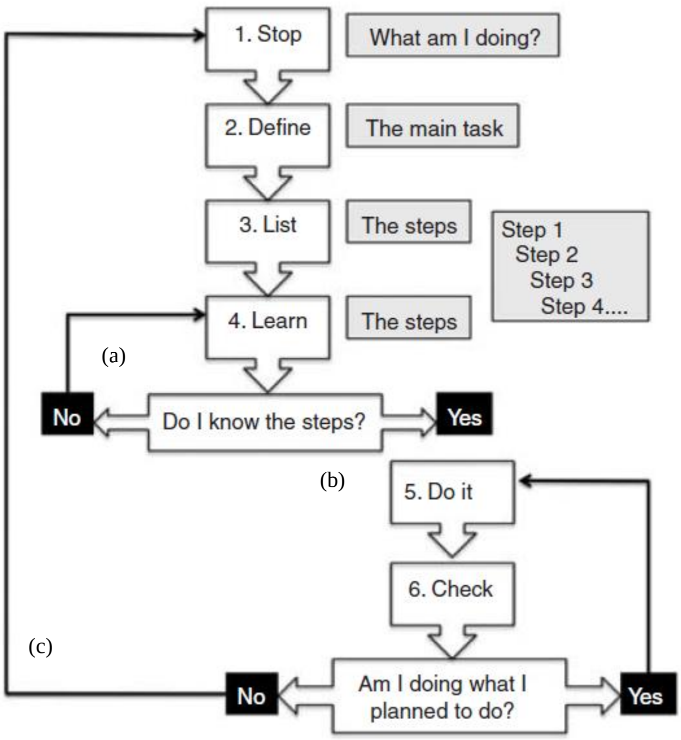

Figure 1.4: GMT framework (McPherson et al., 2009)

Kardiasmenos et al. (2008) reported that visualisation together with implementation intentions improved performance on a laboratory task of PM in a group of 24 patients with MS. The MS group rarely reported visualising during the task unless they had been instructed to do so.

1.9.2 Evidence for the efficacy of GMT

1.9.2.1 Patient groups

Levine et al. (2000) were the first to test the test usefulness of GMT. Thirty patients with mild to severe TBI (3-4 years post injury) were randomly assigned to GMT or to a motor skills training (MST) group that included mirror reading and mirror tracing training. Groups were matched for injury severity, age and education level. Both groups were tested on everyday paper- and pencil tasks that were designed to mimic unstructured situations known to be problematic for people with TBI. All tasks required holding goals in mind, performing subgoal analysis and monitoring. Patients assigned to GMT showed significant improvement on laboratory paper and pencil tasks whereas patients assigned to the MST group did not. Despite showing an improvement in laboratory tests of PM this study did not address how well this would generalise to improvements in real life tasks.

Levine et al. (2007) addressed this issue in a second study where GMT was administered to a 35-year-old postencephalitic patient K.F in order to see if it could be used to improve her meal preparation ability. She was impaired on tests of everyday attention and memory but had low average score on tests of executive functioning. K.F was assessed at baseline, post training and 1-, 3- and 6 month follow-ups. She also kept a diary of the difficulties she had encountered at each meal preparation during a two week period at baseline, post training at 3 months. Her performance on everyday paper and pencil tasks improved following training on proofreading and room layout and these were maintained at 3-month follow-up. More importantly, both assessed and her self-reported difficulties in meal preparation were significantly reduced following GMT and these gains were maintained at follow-ups. However, this study did not address the generalisability of the effects beyond cooking ability.

Levaux et al. (2012) also reported improvements on laboratory tasks and on meal preparation ability in a schizophrenic patient following GMT lasting 8 weeks that were found to generalise to non-trained meal preparation tasks and to everyday life tasks involving washing with the beneficial effects of GMT maintained at two year follow-up.

Using a combined laboratory and naturalistic test approach Katz and Keren (2011) compared two treatment approaches - The - Frontal Executive Program (FEP) and the Occupational Goal Intervention (OGI). The FEP was based on a restorative treatment approach and utilised pencil and paper worksheets for exercise where as the OGI was a compensatory strategy approach based on Goal Management Training. They found that both theoretically different treatment approaches were beneficial in improving performance on tests of executive functions in individuals with Schizophrenia but only the OGI intervention was successful in improving day-to-day functioning as measured by the Routine Task Inventory–Expanded (RTI-E; Katz, 2006), the Activity Card Sort (ACS; Baum and Edwards, 2008 and the Reintegration to Normal Living Index (RNL; Wood-Dauphinee, Opzoomer, Williams, Marchand and Spitzer, 1988). The RTI-E is based on observation of basic activities of daily living (ADLs), instrumental activities of daily living (IADLs), communication, and work readiness.

More recently Levine et al. (2011) tested the effectiveness of the expanded version of GMT (7 x 2 hours) by comparing it with Brain Health Workshop intervention that was matched to GMT characteristics that can affect intervention outcome. They found that the GMT group performed better on the Sustained Attention to Response Task (SART) as well as the Tower Test providing evidence for the far transfer of the training effects.

Miotto, Evans, souza de Lusia and Scaff (2008) investigated 30 patients with frontal lobe lesions who were assessed at baseline and allocated to either (1) attention and problem solving group (APS), (2) Education intervention group (EI) or to (3) treatment as usual (TAU) which did not include any form of cognitive treatment. The APS incorporated the GMT mental black board principle to monitor performance. The APS received 10 week problem solving training after which the performance of all groups were assessed followed by APS intervention to those who had previously received either EI or TAU. There were no differences in performance on neuropsychological tests, or on test of executive functioning between groups at baseline apart from better performance of the APS group on virtual planning test. When the APS group was assessed following training they showed better performance on the Wisconsin Card Sorting Test (WCST), Multiple Errands Test and less dysexecutive difficulties measured on the Dysexecutive Questionnaire (DEX). A similar pattern was observed in the other two groups following their APS training with all groups showing similar level of performance at a follow up six months later.

The usefulness of the STOP concept taken from GMT has also been tested using brief versions of GMT. Manly et al. (2002) tested ten patients with dysexecutive syndrome (9 with TBI and one with stroke) and 24 age- and IQ matched controls on the multitasking task called the Hotel Test. Participants performed the test under two different conditions – alerted and unalerted. In the alerted condition, participants were played periodical auditory tones and were told that this cue may be useful in reminding them to think about what they were doing and in reviewing their overall goals (GMT instruction). Patients' performance was significantly worse in the unalerted condition compared with the control participants but on the alerted condition their performance was no longer significantly different from that of the control subjects on measures of number of tasks attempted and deviation from optimal time allocation. Importantly patients did not use the tones as a signal to switch between tasks.

Similar to Manly et al. (2002), Sweeney et al. (2010) assessed the usefulness of brief GMT using auditory alerts in a virtual reality 'Removals,' task that required a group of patients with TBI and healthy controls to collect furniture around virtual house following a set of rules and remembering to perform a PM task every five minutes or on encountering a particular item. They failed to find any benefit of auditory alerts on performance as shown previously (Manly et al., 2002). They suggested that in more complex situations alerting alone is not sufficient and more extensive goal management training may be required.

Assessing performance outside the laboratory, Fish et al. (2007) were successful in using content free cuing in improving the performance of twenty brain injured patients on a real life task that required them to make phone calls to a voice mail service at set times over a period of three weeks. On cued days participants received a text message reading ‘STOP’, which they had been instructed to use as a way of assessing the goals as part of a brief GMT they had received prior starting the study. It is not clear how long lasting this benefit is or how it translates to gains in everyday functioning. Another study is underway to asses the latter issue.

Similarly Rous (2012) administered brief Goal Management Training (GMT) and external content-free cueing in the form of text messages to a group of adolescents (12-17 years) with ABI. After one week of calls they received brief GMT and were sent six text messages reading ‘STOP’ at random times on 5 of the 10 following working days. Four of the seven participants benefitted from content-free cueing and a group the preliminary analyses showed significantly better performance on cued days. Five participants also reported improvements in real-life PM tasks.

Koehler et al.’s, (2011) review by the Institute of Medicine (IoM, USA) for the Department of Defence of mainly compensatory strategies for rehabilitation of the executive function following moderate to severe TBI indicated that there is evidence to suggest that Goal Management Training (GMT) using goal setting, use of prior planned tasks as guides to planning new tasks and using content-free alerting during performance of complex tasks may enhance goal achievement. They however concluded that the studies did not address how these strategies are spontaneous used in everyday life after rehabilitation and the range of tasks for which these strategies might be useful with the generalisability of the training effect beyond trained tasks being questionable.

1.9.2.2 Healthy individuals

Older adults often show poorer performance on laboratory tests of prospective memory (Uttl 2008). Levine et al. (2007) assessed the usefulness of GMT (including memory skills training and psychosocial training) in a group of 46 older adults (71-87 years of age) with subjective complaints of cognitive or memory impairment. Participants were randomised into an early training group (ETG) that received training immediately or a late training group (LTG) that received training three months after the start of the study. The two groups did not significantly differ from one another at baseline. The effect of GMT on performance was assessed by using Stimulated Real Life Tasks (SRLT), which were designed to mimic everyday problems that participants experienced problems with, due to demands on working memory, attention and strategic processing. Performance on SRLT was found to negatively correlate with WCST set loss errors suggesting that small number of errors on WCST would predict better checking and monitoring ability on the SRLT. When performance was compared following training for ETG (pre-training for LTG), the ETG group had significantly better total score, task strategy and checking on SRTL than the LTG whose performance remained at baseline level. After both groups had received intervention the performance between the two groups was no longer different at the six months post training follow up. The gains from GMT were maintained at follow up on all measures by the ETG and on two of the measures by the LTG. Participants' subjective reporting of executive failures on the Dysexecutive Questionnaire (DEX) also significantly reduced at the follow-up.

Van Hooren et al. (2007) administered GMT to a group of older adults (over the age of 55) with cognitive complaints of distractibility, dualtasking and planning problems over a period of six weeks. Following training, older adults reported being less annoyed and better able to manage their cognitive failures, however this significantly change their overall score on the Cognitive failures questionnaire (CFQ). The CFQ however, is not specific to PM. The GMT group also showed better performance on the Stroop colour word test (SCWT) with gains maintained at a seven week follow up. They further reported less anxiety at follow up compared to a control group of waiting list participants.

Goal Management Training would appear to be effective in improving prospective memory performance in the laboratory and on the trained tasks in real life. The evidence for generalisability of the training effects to untrained task remains limited and maintenance of treatment gains beyond six months is still unreported in the literature.

1.10 Implementation Intention

Implementation Intentions (Gollwitzer, 1993; 1996) is another cognitive strategy that has been used to improve the effectiveness of carrying out future goals. Positive effects have been reported on wide range of behaviour ranging from health behaviours (dieting, smoking alcohol misuse, anxiety management exercise and self-examination), to achieving personal goals, New Year's resolutions and academic goals. For example, the use of implementation intentions successfully increased the success of exercise in the following week with 91% of the college student who used implementation intentions engaging in vigorous exercise for 20 minutes compared to only 29% of the control participants who simply formed the intention to exercise in the upcoming weeks (Sheeran and Orbell, 2000). In another study the implementation intentions group was still exercising at twice the rate of the control group (Stadler et al., 2009)

Implementation intentions are if-then plans that link situations (cues or critical moments) with the desired outcomes (if I encounter X then I will do Y) as opposed to goal intentions that simply state the desired goal (I will have to do Y).

Implementation intentions work by strengthening the cue–action association during the encoding phase (Chasteen et al., 2001). Therefore further intention recall is more likely to be supported by automatic cognitive processes according to the multiple processes model of PM (McDaniel and Einstein, 2000) as opposed to effortful remembering demanded by goal intentions. A recent meta-analysis (Gollwitzer and Sheeran, 2006) found that implementation intentions improve goal attainment to a medium-to-large effect (effect size Cohen's d =.65).

The studies presented in this thesis will use a combination of GMT and Implementation intentions to assess whether brief exposure their key concepts can improve performance on computerised tasks of PM. Neural changes associated with cognitive training is a research area that is growing in interest. This thesis will aim to assess whether brief cognitive training is associated with detectable pattern of brain activation using fMRI. At the time of starting work on this thesis, to my knowledge, no studies investigating the neural basis of rehabilitation interventions aimed at improving prospective memory existed.

1.11 Assessing the effectiveness of cognitive rehabilitation interventions

The level of prospective memory ability is relevant during cognitive rehabilitation beyond prospective memory interventions. Cognitive rehabilitation often involves teaching patients strategies to improve their everyday functioning. Impairment in prospective memory is likely to have a negative impact on patients' ability remember to use the very strategies they need to improve functioning say in taking medication for example, resulting a double deficit (Gracey, 2012).

There appears to be a growing recognition in that neuropsychological assessment of PM can be of value as it can determine both strengths and deficits in functioning yet assessment tends to highlight inabilities. The main challenges assessing PM pre- and post-rehabilitation are: (1) Ecological validity; given that performance on tasks tend to show only moderate correlation with everyday functioning and following frontal lobe injury, some people show little or no impairment on the wide range of formal clinical tests of cognition yet have impairments in 'everyday' life settings, (Burgess, Alderman, Volle, Benoit and Gilbert, 2009). (2) Lack of validated and standardised tests that are suitable for clinical use and reflect the functions of a particular cognitive process or brain region and are based on a theoretical framework. (3) Convergent validity with other tests developed to assess the same cognitive construct (4) Novelty and therefore parallel or multiple versions of test as impairment in PM is likely to be most marked in novel situations. In addition, PM tasks ability to reliably measure and quantify the effects of cognitive rehabilitation interventions is still in its infancy. The ability to measure or monitor post-injury change is important in making decisions about rehabilitation for patients as well as determining the effectiveness of rehabilitation and the theoretical underpinnings of rehabilitation interventions. Therefore measures that lack floor and ceiling effects and that both sensitive and have good psychometric properties are needed.

1.12 Thesis summary and aims

The overall aim of this thesis is to develop paradigms suited for measuring the neural effects of brief cognitive rehabilitation interventions aimed at improving prospective remembering in a brain imaging environment. This will be investigated using a two part approach. The first part focuses on validation of prospective memory paradigms that can be administered to subjects in a brain imaging scanner environment. The second part then takes these paradigms to assess whether they are suitable and sensitive for measuring change using compensatory training approaches.

Chapter 2 and 3 will investigate the ecological and convergent validity of computerised prospective memory tasks in neurologically healthy adults (Chapter 2) as well as assess their suitability for measuring the effects of rehabilitation interventions (Chapter 3). Chapter 2 further aims to assess the extent to which, PM ability declines with age. Chapter 4 will assess the ecological and convergent validity of computerised PM tasks in individuals with acquired brain injury.

Chapters 5 and 6 will assess whether brief Goal Management Training with Implementation Intentions (GMTii) can improve performance on computerised prospective memory tasks (Chapter 5) and produce changes in the underlying neural activations within the PFC (approximately Brodmann's area 10) as measured by fMRI (Chapter 6).

Chapter 7 will discuss the contribution of the studies presented in this thesis with the existing literature on the assessment and rehabilitation of PM including its neural basis and explore the clinical applications of the work together with directions for future research.

Chapter 2

Validation of Simple Computerised Tests of Prospective Memory in Neurologically Healthy Adults

Abstract

Frontal lobe functions such as prospective memory (PM) have been argued to decline with age (Burke and Barnes 2006) yet evidence contradicting this view exists (Einstein and McDaniel 1990). This study investigated age related effects of PM performance using computerised PM tasks shown to activate areas in the prefrontal cortex and a modified version of the multi-element Hotel Test (Manly et al., 2002) in a group of 20 neurologically healthy young and 21 older individuals. The extent to which performance on these two tests was related (convergent validity) was also assessed. Further, the ecological validity of computerised tasks was assessed using self-report measures of everyday functioning. Both tests were found to be sensitive to the effects of ageing and possess reasonable convergent validity. Performance on the computerised tasks was not strongly related to self-reported cognitive functioning in everyday life.

2.1 Introduction

Cognitive processes such as learning, memory and executive functions that rely on the prefrontal and medial temporal cortex functions are believed to show considerable decline with age (Burke and Barnes, 2006). Prospective memory is one type of executive function, which may therefore be subject to decline with age. Very few prospective memory paradigms that are both known to tap into prefrontal cortex functions and suited to assessing change in performance over time or following interventions aimed at minimising effects of brain trauma or ageing exists. Studying older and younger subjects may further the understanding of PM processes and aid the development of paradigms that are sensitive to changes in PM functioning

2.1.1 The Prospective Memory Age Paradox

Early research into the effects of ageing on prospective memory performance dealt with the so-called age-PM paradox with two opposing views. One account proposed that PM ability declines with age (Craik, 1983) whereas the other hypothesised that PM ability is spared by ageing (Einstein and McDaniel, 1990).

Early studies (Moscovitch, 1982) found that older participants outperformed younger participants on a naturalistic PM task where they had to remember to phone the experimenter every day at a specified time for two weeks. A similar paradigm was later used to confirm this finding (Kvavilashvili and Fisher, 2007). Similarly, Einstein & McDaniel (1990), found no differences in performance between a group of young and elderly subjects performing a short-term memory task into which a PM task had been embedded, despite observation of age-related differences being observed on RM performance. Furthermore, the level of familiarity of the PM target word also did not produce age related changes in performance. The PM task required participants to press a designated key whenever a target word appeared on the computer screen, which occurred on 7% of all trials. They also found that there were no differences between younger and older individuals in the benefits gained from using a memory aid. As the short term memory task administered to the older participant group was easier than the short term memory task given to the younger participant group, the significance of this finding is debatable.

By contrast, Kvavilashvili, Kornbrot, Mash, Cockburn and Milne (2009) reported age-related decline in PM performance with age. Other studies (Einstein et al., 1997) have found age related decline in PM performance only when background activities are demanding. However, some studies suggest that age related decline is evident even in low-demanding PM tasks, particularly when working memory demand is high (Bisiacchi, Tarantino and Ciccola, 2008).

Einstein, Richardson, Guynn, Cunfer and McDaniel (1995) and Park, Hertzog, Kidder, Morrell and Mayhorn (1997) both found that on laboratory tests of PM, age related deficits in time based PM are more evident than in event based PM. Einstein et al.'s (1995) failure to find age related differences in event based PM may have also been due to lower self-initiation demand in the event based PM condition compared with the time based PM condition, which is considered as high in self-initiation demand. According to Craik (1986) self-initiated retrieval is particularly prone to decline with age and age-related differences are likely to be greater on tasks that require a higher level of self-initiation.

Some studies have tried to address the age paradox by administering a similar PM task to younger and older individuals in both a laboratory and a real life setting (Rendell and Craik, 2000). They tested three groups of adults (19-24 yrs, 61-73 yrs and 75-84 yrs of age) on a laboratory board game called 'Virtual Week'. The game required subjects to move around the board with the roll of a dice and make choices about their daily activities, while remembering to carry out life-like regular, irregular as well as event- and time-based PM activities. They found that in the laboratory, performance declined with age and regular PM tasks (e.g. taking medication) were better remembered than irregular (e.g. returning library books) and time based PM tasks in all age groups. The differences in the two latter types of tasks were significantly larger in the two older groups than in the younger group when compared with regular PM tasks. In a second experiment, the participants were asked to complete 'Actual Week' PM memory task, which is similar to 'Virtual Week' with the exception that it is performed in a naturalistic setting over the course of one week. The Actual Week does not require physical completion of the tasks given. Contrary to the findings on the laboratory based 'Virtual Week', older adults outperformed younger adults on both regular and irregular tasks. Similarly, Rendell and Thomson (1999) reported that older participants' performance was superior to that of younger participants on a naturalistic PM task but that this pattern was reversed on a laboratory based PM task. One possible explanation for these conflicting findings on these tasks is that older people are more aware of their prospective memory ability and thus are better at compensating for their ability in real life (e.g. using reminders, associations), which is not possible in a laboratory setting. Older people may also have more stable routines in daily life compared to younger individuals. On the other hand, laboratory tasks may be of greater novelty and thus require a higher level of attentional resources than naturalistic tasks (Einstein et al., 2000).

Several attempts have been made to better explain the age-PM paradox through meta-analyses (Uttl 2008; Kliegel, Phillips and Jäger 2008a; McDaniel and Einstein, 2007). The current evidence suggests that, older adults display impaired prospective memory performance in some situations, whereas in other situations they show relatively small or no declines in prospective memory performance. Age-related deficits tend to be evident on standard laboratory-based PM tasks whereas age-related benefits tend to be evident on naturalistic tasks. In a selective review of the literature, Uttl (2008) suggested that deterioration in PM ability begins around 60 years of age. McDaniel and Einstein (2007) interpreted this apparent paradox based on the assumption that because aging especially disrupts frontal lobe functioning, elderly individuals experience the greatest age related decline on laboratory-based PM tasks, which require greater prefrontal cortex involvement. Conversely, older adults still maintain adequate day to- day functioning because they use routine behaviours and rely on cognitive processes, which minimize recourse to attentional and executive resources.

Research studies investigating the cognitive processes involved in prospective memory in healthy individuals have often employed simple computerised prospective memory paradigms that aim to imitate real life situations in that they require participants to maintain an intention while doing something else. These typically require participants to maintain an intention while performing a task (known as the background or ongoing task), into which is embedded a prospective memory task that involves a) retrieving the intention and b) making a different response when a pre-determined cue is presented or after certain amount of time has lapsed (Einstein and McDaniel, 1990; Einstein, Richardson et al., 1995). Computerised tasks of this type have been shown to activate Brodmann's area 10 in the prefrontal cortex (Burgess et al. 2001, 2003; Gilbert et al., 2009; Simons, 2006), making them a candidate in assessing whether age related decline in performance is due to disruption in frontal lobe functioning. These relatively simple tasks are considered to have poor ecological validity as they do not reflect the use of PM in a multitasking environment that is typical of everyday life. Very little work has been undertaken to establish the convergent and ecological validity of computerised PM tasks, which makes comparison of any findings from different studies difficult. This approach however, does lend itself to brain imaging paradigms such as functional magnetic resonance imaging (fMRI) or positron emission tomography (PET), unlike the more complex multi-element tasks. This raises a question of whether these two apparently different approaches (computerised PM tasks and complex multi-element tasks such as the Hotel Test) are measuring the same cognitive functions, whether they are drawing on the same underlying neural systems and whether performance on them reflects actual functioning in everyday life.

Given that the age paradox is still debated in the literature and that the neural, underpinnings of PM tasks employed in the aging literature are not routinely assessed to confirm prefrontal involvement, this chapter aims to assess whether older adults show decrements on both computerised PM tasks and multi-element laboratory tests of PM that are shown to be problematic for individuals with prefrontal damage.

In addition to computerised tasks having questionable convergent and ecological validity, many suffer from ceiling effects when administered to healthy adults (Burgess et al., 2001, 2003), and thus may not be suitable for assessing change in PM ability over time or following cognitive interventions aimed at improving PM. This study will seek to assess whether this is also the case for older adults. Developing paradigms that are sensitive to PM, do not produce ceiling effects, and are suited for administration in movement-restricted environments (such as fMRI scanners), would allow the assessment of neural changes associated with ageing or the measurement of the effects of rehabilitation interventions aimed at improving prospective memory

2.1.2 Questionnaire Measures and Ageing

Studies using subjective assessment tools have reported no age related decline in PM, which supports the view that older people may only show poorer PM performance when tested in a laboratory setting. Smith, Della Sala, Logie and Maylor (2000) used the Prospective and Retrospective Memory Questionnaire (PRMQ) and found no difference in the reported memory errors between the young and the elderly. Similarly Crawford, Smith, Maylor, Della Sala and Logie (2003) found no influence of age on the PRMQ scores. A recent study (Chau et al., 2007) even reported that those under the age of 30 exhibited more frequent PM failures on the Comprehensive Assessment of Prospective Memory (CAPM) than older participants (31-60 years of age). However, their older group was significantly younger than the age at which deterioration in PM ability is thought to begin (Uttl, 2008).

Few studies have correlated laboratory PM task performance with subjective measures of PM such as the PRMQ. Zeintl et al., (2006) tested whether PM complaints reflected objective PM performance on a laboratory test of PM, finding that the PRMQ to correlated with task performance in older adults. Kliegel and Jäger (2006) also found the PRMQ to correlate with performance on time- and event-based PM tasks. However, only the PM subscale and not the RM subscale was useful in predicting PM performance in both time- and event-based PM, which provides evidence of the separation of PM and RM functions. Furthermore, Mäntylä (2003) also found that the PRMQ correlated with a single trial laboratory task of PM, where participants were asked to remember to remind the experimenter to sign a piece of paper at the end of the testing session. However a recent study by Chan et al. (2008) did not find a strong relationship between the PRMQ and an event based computer test of PM where young participants were asked to press an assigned key whenever a PM cue (an animal) appeared. Nevertheless, their performance on time-based (press assigned key every minute) and activity-based (press assigned key upon seeing a message saying the testing session was over) PM correlated with the PRMQ.

Given that previous studies have found only a weak correlation between the PRMQ and computerised PM tasks similar to Burgess et al.'s (2003) paradigm, they may lack good ecological validity or the ability to capture the PM demands that people experience in their everyday life. The aim of the first study was to investigate both the ecological and convergent validity of the simple computerised prospective memory tasks used by Burgess et al., (2003). The convergent validity of these tasks was assessed against performance on a modified version of a tabletop multi-element task Hotel Test (Manly et al., 2002). The ecological validity of these tasks was assessed against three self reported questionnaires assessing cognitive and memory failures in everyday life. In addition to investigating the effects of age on performance, this study also assessed whether the simple computerised tasks would be suited for assessing the effects of cognitive rehabilitation interventions by being capable of capturing a range of performance without producing ceiling effects.

2.1.3 Hypotheses

Primary hypothesis: It is expected that younger individuals will show significantly better performance on the objective prospective measures compared to older individuals.

Secondary / exploratory hypotheses: It is expected that the simple computerised tasks will have good convergent validity with the modified Hotel Test with performance on the simple computerised tasks expected to correlate significantly with performance on the mHT.

Significant negative correlations are expected to be found between objective task performance and self reported memory functioning using questionnaire measures.

In order for the simple computerised tasks to be suited for assessing the effects of cognitive rehabilitation intervention, the mean accuracy to PM targets should be no greater than 75%.

2.2 Method

2.2.1 Participants

Forty one participants between the ages of 18-30 (mean = 21.1, SD = 1.59) and 60-80 (mean = 69.8, SD = 5.1) completed the study. Participants were included if they had no history of a neurological or psychological disorder, were right handed and spoke English as their first language. In addition to those included, seven participants were excluded after initial screening due to a pre-existing neurological (n=4) or psychological (n=1) condition left-handedness (n=1) or not speaking English as their first language (n=1). The younger participants were recruited from the University of Glasgow whereas older individuals were recruited from the University of Glasgow retired staff association and from clubs attended by older people in the Glasgow area. The average length of time participants had attended full-time education was 16.5 years (SD = 1.5, range 14-20) for the younger individuals and 15.0 (SD = 3.9, range10-22) for the older participants.

2.2.2 Measures

2.2.2.1 Wechsler Test of Adult Reading

The Wechsler Test of Adult Reading (WTAR, Wechsler, 2001) was used as an estimate of general intellectual ability.

2.2.2.2 The Modified Hotel Test (mHT)

The modified Hotel Test (modified from Manly et al., 2002) is a test of “multitasking” and consists of five simple tasks that could be completed in the course of running a hotel. There is insufficient time to complete all tasks, hence why the main aim is to try and do at least something from each of the five tasks while spending as much time on each task as possible within the total time available.

The original Hotel Test was modified in order to make it suitable for use in neurologically healthy individuals and to enable a wider range of performance to be measured in patients with brain injury at a later stage. A study using the original version (Manly et al., 2002) reported healthy individuals to perform very close to ceiling levels, attempting on average 4.96 out of 5.0 tasks (SD 0.20). A group of patients with dysexecutive difficulties were also found to show fairly good performance attempting 4.10 tasks (SD 0.88) on average. It was therefore felt that the original version would be too easy for neurologically healthy individuals and some high functioning patients and that there would not be sufficient variation in performance to measure the effects of age on performance between the young and the older participants.

The Modified Hotel (mHT) consists of five tasks, which are summarised in Table 2.1. The tasks were laid out in a counterbalanced manner as shown in Figure 2.1.

Table 2.1: Summary of the modified Hotel Test main tasks

Task	Description
Sorting Coins	Sort a box of coins into bags of £1 exactly using British currency only. The box contained 196 coins. Twenty one of the coins were foreign coins and were drawn from four different currencies. The British coins comprised the following: 5×1p, 4×2p, 96×5p, 46×l0p, 24×20p as per Manly et al. 2002.
Sorting Conference Labels	Sort 100 conference labels into alphabetical order from A to Z according to the last name of each person.
Compiling bills	Compile an individual bill for each of the ten hotel customers using the entries from the hotel till roll.
Sorting Playing Cards[1]	Sort three decks of playing cards into individual decks and into the correct order by the suit. All three decks had a different pattern at the back.
Proofreading	Check a seven-page draft of a proposed new hotel leaflet for spelling errors and cross out any spelling errors with a pen.

[1] This was a substitution for the task of looking up phone numbers specified in Manly et al., (2002) and was introduced by Fish (2008). It appeared that participants had found looking up the telephone numbers rather tedious and tended to switch from this task sooner rather than later. In contrast, the card sorting tasks appear both to engage people and make them somewhat reluctant to switch before completion making the task potentially more sensitive as this contributes to the key error of becoming immersed in current activity to the detriment of the overall goal.

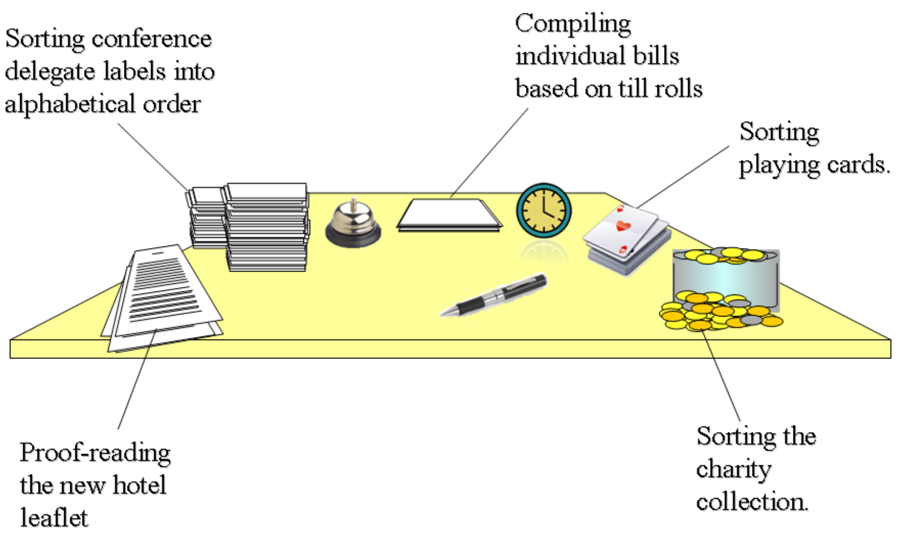

Figure 2.1: The modified Hotel Test layout

The initial set of instructions was identical to the original Hotel Test and the participants were free to complete the tasks in any order they wished:

> “In this task you are asked to imagine that you are working in a hotel. Your manager is keen for you to try each of these five everyday activities during the next 15 min so that you can get a ‘feel’ for the work—and make an informed estimate of how long each would take to complete. Your main job is therefore to try to do at least some of all these five tasks over the next 15 min. There are five main tasks to do. Each of the tasks may well take longer than 15 min to complete on its own so there is no way that you will be able to complete them all. The most important thing is to try and do something from each task — spending as much time on each as possible within the total time available’’.

Some theories of prospective memory (SAS model and the Multiprocess theory) propose a distinction between situations that are more effortful (require strategic processes or self initiation) and those that are more automatic (spontaneous retrieval). With this in mind, a secondary listening task was added to the modified version. The additional task was designed to require less strategic processing and self-initiated switching between different tasks. The task had to be plausible in the hotel context while bearing some relevance to everyday life (e.g. doing house chores while having the TV on in the background and waiting for a particular program to start or helping the children with homework whilst remembering to keep a check on the dinner that is cooking on the hob from time to time). Another requirement was that the secondary task should not require active time monitoring like the garage door task in the original version. More than two opportunities responding to a PM cue should be presented in order to better measure variations in performance but presentation of a PM cue should result in no obvious change in the task environment that could cue participants to detect the target (e.g. change from speech to music). Further, the additional listening task should not require excessive monitoring (e.g. picking up a particular phrase from continuous speech) or load heavily on RM through having to remember several additional task instructions.

In the secondary event-based auditory PM task, participants heard a continuous recording of car registration plates. Participants were told that the hotel was hosting a major conference and that cars arriving at the hotel would have their car registration plates read out loud on entrance to the hotel car park. They were then advised that ten company executives from the Canadian Broadcasting Company were going to be arriving at the hotel during the course of 15 minutes and that they were to ring the bell each time they heard a company executive arriving at the hotel, so that someone could be sent down to collect their bags. All the company executives had a car registration plate ending in CBC (Canadian Broadcasting Company).

The instruction was designed so that it avoided making a direct link between the cue and the action (i.e. ring the bell when an executive arrives at the hotel as opposed to ring the bell when you hear a car registration plate ending in CBC). No targets were presented during the first minute of the task so that participants became acclimatised to the main tasks while allowing for time to lapse in order to increase the likelihood of the intention being forgotten. The approximate times (minutes, seconds) of executives arriving at the hotel were:

1.18, 2.30, 3.45, 4.31, 6.10, 7.34, 8.29, 10.57, 11.14, 13.29

Further modifications included removal of the time-based closing and opening of the garage door task, as this has been found to make participants to monitor their time more effectively and make them more likely to switch tasks (Fish, personal communication). An event-based task is expected to be less prone to time monitoring. A clock was provided and participants were free to check the time as often as they liked but were asked to keep the clock lid closed when they were not checking the time so that the experimenter could see when they checked it.

Performance was scored as follows: total number of tasks attempted (out of 5), total number of PM targets detected (out of 10), time deviation from optimal time allocation, with the optimal time being 180 seconds per task (time spent on a task minus 180 seconds unsigned). This is calculated separately for each task and totalled to form a total time deviation score. The number of clock checks made was also recorded. In addition, overall PM performance score was calculated by converting the total number of tasks attempted and total number of correct bell rings into a percentage score out of 100% with the two scores added together.

2.2.2.3 Simple Computerised Tasks

Three different simple computerised tasks (letter task, number task, picture task) based on the work of Burgess and colleagues (2003) were administered to all participants. All computerised tasks were subject-paced and the presentation order of the tasks was counterbalanced across subjects. All tasks had three different conditions: baseline, ongoing task and ongoing task with a prospective memory demand. The conditions were always completed in this order so that participants were not introduced to the prospective memory instructions before having completed the baseline and ongoing conditions within each task.

In the baseline condition (BL) subjects were required to make a simple motor response as fast as they could whenever stimuli on the screen changed. This was always 300 ms after their last response. In the ongoing condition (OG), participants performed a simple cognitive task that required continuous attending to the stimuli. The prospective memory condition was identical to the ongoing condition except that there was an additional requirement to execute a delayed intention on some of the trials. The baseline and ongoing conditions comprised 176 trials with the first trial excluded from analysis. The prospective memory condition (PM) comprised of 350 analysable trials and these were divided into two identical blocks of 175 trials each with a subject paced break between the two blocks. The first block is referred to as “PM1” and the second block as “PM2”. The prospective memory targets appeared on 20% of trials and no PM targets were presented during the first 36 trials. Similar to the BL condition, there was a 300 ms blank screen between trials in both the ongoing and prospective memory conditions. The stimuli were presented on a “14.1” computer screen using E-Prime Psychology Software Tools, Inc., USA.

Letter processing

Participants were presented with pairs of black capital letters on a white background (Figure 2.2). In the baseline conditions subjects were required to press two buttons in an alternating fashion (as above) as fast as they could whenever a new set of stimuli appeared on the screen. In the ongoing task they were asked to indicate which of the two letters was nearer to the start of the alphabet by pressing the response button on that side of the screen. The letters were always between 11 and 16 letters apart in the alphabet. On half of the trials, the correct answer was on the left, while the correct number was on the right in the other half on the trials. In the PM condition, participants were also asked to decide which one of the two letters was closer to the start of the alphabet, but whenever two vowels appeared together, they were required to press a third button using their right middle finger.

Number Task

Participants were presented with pairs of digits raging from 1-9 (Figure 2.2). They were presented in black on a white background. In the baseline conditions subjects were required to press two buttons in an alternating fashion as fast as they could whenever a new set of numbers appeared on the screen (using their left index finger for the left hand key and right index finger for the right hand key). In the ongoing task they were asked to indicate whether the number on the left or right hand side of the screen was greater by pressing the response key on that side of the screen. On half of the trials, the correct answer was on the left while the correct number was on the right in the other half of the trials. In the PM condition, they were also asked to decide which one of the two numbers was greater by pressing the response button on that side of the screen, but whenever even numbers appeared together, they were required to press a third button using their right middle finger.

Picture processing

Participants were presented with a four-by-six grid containing two black circles in all conditions (Figure 2.2). In the baseline condition they were asked to press one of the two response buttons in an alternating manner whenever the circles change position. In the ongoing task they had to press the right hand response button if the position of the two circles was horizontal or vertical to one another and the left response button if their position was diagonal to one another. In the PM task subjects were be require to press both response buttons together if the two circles were presented in the middle two rows of the grid, regardless of their orientation.

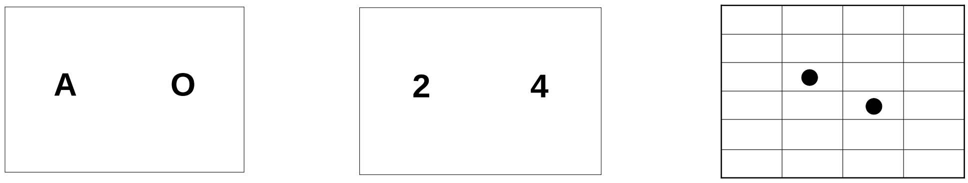

Figure 2.2: Simple computerised tasks stimuli. The figure on the left shows letter task stimuli, figure in the middle number task stimuli and figure on the right picture task stimuli.

2.2.2.4 Questionnaire Measures

2.2.2.4.1 Prospective and Retrospective Memory Questionnaire

The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith, Della Sala, Logie and Maylor, 2000) is a sixteen-item questionnaire developed to measure the frequency of prospective (PM) and retrospective (RM) memory failures in everyday life. Half of the questions measure PM (e.g. Do you decide to do something in a few minutes' time and then forget to do it?), while the other half measures RM failures (e.g. Do you forget what you watched on television the previous day?). Participants are required to rate how often each type of memory failure happens in their everyday life on a 5-point scale ranging from very often (5) to never (1). The overall reliability of PRMQ is considered high with Cronbach's alpha ranging from 0.72 (Zeintl et al., (2006) to 0.89 (Crawford et al., 2003) and 0.92 (Crawford et al., 2006). A score for PM and RM in addition to total score can be calculated by totalling questions for each subscale with higher scores indicating more frequent everyday PM and RM failures. It is also possible to derive long and short-term self- and environmentally-cued memory scores for both prospective and retrospective memory scales.

2.2.2.4.2 Cognitive Failures Questionnaire

The Cognitive Failures Questionnaire (CFQ; Broadbent, Cooper, Fitzgerald and Parkes, 1982) is a 25-item questionnaire that was used as a measure of general cognitive failures. The frequency of failures is assessed using a 5-point Likert scale ranging from 0 (never) to 4 (very often).

2.2.2.4.3 Goal Management Questionnaire

The Goal Management Questionnaire (GMQ; Robertson, Levine and Manly, 2000; Levine, Manly and Robertson, 2012) (Appendix A) is a 34-item questionnaire, which measures the extent of goal management difficulties experienced by an individual in their everyday life by using a 10-point Likert scale ranging from 0 (no problem at all) to 10 (major problem). Items refer to problems with time management, decision making, and general organisation, as well as attentional/mnemonic lapses and affective responses to goal management difficulties. This questionnaire is yet to be formally validated, though it is included in a training manual for a rehabilitation programme aimed at promoting strategic adaptation to acquired executive dysfunction.

2.2.3 Procedure

Participants were provided information about the study and gave written consent prior to taking part in the study. Participants completed the WTAR, which was followed by the modified Hotel Test (mHT). The mHT task instructions were read to participants from a script and repeated where necessary. The task was began once the participant understood the main goal in the task – to try and do something from each of the five tasks and ring the bell each time an executive arrives at the hotel. The order of tasks on the table was counterbalanced across subjects in both groups. A written copy of subtask instructions was placed on top of the materials for each of the five tasks and a reminder of the executive number plate ending was placed under the bell. These were visible to participants throughout the task. This was done in order to minimise demands on retrospective memory particularly with the older individuals. On completion of the mHT, each participant's recall of the task's main goal was checked. The purpose of this was to ascertain whether any participants who did not attempted all of the tasks (or missed some executives), was due to failures in retrospective memory (i.e. forgetting the instructions) or for another reason (e.g. got caught up on a task, lost track of time).

Participants then completed the simple computerised tasks. The order of task presentation was counterbalanced across participants in both groups. After having completed a practice block, but prior to starting the prospective memory condition in each task, subjects were asked to complete a questionnaire (PRMQ, CFQ or GMQ) in order to introduce a time delay between the task instructions and the task itself. The order in which the questionnaires were completed was counterbalanced across participants.

2.2.4 Ethical Approval

This study was reviewed and approved by the University of Glasgow Faculty of Medicine Ethics committee.

2.3 Results

Data analyses were carried out using PASW Statistics 18 (SPSS, Chicago). Descriptive statistics were used to calculate participants' characteristics (Table 2.2).

Table 2.2: Participant characteristics

Variable	Younger Individuals (N=20) Mean ± SD	Older Individuals (N=21) Mean ± SD
Age (years)	21 ± 1.6 (Range 19-24)	70 ± 4.6 (Range 62-78)
Gender (Female / Male)	11 / 9	14 / 7
Length of Full-Time Education (yrs)	16.5 ± 1.5	15 ± 3.9
WTAR (FSIQ)	110.9 ± 7.0	112.2 ± 6.1

WTAR (FSIQ) = Wechsler Test of Adult Reading full scale intelligence quotient

The two groups did not significantly differ in their mean length of full-time education (t = 1.63 (25.9), p = .12, r = 0.31) or their general intellectual functioning as measured by the WTAR FSIQ (U = 183.0, z = -.71, p = .48, r = -0.11). The proportion of men and women was also similar between groups (X^2 (1, N = 41), = .59, p = .53).

2.3.1 Effects of Age on performance

A summary of performance on simple computerised tasks is provided in Table 2.3. Data from all tasks were collapsed and analysed together in order to ascertain whether any findings were attributable to prospective memory processes per se rather than to the demands posed by an individual task. A breakdown of performance in each of the three tasks for both groups is presented in Appendix B.

Table 2.3: Summary of performance on the simple computerised tasks per group

Variable	Younger Individuals (N = 20) Mean ± SD		Older Individuals (N=21) Mean ± SD	
	Accuracy (%)	Reaction Time (ms)	Accuracy (%)	Reaction Time (ms)
Baseline Condition	96.5 ± 4.8	173.4 ± 84.3	98.0 ± 2.5	266.5 ± 95.9
Ongoing Condition	94.5 ± 5.0	620.4 ± 68.6	97.5 ± 1.9	787.7 ±170.5
PM Condition	91.2 ±6.6	839.5 ± 109.4	93.3 ± 5.6	1189.1 ± 274.9
PM targets only	80.8 ± 11.6	813.7 ± 124.4	82.5 ± 16.8	1178.2 ± 282.4
OG targets only	93.8 ± 6.2	843.9 ±111.2	96.1 ± 3.4	1191.3 ±277.4
PM1 PM targets	82.3 ±11.5	835.3 ±139.8	82.5 ±15.6	1236.1 ±297.3
PM2 PM targets	79.3 ± 12.7	792.2 ± 113.9	81.0 ±18.6	1118.1 ± 277.1

PM = Prospective memory, OG = ongoing, PM1 = first prospective memory block, PM2 = second prospective memory block

The older participants were found to be slower overall on the computerised tasks. They had significantly longer reaction times in the baseline (U= 86.0, z = -3.2, p < .05, r = -0.50) ongoing (U = 47.0, z = -4.3, p < .05, r = -0.67) and PM conditions (overall U = 18.0, z = -5.0, p<.05, r = -0.78, to PM targets U= 30.0, -4.70, p < .05, r = -0.73; and ongoing targets U = 18.0, z = -5.0, p <.05, r = -0.78) compared with the younger individuals. The older and younger individuals had similar accuracy in the baseline condition (U = 167.0, z = -.88, ns, r = -0.14) but the older individuals were more accurate in the ongoing condition (72.0, z = -3.6, p < .05, r = -0.56). Accuracy in the PM condition was similar between groups (overall U = 162.0, z = -1.3, p = .21, r = -0.20; to PM targets U = 167.5, -1.1, p = .27, r = -0.17).

In order to account for the effects of speed and accuracy on performance while allowing for the cost of PM instruction to be assessed against performance in the OG condition, an overall performance score (OGPM difference score) was calculated. This was determined by subtracting accuracy in the OG condition from PM condition accuracy and converting this into a z-score. Reaction time in the OG condition was then also subtracted from PM condition reaction time and converted into a z-score. Given that longer reaction times indicate poorer performance, an inverse z-score was calculated. The z-scores for speed and accuracy were then added together. Higher overall performance score indicates poorer performance in the PM condition in comparison with the ongoing condition. The mean score for the younger group was -.78 (SD .98) and .75 (SD 1.88) for the older group.

Because of the non-normality of the overall performance score before and after attempts of normalisation of the data, a non-parametric Mann-Whitney U-test was performed to assess differences in performance between groups. The older participants were found to show disproportionately poorer performance than the younger individuals in the PM condition compared with the OG condition (U = 67.0, z = -.3.7, p < .05, r = -0.58).

Given that the two groups showed qualitative differences in behaviour during the subject paced task in the PM condition, it was decided to assess whether older and younger individuals showed similar performance before (PM1) and after (PM2) the short break. Participant's performance in the first (PM1) and second (PM2) block is summarised in Table 2.4.

Table 2.4: Summary of performance on first and second PM blocks per group

Variable	**Younger Individuals (N = 20) Mean ± SD**		**Older Individuals (N=21) Mean ± SD**	
	Accuracy (%)	Reaction Time (ms)	Accuracy (%)	Reaction Time (ms)
PM1 PM targets	82.3 ±11.5	835.3 ±139.8	82.5 ±15.6	1236.1 ±297.3
PM2 PM targets	79.3 ± 12.7	792.2 ± 113.9	81.0 ±18.6	1118.1 ± 277.1

PM1 refers to first PM block (i.e. before break), PM2 refers to second PM block (after brief break)

A change score was calculated to assess changes in performance block from 1 to block 2 (PM2 minus PM1), with positive scores indicating better performance in PM 2 compared to PM 1. Due to non-normality of the data pre- and post attempts of normalisation, group differences in performance were assessed using a Mann Whitney U-test. The older participants were found to show significantly greater improvement in overall PM condition accuracy from PM1 to PM2 compared with the younger individuals (U = 113, z = -2.5, p = .011, r = -0.39) but there were no significant differences in PM target accuracy between groups (U = 167, z = -1.1, p = .267, r = 0.17).

A summary of performance on the mHT is provided in Table 2.5.

Table 2.5: Summary of performance on the mHT by group

Variable	**Younger Individuals Mean ± SD**	**Older Individuals Mean ± SD**
mHT number of tasks attempted (/5)	4.7 ± .47	4.4 ± .81
mHT number of correct bell rings (/10)	8.8 ± 1.6	6.3 ± 2.8
Total PM score (%)	181.5 ± 17.9	151.4 ± 35.0
Time deviation	294.7 ± 156.9	400.1 ± 153.7
Number of clock checks	3.20 ± 1.7	.90 ± 1.2

mHT = modified Hotel Test, PM = prospective memory, Time deviation in seconds

Older individuals made significantly fewer clock checks compared with the younger individuals (U = 60.5, z = -.3.99 $p < .05$, r = -0.62). They also had greater total time deviation (U = 131.5, z = -2.05, $p < .05$, r = -0.32), fewer correct bell rings (U = 99.5, z = -2.93, $p < .05$, r = -0.46) and a lower overall total PM score (U = 102, z = -2.85, $p < .05$, r = -0.45) compared with the younger individuals. Older individuals however, did not attempt significantly fewer tasks (U = 177, z = -1.0, $p = .308$, r = -0.16) compared with the younger individuals. The pattern of correct bell ring is presented in Figure 2.3. Visual inspection of the pattern suggests somewhat poorer maintenance of the intention over time in the older participant group, given that they do not return to initial accuracy level later during the task, unlike the younger individuals.

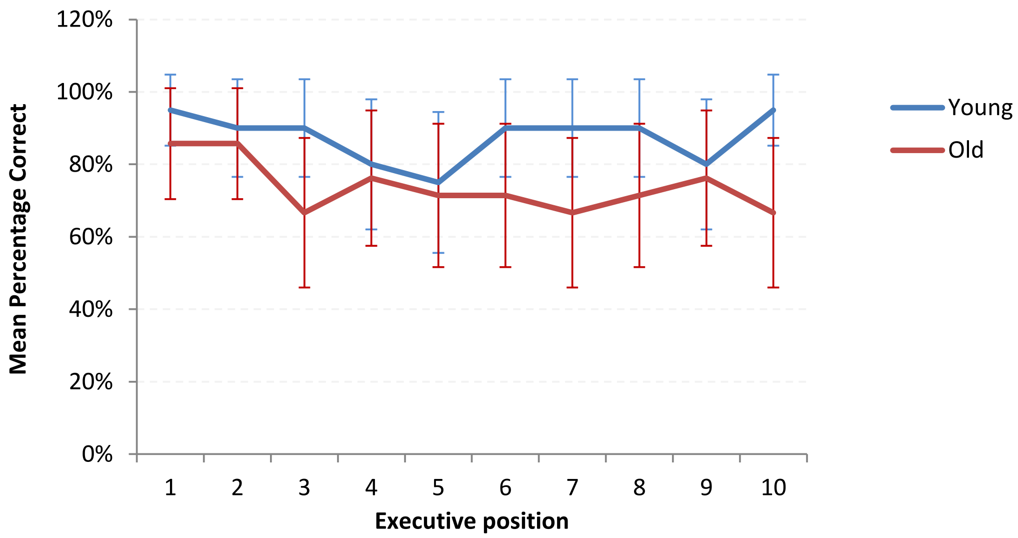

Figure 2.3: The pattern of bell rings in young and older groups on the mHT. Error bars represent 95% confidence intervals.

2.3.2 Convergent Validity

The relationship between performance on the simple computerised tasks and the mHT is presented in Table 2.6. The convergent validity of the simple computerised tasks was assessed separately for the younger and older groups using Spearman’s correlation.

Table 2.6: Relationship between performance on simple computerised tasks and the mHT

Correlations Spearman's *rho*	Simple computerised task Overall performance score	
	Younger participants	**Older participants**
Number of tasks attempted	-.13	-.41
mHT number of correct bell rings	-.22	-.56**
mHT total PM score	-.38	-.57**
Total time Deviation	-.07	.027
Total number of clock checks	-.16	-.15

mHT = modified Hotel Test, PM = prospective memory, time deviation in seconds, **correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

No relationship was found in performance on the simple computerised task and the mHT in the younger participant group but a significant relationship was seen between number of correct bell rings and mHT total PM score and performance on simple computerised tasks in the older participant group with those showing better overall performance on the simple computerised tasks also demonstrating better performance on the mHT.

2.3.3 Ecological Validity

Self-ratings of memory failures in everyday life by each group are shown in Table 2.7.

Table 2.7: Mean self-rated Questionnaire scores per group

Variable	**Younger Individuals Mean ± SD**	**Older Individuals Mean ± SD**
CFQ Total Score	**41.6 ± 7.6**	**38.8 ± 12.8**
GFQ Distraction	17.4 ± 3.3	16.2 ± 5.2
GFQ Memory	9.3 ± 2.4	8.9 ± 3.7
GFQ Blunders	10.6 ± 3.2	9.2 ± 4.1
CGQ Names	4.3 ± 2.0	4.5 ± 2.0
PRMQ Total Score	**39.7 ± 6.2**	**37.4 ± 7.7**
PRMQ PM Scale	20.0 ± 3.5	19.3 ± 4.1
PRMQ RM Scale	19.7 ± 3.1	18.1 ± 4.1
GMQ Total Score	**131.9 ± 50.5**	**82.7 ± 52.1**

CFQ = Cognitive Failures Questionnaire, PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire

The younger and older participants reported similar levels of everyday cognitive failures as measured by the CFQ (U = 167.0, z = -1.1, p = .26 r = -0.17). Both groups also reported similar levels of general memory (PRMQ Total score, t (39) =1.03, p = .31, r = 0.16), prospective (PRMQ PM Scale: t (39) = .55, p = .58, r = 0.09) and retrospective memory failures (PRMQ RM scale: U = 156.-, z = -1.4, p = .16 r = -0.22). However, the older individuals reported significantly fewer difficulties in managing goals in their everyday life compared with the younger individuals (t (39) = 3.1, p > .05, r = .45)

Relationship between Performance on the Simple Computerised Tasks and Questionnaire Measures of Everyday Functioning are shown in Table 2.8.

Table 2.8: Relationship between performance on simple computerised tasks and self reported memory failures in young and old participants

Correlations[1]		**Simple computerised task Overall performance score**	
		Young participants	**Older participants**
CFQ	**Total Score**	.22	-.39
PRMQ	**Total Score**	-.23	-.04
	PM Scale Score	-.14	-.05
	RM Scale Score	-.15	-.23
GMQ	**Total Score**	.30	-.17

CFQ = Cognitive Failures Questionnaire, PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire

[1]Spearman's rho correlation coefficients are reported for all variables with the exception of CFQ total score and PRMQ RM scale score for which Pearson's r correlation coefficients are reported

**correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

No significant relationship was found between self-reported everyday memory functioning and performance on simple computerised tasks in either participant group.

2.4 Discussion

The present study investigated the sensitivity of simple computerised PM tasks and the modified Hotel Test to detect the effects of ageing in prospective memory performance in the laboratory. Both tests were found to be sensitive to the effects of ageing.

Older participants were found to show significant decrements in performance on simple computerised tasks in the PM condition in relation to the ongoing condition. Although both groups were found to show similar levels of accuracy in the ongoing and PM conditions, and introduction of the PM demand slowed both groups down in comparison to the ongoing condition, the older participants showed disproportionate slowing in the PM condition in contrast with the ongoing condition. One possibility is that older adults have slowed down in order to maintain same level of accuracy than the younger individuals.

Although older participants have consistently shown an increase in reaction times on laboratory tasks, the rate of slowing shown in the PM condition by the older group is disproportionately greater than slowing down shown by the younger individuals between the two conditions. This suggests that the older participants may have approached the PM task in a different way compared with the younger individuals or that normal ageing may compromise PM processes. Einstein and McDaniel's (2000) Multiprocess theory of PM makes a distinction between conscious monitoring and spontaneous retrieval processes. It is possible that ageing disrupts the intention retrieval mechanism, resulting in older individuals adopting a conscious monitoring approach. According to the SAS model's (Shallice and Burgess, 1996), contention scheduling system, the presence of a cue can lead to the triggering of the intention marker. It may be that older participants evaluate events during performance on the PM task on a trial by trial basis instead of relying for the intention marker to be automatically triggered and the to-be-performed intention spontaneously retrieved via spontaneous retrieval route when the relevant cue is encountered. Alternatively, older individuals may be less confident that a cue will trigger their to-be-performed intention, and choose to use active goal maintenance processes instead.

Older participants were also found to show poorer performance on the secondary listening task on the modified Hotel Test. Poorer performance on the mHT cannot be simply accounted for by allocation of more resources towards the main goal of attempting all five subtasks. This is because older participants also showed significantly longer time deviation and lower overall score on the mHT, which accounts equally for number of tasks attempted and correct number of executives arriving at the hotel being attended to. A closer inspection of the pattern of bell rings would suggests that the maintenance of the PM intention over time may be affected to a greater extent compared with younger individuals. This view is supported by older participants having made significantly fewer clock checks compared with the younger individuals. The clock checks may prompt internal goal reviewing or vice versa similar to auditory alerts having been shown to prompt internal goal review (Manly et al., 2002). Nothing in the task prompts the participant to check the clock, therefore clock checking is likely to rely on self-initiated retrieval mechanism supported by the PFC. PM has been argued to require greater self-initiated retrieval than retrospective memory (Craik, 1986). McFarland and Glisky (2009) found that low frontal lobe functioning was associated with less frequent monitoring of the clock supporting the involvement of the PFC in clock monitoring. Whether clock checking may be a useful marker of goal maintenance and is affected by ageing would need to be further assessed to confirm the significance of this finding.

Despite the addition of another task to the mHT, performance on the task remained close to ceiling in line with previous studies (Manly et al., 2002; Levine et al., 2011). Whether the level of difficulty following modification will be sufficient to allow assessment of change in performance over time or following rehabilitation interventions in patients with brain injury remains to be assessed.

The convergent validity of the simple computerised PM tests was found to be poor for the young participants but higher in the older participant group, further supporting the view of the two groups having treated the task differently, or having different levels of PM ability. The frequency of PM targets with an average of one target presented every four trials after first 50 trials, may have been too high for younger individuals making the task easy in comparison with the mHT. High PM target presentation frequency may have compromised a key aspect of prospective remembering, namely that the intention is not continually maintained in working memory. Therefore the task may not sufficiently tap into PM demand and the lack of convergent validity in the younger individuals is perhaps unsurprising. Reducing the frequency of PM target may allow the task to be more akin to complex multielement task and everyday life demands by increasing the amount of self-initiation demand needed to complete the intended actions. Reducing PM target frequency would be expected to reduce PM target accuracy, which is currently too high in order to allow for change resulting from cognitive rehabilitation interventions to be assessed using simple computerised tasks.

Whereas laboratory studies of prospective memory tend to be very short in duration and may allow for trial by trial approach to be used by older individuals, it is highly unlikely that older individuals would be able to maintain a continuous monitoring strategy for long intervals while being able to engage effectively in diverse other activities in everyday life.

The current study failed to find any significant relationship between objective task performance and self reported functioning. This is in line with previous studies that have reported older adults to do better in naturalistic PM tasks (Moskovitch, 1982; Rendell and Craik, 2000), older adults were found to report fewer goal management difficulties in everyday life suggesting that they are better at compensating for their ability in real life. The majority of the older individuals in this study were retired where as the younger participants were university students with a busy study schedule thus the two groups are likely to have different environmental PM demands in life for which questionnaires do not account. Previous studies have reported busy people experience more PM failures and subsequently rate their PM as poor (Uttl and Kibreab, 2011). As a result, PM questionnaire scores should not be interpreted as reflecting differences in PM ability without accounting for the level of environmental PM demand for each individual or group. Chaytor et al. (2006) has attempted to address this issue when using the Dysexecutive questionnaire (DEX) by asking people to rate the extent to which failures interfere with everyday functioning and how often people would compensate for difficulties. With the current approach, it is difficult to determine whether older individuals experience less goal management difficulties because their daily life has a low PM demand, they frequently compensate for their difficulties, do not notice them or that their PM ability really is intact. Future studies should address this issue when comparing two groups with different environmental demands.

During the brief break in simple computerised PM task PM conditions, it was noted that many older individuals took time to stop and review their performance during the first block, with some verbalising their intention of having to remember to respond to PM targets during the second block. Subsequent analysis of change in performance from the first to the second PM block revealed that the older individuals showed significant better maintenance in overall performance in comparisons to younger individuals but they were not significantly more accurate in maintaining their accuracy to PM targets in the second block than the first block compared with the younger individuals. This finding contradicts recent findings from an fMRI study suggesting that the elderly have difficulty in disengaging from interruptions on dual task paradigms (Clapp et al., 2011) and therefore warrants further investigation.

In summary, the current finding support the view prospective memory declines with age and decrements in performance can be assessed using laboratory tests of prospective memory. Due to methodological limitations, it cannot be determined whether performance on objective tests reflects an individual PM ability rather than functioning in everyday life.

Given that older participants were found to show age related decrements in performance once performance beyond accuracy was accounted for, future research should use composite scores in the assessment of PM ability to allow for any changes in the PM processes and task approach.

Chapter 3

Assessment of the effects of brief task interruption on prospective memory performance and its relationship with everyday memory functioning

Abstract

Background and aims: Many everyday tasks such as taking medication require prospective memory (PM). Computerised PM tasks used to study cognitive processes involved in PM typically involve performing an ongoing task into which PM targets are embedded. Such tasks often have a relatively high frequency of PM targets, which may prompt higher levels of attention and monitoring than is likely in real life situations and therefore may not provide an accurate measure of the likelihood of everyday PM errors. Whether performance on these simple tasks also reflects functioning in everyday life has not been established. This study investigated whether incorporating a brief break filled with an unrelated that would better reflect the attentional demands of everyday life and correlate with self-reported everyday functioning. **Method**: Twenty young healthy individuals completed two simple computerised PM tasks incorporating a brief break during which participants had to perform an unrelated task that prevented continuous maintenance of the PM intention. The ecological validity of these tasks was assessed using self-reports of everyday memory and cognitive functioning. **Results**: Significant reduction in PM target accuracy was seen following the brief break whilst performance on ongoing trials remained unchanged. PM performance was found to significantly correlate with self-reported memory and cognitive functioning. **Discussion and Conclusions**: The simple computerised PM tasks appear to be promising in assessing PM ability, perhaps capturing the attentional demands that are present in everyday prospective remembering.

3.1 Introduction

Tasks carried out in certain work settings, such as health care or aviation, rely heavily on prospective memory and are frequently interrupted. For example a nurse may be responsible for caring for several patients simultaneously and therefore needs to switch back and forth between patients, continually having to adapt their plan, prioritise and remember to return back to tasks started earlier. Interrupting an ongoing activity inherently creates a PM task (Dodhia and Dismukes, 2009) as the interrupted task needs to be remembered to be completed at some point later on. Interruptions themselves may potentially increase the likelihood of PM slips occurring due to the demands they place on encoding and working memory for example.

Much of the research into interruptions has focused on the adverse effects of interruptions and how interruptions might be reduced. Failing to carry out an intended action after an interruption can be annoying but prospective memory failures can have serious consequences to safety at home or in a work setting. For example, following a series of interruptions, failure of an airline crew to set the flaps to the take-off position among technical failures, caused a plane to crash, killing all but one person on board (Holbrook & Dismukes, 2005). Surgeons' failures to remove instruments following operations have also partly been suggested to be failures of PM (Dismukes, 2012).

Several studies have suggested that brief interruptions can have a negative effect on PM task performance (Dismukes, Young and Sumwalt, 1998; Walders, 2012) where as other have failed to find an effect or have found effects only in some situations. For example, Shum, Cahill and Hohaus (2013) suggested that unexpected interruptions were only found to reduce performance on time-based PM task.

Several reasons for why memory slips following interruptions occur have been suggested: interruptions may divert attention, preventing sufficient encoding of an intention to resume the interrupted task and forming an implementation plan, new task demands after an interruption may reduce the opportunity to interpret cues that might remind the individual of the interrupted task (Dodhia and Dismukes, 2009) or they may disengage individuals from the demands of the PM task (Einstein et al., 2003; McDaniel et al., 2004)

Prospective remembering also requires, but does not rely on working memory (WM). WM is necessary for encoding of the intention and information held in WM decays rapidly without rehearsal where as there is no difference in PM performance after a 5-second delay compared to a delay of 40seconds (McDaniel and Einstein, 2007). Ongoing activities during the delay period prevent continuous rehearsal of the intention. Delays of as short as 10 seconds have been shown to worsen prospective remembering in laboratory studies with a delay filled with a task further decreasing performance (Einstein et al., 2000; Kliegel and Jager, 2006). Brandimonte and Passolunghi (1994) found that prospective remembering declined from 0 to 3 minutes if the retention interval was filled with a demanding mental task yet Stone et al. (2001) found no differences in retention intervals of 1, 3, and 5 min. Similarly, Guynn, McDaniel, and Einstein (1998) found no difference between 4- and 20-minute retention intervals. Einstein, Holland, McDaniel and Guynn (1992) also saw no differences in performance with longer delays of 15 and 30 minutes. WM may also be required during the execution of the intention particularly when there are fewer cues that can serve to trigger spontaneous retrieval of the intended action (Foster et al., 2009).

Law et al. (2004) suggested that interruptions are neither beneficial nor detrimental to task performance given that they failed to find any difference in the performance of neurologically healthy individuals a multitasking test the Greenwich Test (Burgess et al., 2000), who had no interruption and those who were interrupted early or late or both early and late during the task and required to carry out an unexpected task for one minute before returning to the Greenwich test.

Interruptions have also been reported to have a positive effect on behaviour. Manly et al. (2002) administered periodic auditory tones to dysexecutive patients during performance on the Hotel Test, which requires participants to attempt five different tasks without having enough time to be able complete them all, thus requiring participants to switch between tasks and keep track of their intentions while remembering to complete a time based prospective memory task at two set times. Participants were told that the auditory alert ‘cues’ may be useful in reminding them to think about what they were doing and in reviewing their overall goals during a multitasking task performance. Patients performed significantly better in the condition with auditory alerts compared to when no auditory tones where presented. Importantly patients did not use the tones as a signal to switch between tasks. Similarly, the Neuropage®, used clinically to aid everyday task completion in those with severe brain injury or executive dysfunction, utilises interruptions to aid performance through the delivery of external prompts (Evans et al., 1998).

Laboratory tasks of prospective memory that utilise computerised paradigms with an ongoing task into which PM targets are embedded (Burgess et al., 2001; Einstein and McDaniel, 1990), i.e. those that do not utilise complex multi-element tasks, often tend to have a relatively high frequency of PM targets and be short in duration with no other unrelated tasks introduced to give breaks to OG/PM condition performance as would be typical in everyday life settings. This may prompt higher levels of attention and monitoring, particularly in the early stages of task performance, than is likely in real life situations. These tasks therefore may not provide an accurate measure of the likelihood of everyday PM errors. Whether performance on these simple tasks also reflects functioning in everyday life is not established. Results reported in Chapter 2 using simple computerised PM tasks indicated that they were found to show good convergent validity with the modified Hotel Test (mHT) in older participants but not younger participants. The high frequency of PM targets may have mediated this relationship given the relatively high accuracy to PM targets. This study investigated whether reduction of PM target frequency would increase their convergent validity with the mHT.

Given the mixed findings in the interruption literature of PM, this study also investigated whether performance on tasks designed to reflect more accurately the attentional demands of everyday life by including an unannounced break filled with an unrelated task would increase the ecological validity of these tasks as measured by self reports of everyday memory and goal management behaviours.

3.1.1 Aims & Hypothesis

Aims

The primary aim of this study was to determine whether doing an unrelated task briefly will increase the likelihood of failing to realise a previously created future intention following the short break.

The secondary aim was to assess whether performance decay on the simple computerised PM tasks is related to self-reported memory and goal management functioning in everyday life neurologically healthy individuals.

Hypotheses

Primary hypothesis: A brief break filled with an unrelated activity during performance on the simple computerised PM tasks will have a negative effect on performance resulting in significant reduction in PM target accuracy following the break. Accuracy to ongoing stimuli in the PM condition is expected to remain unchanged.

Secondary hypotheses: It is expected that the simple computerised tasks will have good convergent validity with the modified Hotel Test with performance on the simple computerised tasks expected to correlate significantly with performance on the mHT.

Simple computerised tasks, as measured by performance decay over time will have good ecological validity and show significant correlations with self reported everyday functioning with those showing greater performance decay also reporting more frequent cognitive and memory failures in everyday life.

3.2 Method

3.2.1 Participants

Twenty young healthy individuals were recruited through adverts at the University of Glasgow. Of them, 14 were female and 6 male with a mean age of 22.5 (range 19-30, SD 3.2). On average, they had spent 16.3 years (SD 1.7) in full-time education. Participants were included in the study if they were between 18-30 years of age, right handed and spoke English as their first language and had no history of a neurological illness or a major psychological disorder.

3.2.2 Measures

3.2.2.1 The Modified Hotel Test (mHT)

The modified Hotel Test was administered as described in Chapter 2. In short, participants were told that they were to try and do at least some of all these five tasks over 15 minutes and that each of the tasks may well take longer than 15 minutes to complete on their own, so there was no way that they would be able to complete them all. The most important thing was to try and do something from each task — spending as much time on each as possible within the total time available. They were also told that while they were doing these tasks cars would be arriving at the hotel and they were to ring a bell each time they heard a company executive arriving so that someone could be sent to collect their bags.

3.2.2.2 Simple computerised PM tasks

Two (Number task and Picture task) of the three simple computerised tasks described in Chapter 2, were administered with the following modifications made to them: Two tasks were used instead of three in order to reduce time taken to complete them. Tasks with lowest mean PM accuracy scores were chosen.

1. The length of the tasks was changed from having a fixed number of trials to duration based with the ongoing condition lasting 2,5 minutes and the prospective memory condition lasting 3,5 minutes. The background colour of the stimuli was changed to black and the stimuli to white (Figure 3.1)

2. The baseline condition stimuli was changed from number and grid stimuli to a bar that flipped ('tip the seesaw') each time a participant pressed a button (Figure 3.1) but the participants motor response to stimuli remained unchanged (i.e. responses were still alternating between the left and right responses buttons). The inter stimulus interval (ISI) between trials in the baseline condition was changed to vary randomly between 300 and 700 ms to prevent participants from anticipating when next to press a response key The baseline condition was performed for 30 seconds before starting the PM condition in order to create a time delay between receiving the PM instruction and performing the task itself. The baseline condition was also performed between the first and the second PM block for 30 seconds in order to add a brief break filled with an unrelated activity in order to make the task more akin to the demands of everyday life (Figure 3.2).

3. Participants completed 10 baseline condition practice trials at the end of the ongoing condition in both the number and picture task. A total of 10 practice trials were also completed before starting the OG and PM conditions.

4. In the PM condition, the ISI between trials was set to vary randomly between 150 and 350ms and the PM target frequency was decreased from 20% to one PM target being presented at a randomly selected point between 3rd and 21st second per every 30 seconds of task performance or two PM targets per every 30 seconds of task performance with one PM target being presented at a random time between 3rd and 10th second and one and between 14th and 21st second.

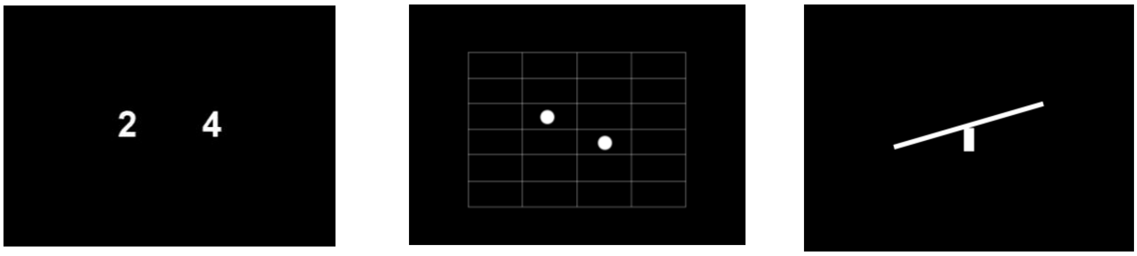

Figure 3.1: Computerised task stimuli. The figure on left shows Number task stimuli, figure in the middle picture task stimuli and the figure on the right baseline condition stimuli.

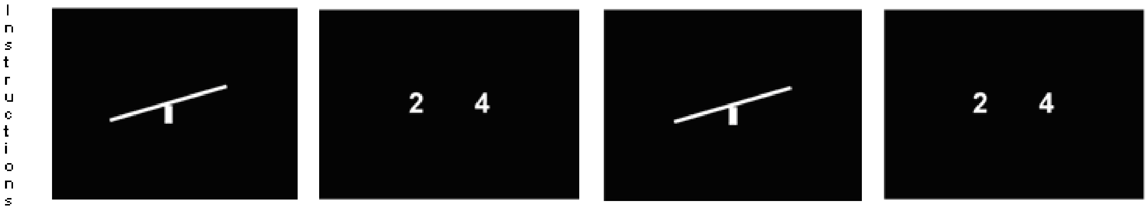

Figure 3.2: Stimuli sequence in the prospective memory condition; Baseline, PM1, Break (baseline), PM2.

3.2.2.3 Questionnaires

Cognitive Failures Questionnaire (CFQ; Broadbent et al., 1982), Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford et al., 2003; 2006), and Goal Management Questionnaire (GMQ; Robertson, Levine and Manly, 2000; Levine, Manly and Robertson, 2012) were administered as measures general cognitive, memory and goal management functioning in everyday life.

3.2.3 Procedure

Participants completed the mHT and simple computerised tasks. The mHT was administered as in Chapter 2 and the order of task presentation in the simple computerised tasks was counterbalanced across subjects. The ongoing task condition in each task was completed before the prospective memory condition. The questionnaire measures were completed at the end of the testing session.

3.2.4 Ethical approval

Ethical approval for the study was obtained from the University of Glasgow Faculty of Medicine ethics committee.

3.3 Results

Data analyses were carried out using PASW Statistics 18 (SPSS, Chicago). Descriptive statistics were computed for variables of interest in the computerised task (Table 3.1) and the modified Hotel Test (Table 3.2). Variables were assessed for normality and non-parametric statistical tests were used to compare conditions or to assess the relationship between variables where the assumptions of normality were violated.

Table 3.1: Performance on Simple Computerised Tasks

Variable	**Mean Accuracy (%)** **Mean ± SD**	**Mean Reaction time (ms)** **Mean ± SD**
Ongoing condition	96.6 ± 2.3	582.6 ± 61.6
Prospective memory Condition	94.3 ± 3.0	810.3 ± 154.8
Block 1 PM targets only	65.0 ± 21.4	931.9 ± 171.6
Block 2 PM targets only	49.6 ± 39.6	793.8 ± 207.0
PM Block 1 OG trials only	95.9 ± 2.3	811.6 ± 152.8
PM Block 2 OG trials only	96.5 ± 2.5	777.8 ± 244.1

PM = prospective memory, OG = ongoing

Wilcoxon signed rank test revealed that PM instruction had a significant cost to both accuracy (z = -3.58, p < .05, r = -0.80) and reaction times (z = -3.92, p < .05, r = -0.88) compared to the ongoing condition. PM target accuracy was significantly lower following the brief break compared to pre-break (z =-2.0, p < .05, r = -0.45) Participants were also significantly faster in responding to the PM targets following the brief break (z = -2.3, p < .05, r = -0.51). Despite reduced accuracy to PM targets, no significant change in accuracy (t = -.96 (19), p = .35, r = 0.22) or reaction times z = -1.83, p = .07, r = -0.41) to ongoing trials in the PM condition were seen from before to after brief break (Figure 3.3).

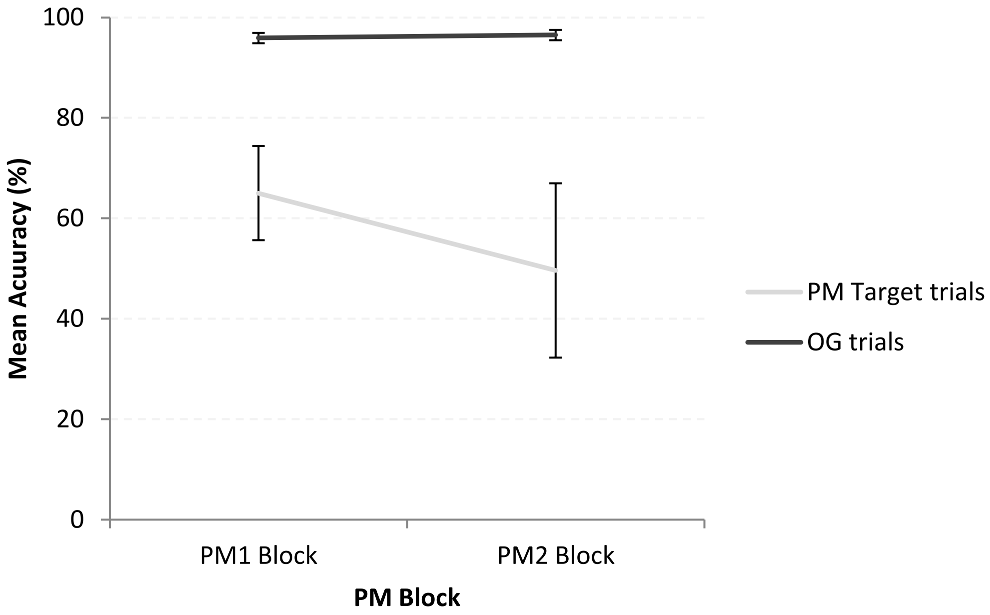

Figure 3.3: Accuracy to ongoing (OG) and prospective memory (PM) trials in the PM condition before and after brief break. Error bars represent 95% confidence intervals.

Table 3.2: Performance on the Modified Hotel Test

Variable	**Mean ± SD**
mHT number of tasks attempted (/5)	4.7 ± .57
mHT number of correct bell rings (/10)	8.7 ± 1.3
Total PM score	180.5 ± 16.1
Time deviation (seconds)	301.1 ± 146.4
Number of clock checks	3.7 ± 2.3

mHT = modified Hotel Test, Total PM score = % of number of tasks attempted + % of correct bell rings

Ceiling effects were noted to be present with regards the number of tasks attempted on the mHT.

3.3.1 Convergent Validity

Correlational analyses were performed to assess whether modification of the simple computerised PM tasks had improved the convergent validity of the tasks with the mHT in young adults. A summary of the relationship between mHT variables and overall performance on the simple computerised PM tasks is provided in Table 3.3.

An overall performance score was calculated as per Chapter 2 by subtracting accuracy in the OG condition from PM condition accuracy and converting this into a z-score. Reaction time in the OG condition was then also subtracted from PM condition reaction time and converted into a z-score before an inverse z-score of the reaction time was calculated. The inverse z-scores for speed and the z-score for accuracy were then added together. Higher overall performance scores indicated poorer performance and lower overall scores better performance in the PM condition while accounting for performance in the ongoing condition.

Table 3.3: Relationship between Performance on the Simple Computerised Tasks and the mHT.

Correlations mHT variable	Simple computerised task Overall performance score
Number of tasks attempted	-.08
mHT number of correct bell rings	-.54*
mHT total PM score	-.54*
Total time Deviation	-.05
Total number of clock checks	.51*

mHT = modified Hotel Test, Total PM score = % of number of tasks attempted + % of correct bell rings
Pearson's *r* correlations reported for all variables with the exception of number of tasks attempted and number of correct bells rings for which Spearman's *rho was* used due to assumptions of normality not being tenable. **correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

The relationship between performance on the simple computerised tasks and the mHT, demonstrated a significant correlation of large effect between the overall performance on the simple computerised tasks and number of correct bell rings (*rho* = -.54, $p < .05$) and total PM score on the modified Hotel Test ($r = -.54$, p = < .05). A positive relationship of large effect was also seen between overall performance and the number of clock checks with those showing poorer performance on the simple computerised tasks also making more frequent clock checks.

3.3.2 Ecological Validity

Mean scores for the self -rated questionnaire measures are presented in Table 3.4.

Table 3.4: Mean Questionnaire Self-Rating for the Sample

Variable	Mean ± SD
CFQ Total Score	**44.4 ± 16.0**
PRMQ Total Score	**43.1 ± 9.8**
PRMQ PM Scale	23.1 ± 5.0
PRMQ RM Scale	20.1 ± 5.3
GMQ Total Score	**172.2 ± 68.7**

CFQ = Cognitive Failures Questionnaire, PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire

The mean PRMQ indicate that on average the participants reported both their PM and RM abilities to be in normal range (*T* = 44 [Confidence Intervals (CI) 39-52] and *T* = 47 [CI 41-55] respectively).

To assess whether performance decay (performance to PM targets following brief break minus performance to PM targets before brief break) is a useful measure of everyday cognitive and memory functioning, performance decay was correlated with questionnaire self-ratings (Table 3.5). Performance decays was calculated by deducing mean accuracy to PM targets post-break from the mean accuracy to PM targets pre-break

Table 3.5: Relationship between Performance decay on Simple Computerised Tasks and Self-reported Everyday Functioning.

Questionnaire	Simple computerised task performance decay
CFQ Total Score	-.65**
PRMQ Total Score	-.66**
PM	-.65**
RM	-.60 **
GMQ Total Score	-.27

CFQ = Cognitive Failures Questionnaire, PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire

Pearson"s *r* used for all analyses * Correlation is significant at the 0.05 level (2-tailed). **Correlation is significant at the 0.01 level (2-tailed).

Significant correlation of large effect between was seen between overall performance on the simple computerised PM tasks and general everyday cognitive failures as measured by the CFQ (r = -.65, p < .05). Large effect was also seen between overall task performance and all the PRMQ scales (p<.05). Small to medium effect was found between task performance and the GMQ (Figure 3.4). An outlier was identified in the self-reported GMQ data (top right corner on the figure on the left). Should this have been excluded, the relationship between task performance and self reported everyday goal management difficulties would have yielded a large effect (r = -.50, p < .05).

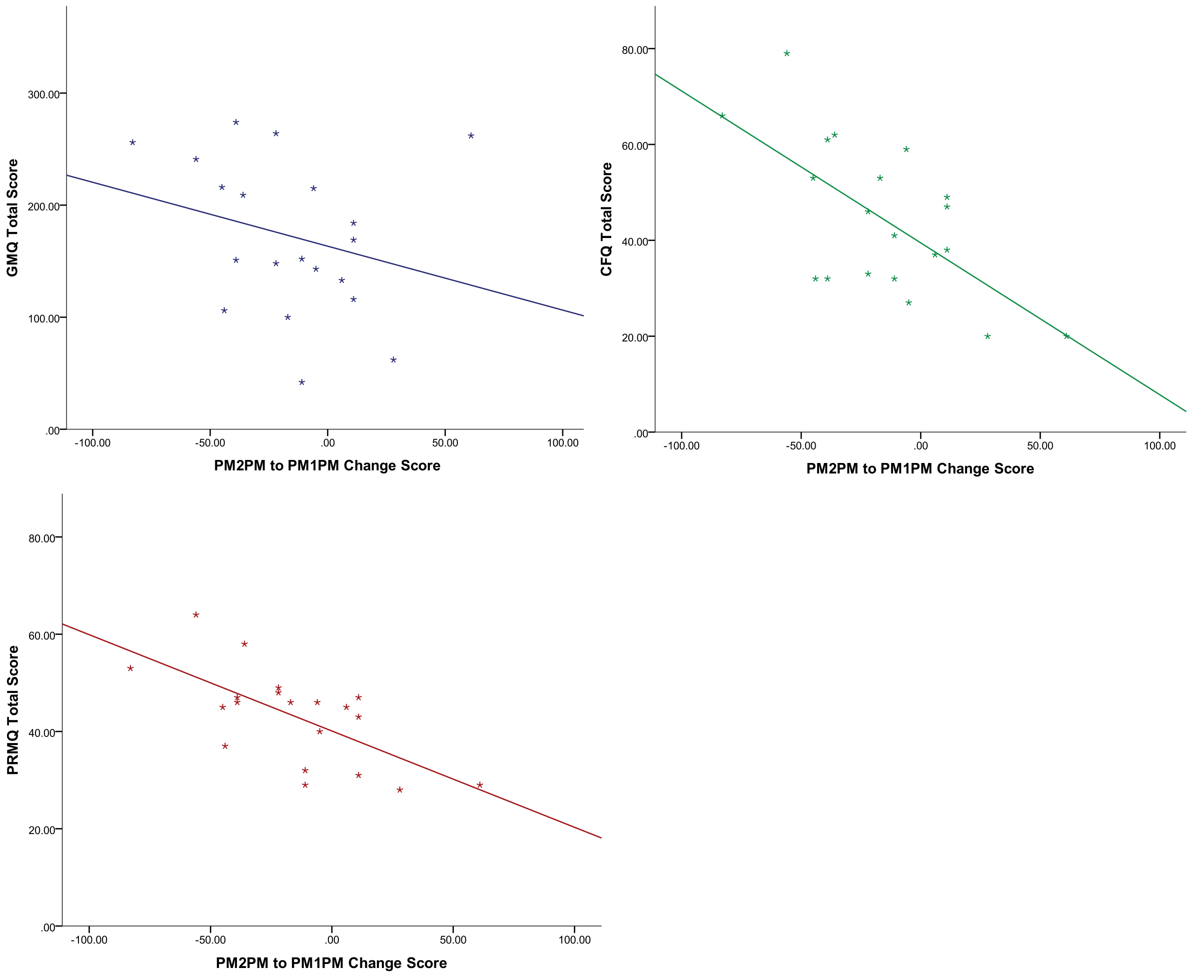

Figure 3.4: Relationship between performance decay and GMQ total score (top left), CFQ total score (top right) and PRMQ Total score (bottom left).

3.4 Discussion

This study investigated the effects of a brief break on performance on simple computerised prospective memory tasks. The convergent- and ecological validity of these tasks were also evaluated in a group of young neurologically healthy individuals.

A brief break filled with an unrelated task was found to have a negative effect on performance on simple computerised PM tasks with participants showing performance decay characterised as a significant drop in PM target accuracy following the brief break compared to PM target accuracy pre-break. Given that this effect was seen only for the PM targets and the accuracy to the ongoing trials in the PM condition was maintained, this finding is unlikely to be due to general drop in attention over time.

This effect may have been due to the effects of taking a brief break from the current task or due to the effects of briefly performing an unrelated task. One possible explanation for the finding is that the brief interruption to the PM task may have reduced the cognitive resources available to maintaining the intention during the delay period by interfering with the rehearsal of future intentions when performing a new unrelated task. This is turn, may have displaced information held in the working memory.

The concentric model of working memory (Oberauer, 2002) suggests that working memory has three regions of attentional centres with the ‘focus of attention’ being able to hold only one chunk of information at any time that can be selected as the focus of the next cognitive operation. The region of ‘direct access’ can hold a limited number of items that are not needed for ongoing task processes but can remain available in the background for later recall. Items outside the region of direct access are part of long-term memory and can be accessed only indirectly via ‘associative links.’ Thus it is possible that during initial performance in the ongoing condition, items are within the ‘focus of attention’ and ‘region of direct assess’ centres of working memory model but when performance is interrupted with an unrelated task, the PM element of the intention drops to the ‘long-term memory’ region of the model making recall of the intention more difficult following the break if ‘associative links’ have not been created to aid recall.

The Gateway theory (Burgess et al., 2007) offers an alternative interpretation of the findings. It suggests that successful realisation of future intentions requires switching of attention between internal and external processing; hence it may be that performing an unrelated task reduces the amount of cognitive processes available to internal processes.

This study did not find evidence to indicate that younger participants would have used the break during which they were asked to perform an unrelated task that was low in cognitive load to refresh or review their future intentions. This finding is in line with previous research suggesting that people do not tend to take advantage of brief breaks to improve PM unless they are give specific instructed to do so (Finstad, Bink, McDaniel and Einstein, 2006).

Given that no ceiling effects were present of performance on the computerised tasks, they may be suited for repeated assessment of PM or for assessing the effects of brief rehabilitation interventions as participants will have room to improve their performance

Future research should investigate whether it is possible to reduce performance decay on simple computerised PM tasks by asking participants to apply cognitive strategies aimed at increase the likelihood of the PM intention remaining in the centre of direct access without compromising performance on the ongoing task or other unrelated tasks. McDaniel, Einstein, Graham and Rall, (2004) showed that presenting participants with an external cue, in the form of a small blue dot that was shown on the corner of a computer screen, following a task interruption improved PM performance presumably by serving as a reminder of participants future intentions.

Convergent validity

The simple computerised tasks were found to show good convergent validity with the mHT in a group of young neurologically healthy adults following a reduction in PM target frequency in comparison to Chapter 2. Overall PM performance and the number of correct bell rings on the mHT was found to be significantly related (medium to large effect size) to performance on the simple computerised PM tasks. Clock checking was also found to show significant correlation of a large effect size with those performing more frequent clock checks also showing better performance on the computerised task. This replicates the findings presented in Chapter 2 supporting the view that clock checking may be a marker of internal goal review or PM ability given that those better able to remember to check the clock may also show better performance on PM tasks. The convergent validity of the simple computerised tasks was thus increased as a result of the task manipulation. This may suggests that a sufficiently long delay that prevents constant rehearsal of the PM intention is required between PM targets.

Ecological Validity

The simple computerised PM tasks were found to show good ecological validity with self-reports of general cognitive- and memory failures. However, the strong relationship shown between task performance and everyday functioning was not specific to PM memory given that the strength of relationship between general cognitive failures and prospective and retrospective memory failures was equal. Nevertheless, this finding is encouraging given that performance decay may be a more sensitive predictor of functioning in everyday life compared with overall task performance presented in Chapter 2. It is possible that it better captures the attentional demands of everyday life by taking into account the effect other unrelated tasks have on the maintenance on PM intentions. In everyday life, intentions that are created to be performed later, for example, posting a letter in the evening, need to be maintained throughout the day, with several other tasks completed before the intention of posting a letter can be realised. Performance decay may therefore reflect the likelihood of an individual making a PM slip following completion of other tasks, with greater decay indicating greater likelihood of future goals and intentions going uncompleted in everyday life.

Limitations and Future research

A limitation of this study is a shorter duration of the PM block following the brief break and future studies should confirm this finding using blocks of equal length before and after an intervening task. Another limitation of this work is the lack of control condition with no break to which performance decay could have been compared to. Future work could investigate this further given that the main purpose of this study was to develop a method that could be used to measure the maintenance of future intentions.

Given that most research on the effects of interruptions has focused on the adverse outcomes of interruptions, future research should aim to utilise any possible beneficial effects of interruptions and investigate how they could be used to aid PM performance through the use of cognitive strategies. Strategies should be theoretically driven and target different stages of the PM process, for example by reducing working memory interference through strategies aimed at enhancing encoding of the intentions or maintenance of intention through strategies tapping into attentional processes of PM.

In summary, the findings suggest that simple computerised PM tasks possess good convergent and ecological validity and performing an unrelated task briefly can affect the subsequent maintenance and realisation of future intentions.

Chapter 4

Assessment of Prospective Memory following Brain Injury: Validation of the Simple Computerised Tests in Individuals with Acquired Brain Injury

Abstract

Difficulties with prospective memory (PM) and multitasking are common after brain injury. When clinicians assess these problems, particularly in a rehabilitation context, it is important that the tests applied are sensitive to difficulties experienced in real life (i.e. that they are ecologically valid), and that different tests intended to measure the same function produce similar results (i.e. that they have convergent validity). At present few tests of PM have been developed that have been shown to have both strong ecological and convergent validity. Even fewer tests that are suited to use with current brain imaging technology to assess the neural basis of PM in brain injured patients exist. This study investigated the degree of convergent validity between simple computerised PM tasks, suited for use with brain imaging methodologies (fMRI), and the modified Hotel Test. Their relationship with currently used clinical PM assessment tool, Cambridge Prospective Memory Test (CAMPROMPT), was also investigated in a group of 39 patients with ABI. Furthermore, the ecological validity of all three tests was investigated using self- and informant rated questionnaire measures of everyday functioning. Results indicate that both the simple computerised PM tasks and the mHT have reasonable ecological validity and good convergent validity with the CAMPROMPT. All but the Picture simple computerised PM task were found to be sensitive to the effects of ABI. The findings have implications for enhancing the validity of assessments used in clinical practice.

4.1 Introduction

Acquired brain injury (ABI) often involves damage to the frontal lobes (Levin, 1995) and is characterised by deficits in several distinct areas of executive functioning, such as planning and prospective memory (PM), while other primary cognitive functions such as memory or language may remain intact (Shallice and Burgess, 1991). Executive functions have a central role in maintaining adaptive independent functioning as tasks commonly encountered in everyday life often require management of multiple goals, sub-tasks and changing priorities (Shallice and Burgess, 1996).

Traditional tests of frontal lobe functioning such as the Stroop and the WCST were not originally designed to be used in patient populations (Burgess et al., 2006a). Performance on these tests often fails to capture the level of executive impairment experienced by patients outside the laboratory setting (Shallice and Burgess, 1991) hence they have poor predictive value in how a patient might function in situations in their daily life – for example whether they are likely to able to operate the hob safely or to return to previous employment.

Consequently, efforts have been made to develop assessment measures that are ecologically-valid – such as the Behavioural Assessment of Dysexecutive Syndrome (BADS; Wilson et al., 1996), the Hotel Task (Manly et al., 2002) the Executive Secretarial Task (EST; Lamberts, Evans and Spikman, 2010), Virtual Mall (Rand, 2005, 2007) and the Multiple Errands Test (MET; Shallice and Burgess, 1991), and developed based on a theoretical framework. The Hotel Test, for example, was developed around the concept of 'goal neglect' (Duncan, 1986). Although these new assessment measures are considered to have greater ecological validity, they are not as effective at measuring specific cognitive processes, such as prospective memory. Because of their complexity, they can be failed for many different reasons. Recent modifications to one of these tests, the modified Hotel Task (Chapter 2) appears promising in that the test now enables measures of PM to be derived in the context of a complex multitasking environment. The overall PM- and bell ring measures were shown to correlate with performance on simple computerised PM tasks typically used for assessing PM in healthy individuals (Chapter 3). It is not known whether the simple computerised PM tasks are also suitable and valid for assessing the PM functioning of individuals with ABI.

The small number of functional imaging studies that have been carried out using similar computerised PM task (Burgess, Quayle and Frith, 2001; Burgess, Scott and Frith, 2003; Gilbert, Gollwitzer, Cohen, Burgess and Oettingen, 2009; Okuda et al., 1998, 2007; den Ouden, Frith, Frith and Blakemore, 2005; Reynolds, West and Braver, 2009; Simons, Scholvinck, Gilbert, Frith and Burgess, 2006), have consistently shown activations within the rostral PFC in neurologically healthy individuals suggesting the tasks reflect the functions of a specific brain region. The current evidence for the neural basis of PM is based on evidence from studies on healthy individuals and studies using lesion mapping approaches (Burgess et al., 2000). The neural basis of PM remains to be investigated in patient populations using brain imaging methods such as fMRI, yet validated paradigms suited for use with brain imaging technologies in patient populations are lacking.

Whether the seemingly different measures of simple computerised PM tasks, believed to be ‘purer’ measures of PM functioning, and the complex multi-element tasks such as the mHT or other clinical PM tasks such as CAMPROMPT, have good convergent validity measuring the same underlying cognitive constructs when administered to individuals with ABI is not know. It is also not known whether patients with ABI will necessarily show impaired performance on these tasks and whether performance on such tasks reflects the kinds of difficulties reported in everyday life following brain injury.

4.1.1 Aims

The main aim of this study was to determine whether the simple computerised PM tasks display good convergent validity with the modified Hotel Test in a group of individuals with ABI and whether these two task formats are sensitive to the effects of ABI.

Given that clinicians use assessments to gain a better insight into the kinds of difficulties individuals experience in their daily life, this study also assessed the ecological validity of the simple computerised PM tasks and the modified Hotel Test in patients with ABI by examining the relationship between the performance of both assessment measures and informant measures of memory and goal management difficulties in everyday life.

The secondary aim of this study was to see whether both the simple computerised prospective memory tasks and the mHT also have convergent validity with CAMPROMPT, which is a clinical tool used for assessing PM functioning.

4.1.2 Hypotheses

Primary hypothesis: To assess the convergent validity of measures of PM, performance on the simple computerised tasks was expected to show significant correlation with overall performance on the modified Hotel Test.

Secondary hypotheses: To assess convergent validity of the PM measures and currently used clinical assessments of PM, performance on the simple computerised tasks and the mHT was expected to correlate significantly with performance on the CAMPROMPT.

To assess the ecological validity of the measures of PM, reports of informant rated everyday functioning were expected to show significant correlation with performance on simple computerised tasks as with mHT.

To assess sensitivity of PM measures to brain injury, it was hypothesised that individuals with ABI would show poorer performance on the simple computerised tasks and the mHT than neurologically healthy individuals.

4.2 Method

4.2.1 Participants

Forty-seven individuals (36 males, 11 females) with acquired brain injury (ABI) and sixteen control participants (8 males, 8 females), with no history of neurological illness or head injury that has resulted in loss of consciousness, were initially recruited. Over the course of the study, three patients dropped out without having completed the CAMPROMPT. One of these dropped out before having completed the mHT, three individuals failed to return both informant-rated questionnaires and one had only partially completed informant rated GMQ. In addition, three individuals did not complete computerised PM tasks; one was unable to complete them due to a physical disability, one due to a fractured hand and one due to refusal. Thus the final sample comprised 39 individuals (38 individuals where results from the CAMPROMPT are reported). The demographic characteristics of the sample are summarised in Table 4.1.

Table 4.1: Demographic characteristics

Variable	ABI Group Mean (SD)	Control Group Mean (SD)
Age (years)	47.1 (10.3)	40.2 (13.7)
Gender (count) *	32 males /7 females	8 males / 8 females
Education (years)	13.3 (3.1) range 10-17	13.1 (2.1) range 9-22
WTAR (FSIQ)	108.2 (6.9)	99.9 (13.5)
SE Index	3152.4 (2058.9)	3783.7 (1993)
percentile	40-50%	50-60%
PTA (days)	46.5 (61.0) range 0-240	—
Time since Injury (years)	5.7 (6.2) range 0.5-21	—

WTAR = Wechsler Test of Adult Reading; SE Index = Index of Multiple Deprivation (SIMD; 2009), PTA = post-traumatic amnesia
* p<.05

The control and patient group did not significantly differ on any of the following demographic characteristics: age, length of full-time education and socioeconomic deprivation index score (all p-values > .05), however, the patient group had lower estimated pre-morbid IQ (WTAR FSIQ; U = 197.5, z = -2.13, p < .05, r = - 0.29) and a higher proportion of male participants than the control group (X^2 (1) = 5.9, p <.05.).

Aetiology of injury was traumatic brain injury (TBI) (n=22), stroke (n=5), non-traumatic brain haemorrhage (n=10), hypoxia (=1) or viral infection (n=1). The majority of injuries (n=34) were classed as severe to extremely severe (Bigler, 1990).

Thirty-six of the patients included in the final group were right-handed. In the control group, fifteen of the participants were right handed. Epilepsy was experienced secondary to ABI by 5.3% of patients and 23.1% reported experiencing co-morbid psychological difficulties with moderate to severe depression and 33.3% with moderate to severe anxiety. In the control group, this was 6.25% for depression and 12.5% for anxiety. The patient group reported experiencing greater degree of depression (U = 100.5, z = -3.93, p < .001, r = -0.53) and anxiety (t (53) = 3.15, p < .05, r = .40) than the control group.

Participants met the following inclusion and exclusion criteria:

4.2.1.1 Patient group inclusion criteria

Participants had to be between 18 and 65 years old having sustained an ABI, after the age of 16 and at least six months prior testing in order to be past the acute phase. They had to speak English as their first language. They also had to have capacity to consent to research and/or medical treatment and have a significant other who was willing to complete informant questionnaires. The significant other did not have to be a family member but had to have knowledge of how the individual was functioning in their everyday life though regular contact with the participant.

4.2.1.2 Patient group exclusion criteria

Individuals with severe amnesia, major psychological or psychiatric conditions, pre-morbid learning disability and neurodegenerative conditions were excluded. Further exclusion criteria included having severe visual or hearing impairment, severe dysphasia, current substance use problems or physical disability which would have interfered with the individual’s ability to complete the tasks involved in the study. As assessment required individuals to read and write, illiterate participants were excluded. In addition to those 39 included in study and those excluded from the analysis due to missing data, nine individuals were excluded after initial screening procedure for not meeting the inclusion and exclusion criteria. Reasons for exclusion were: paediatric brain injury (n=5), aged over 65 (n=1), learning disability (n=1), no ABI (n=1) and incapacity to consent (n=1).

4.2.1.3 Control group inclusion criteria

Participants were included in the study if they were between 18 and 65 years old, spoke English as their first language and had no history of a neurological disorder or head injury that had resulted in a loss of consciousness. The control participants were matched with the experimental group for age and level of education where possible.

4.2.1.4 Control group exclusion criteria

Exclusion criteria applied to those with a history of major psychiatric or psychological problems, severe visual or hearing impairment and illiteracy. One person was excluded after initial screening due to having a neurogenerative disorder.

4.2.2 Recruitment

Participants were recruited through Headway Scotland, Momentum and IntoWork voluntary-sector organisations as well as from the Glasgow Community Treatment Centre for Brain Injury, the Brain Injury Rehabilitation Trust (BIRT) in Springburn, Glasgow Community Stroke Service, the West Dumbartonshire ABI Team, and the Douglas Grant Rehabilitation Centre in Ayrshire. Verbal and written information about the study was provided to potential participants and accompanying carers/family members that invited them to participate (Appendices C-E). In non NHS recruitment sites group based presentations were used in addition to provide information about the study for potential participants. In NHS sites and inpatients services individuals received study information via a clinician or a worker responsible for their care. A reminder letter was given to a participant (Appendix F) where they had initially expressed intention to take part in the study but had not contacted the researcher after a reasonable amount of time. Relatives and friends of individuals with acquired brain injury were invited to participate in the control group (Appendices G-H). In addition, participants for the control groups were recruited via adverts placed at the University of Glasgow and at the Southern General Hospital in Glasgow. Initial screening of the participants was conducted by one of the researchers involved in the study via telephone (Appendix I).

4.2.3 Measures

The control group completed the following measures only: Wechsler Test of Adult Reading (WTAR; Wechsler, 2001), the modified Hotel Test, simple computerised PM tasks and all self rated questionnaires. The experimental group received all of the following measures:

4.2.3.1 Questionnaires

The Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford et al., 2003; 2006) and the Goal Management Questionnaire (GMQ; Robertson, Levine and Manly, 2000, Levine, Manly and Robertson, 2012) were completed by both participants and a significant other who knew the participant well (patients only) prior to assessment taking place and brought to their first assessment session. Informants' views were seen as necessary because the reliability of patients' reports, may, in some cases, be undermined by lack of insight, unawareness or denial of their neurological illness (anosognosia). The significant other was either spouse (n=18), family member (n=15), friend (n= 1) or carer/professional (n=5). The PRMQ was used to gauge the impact of memory failures on participant's daily living. A score for PM component and RM component was derived from this measure. The GMQ was used as a measure of goal management difficulties.

4.2.3.2 Background neuropsychological assessment measures

The following tests were completed to characterise the brain injured sample: Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as a pre-morbid estimate of IQ, Symbol Digit Modalities Test (Smith, 1982) as a measure of processing speed, Matrix Reasoning subtest of WAIS-III (Wechsler, 1997) as a measure of general intellectual ability, Logical Memory subtest from the Wechsler Memory Scale – 3rd Edition (WMS-III; Wechsler, 1998) to assess immediate and delayed verbal recall, Rey Complex Figure Test (RCFT; Meyers and Meyers, 1995) to assess immediate and delayed visual recall and the Trail Making Test A and B (TMT; Reitan, 1958) to examine the level of executive impairment.

In addition, the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983) was used measure participant's mood and anxiety. A brief Likert-scale questionnaire was also used to assess individual's prior familiarity with computers (Appendix J).

4.2.3.3 Experimental Measures

To assess prospective memory, the participants completed a modified version of the Hotel Test (Manly et al., 2002) and two simple computerised PM tasks (adapted from Burgess et al., 2003).

4.2.3.3.1 Modified Hotel Test

The Modified Hotel (mHT) is described in more detail in Chapter 2. Participants were presented with five tasks they were required to attempt during 15 minutes as well as a secondary listening task, which had to be completed in response to given events during the task.

Administration of the task instructions was scripted to ensure consistency of administration across different researchers. Understanding of the task instructions was checked before commencing the task. Written instructions for subtasks were placed on top of the task materials for each task and the listening task cue (CBC) reminder under the bell in order to reduce demands on retrospective memory. These were visible to the participants throughout the task. Participants were not prompted to switch task as in Manly et al.,

(2002) if they had not switched task after the first five minutes. Participants' recall of the overall aim was checked at the end, if the participant had not attempted all five tasks and rang the bell for each of the ten executives in order to determine whether the failure to switch was due to prospective memory (failure to realise remembered intention) or retrospective memory error (forgetting task instructions). Performance was scored as follows: total number of tasks attempted (out of 5), total number of PM targets detected (out of 10), total time deviation (time spent on a task – 180 seconds) and number of clock checks made. A total PM scored was formed by converting number of tasks attempted and number of bell rings to percentages and added together.

4.2.3.3.2 Simple computerised PM tasks

The computerized tasks were based on tasks used by Burgess et al., 2003 (Number processing, Picture processing) and similar in format to those described in Chapter 3. The tasks were presented using E-prime (Psychology Software Tools, Inc., USA) and the order of task presentation was counterbalanced across subjects. Each of the tasks was subject paced, time limited in duration and consisted of three conditions; baseline, ongoing task and prospective memory (identical to the ongoing task but with an additional prospective memory instruction on some of the trials). In the prospective memory condition participants encountered a PM target either once or twice within every 30 second period. Participants completed a short practice block of trials prior to starting the experiment in each condition. The ongoing condition was presented before the prospective memory condition in both tasks to avoid "contamination" of ongoing task performance with PM task performance (Simons et al., 2006). The baseline condition was completed immediately prior to the prospective memory condition in order to prevent maintenance rehearsal of the task instructions and result in the task becoming a test of vigilance rather than PM.

4.2.3.3.2.1 Number Task

Subjects were presented with pairs of digits ranging from 1-9 (Figure 4.1). In the ongoing task condition participants had to choose whether the number on the left or right hand side of screen was greater by pressing the response button on that side. In the condition that required prospective memory, a different response was required on some of the trials whilst performing the ongoing task (when two even numbers appear together). The duration of the ongoing condition was time limited to three minutes and the PM condition duration was limited to six minutes.

4.2.3.3.2.2 Picture Task

Participants were presented with a four by six grid containing two white circles (Figure 4.1). In the ongoing condition participants were asked to judge the orientation of the two white circles to one another. In the condition that required prospective memory, they were asked to continue to judge the orientation of the two white circles to one another but if both white circles were in the middle two rows of the grid, they were to press a different response button.

4.2.3.3.2.3 Baseline Condition

In the baseline condition in both tasks, subjects were asked to make a motor response (alternating between the left and right response buttons) to a visual stimuli ('seesaw') as fast as they can when they see it reappearing, alternating between two response buttons (Figure 4.1).

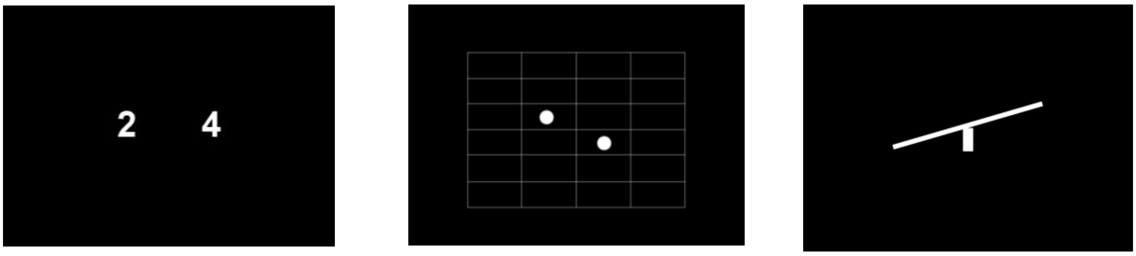

Figure 4.1: Computerised task stimuli. The figure on left shows the Number task stimuli, the figure in the middle the Picture task stimuli and the figure on the right the baseline condition stimulus.

4.2.3.4 Clinical Assessment Measures

The Cambridge Prospective Memory Test (CAMPROMPT; Wilson et al., 2005) was administered as a clinical measure of prospective memory functioning. The CAMPROMPT consists of three time and three event-based PM tasks which need to be carried out after varying delays over approximately a thirty minute period. The test also has excellent inter-rater reliability of 99% (Wilson et al., 2005). Summary of the CAMPROMPT prospective memory tasks is given in Table 4.2. Further information on the properties of the CAMPROMPT is available in the test manual.

Table 4.2: Summary of CAMPROMPT prospective memory tasks

Task Type	Task requirements
Event-based	Report 5 hidden objects and their locations when they are told that the test is over Give the examiner a book when they reach a quiz question about ‘East Enders’ Hand over an envelope marked ‘message’ when told “there are 5 minutes left”
Time-based	Remind examiner not to forget his/her keys when there are 7 minutes remaining Change to another task 7 minutes after the instruction is given Remind examiner to phone the garage five minutes after the end of the task

4.2.4 Research Procedures

Because this study was part of a larger assessment and intervention study on prospective memory and planning, the patient measures were completed over two sessions lasting approximately two hours each. The control participants completed all measures during one session lasting approximately one hour. The questionnaire measures (PRMQ and GMQ) were mailed out to participants prior to assessment and they were asked to bring the completed questionnaires to their first assessment session. Where possible, both assessment sessions were carried out by the same researcher and within the setting from which the individual had been recruited. During the first session, the participant completed the background neuropsychological measures, the HADS the computer familiarity questionnaires, the mHT and the simple computerized PM Tasks. The CAMPROMPT was completed in the second assessment session in addition to other assessment measures of prospective memory and planning (reported elsewhere). In addition to test administration and scoring protocols having been followed, an independent research assistant co-rated all the data collected by three different researchers involved in this study to ensure consistency in scoring.

4.2.5 Ethical Approval

This study was reviewed and approved by the West of Scotland Research Ethics Committee, NHS Greater Glasgow & Clyde Research & Development and NHS Ayrshire & Arran Research & Development.

4.3 Results

Data analyses were carried out using PASW Statistics 18 (SPSS, Chicago). Descriptive statistics were calculated to determine the neuropsychological profile of the sample (Table 4.3). Two-tailed correlational analyses were conducted between various measures of interest (for both convergent and ecological validity) using $\alpha = 0.05$. Independent t-tests or non parametric equivalents were conducted to determine whether the patient group was significantly different from that of the neurologically healthy control group with regards to their performance on the mHT and simple computerised PM tasks. Comparisons of correlation coefficients between the two different groups were carried out using the Williams' test (Williams' 1959).

4.3.1 Clinical characteristics of the sample

Summary of the ABI group's performance on background neuropsychological assessments is presented in Table 4.3.

Table 4.3: Clinical Characteristics of the patient sample

Measure	Mean (SD)	Range	Percentile
Premorbid-IQ			
WTAR (FSIQ)	100.0 (13.5)	70-119	50th
Reasoning Ability			
Matrix Reasoning	10.2 (2.9)	5-16	50th
Visual Memory			
RCFT immediate recall (T-score)	37.9 (16.5)	19-76	9-13th
RCFT delayed recall (T score)	35.9 (16.9)	19-70	7-9th
Verbal Memory			
Logical Memory immediate Recall	7.6 (3.7)	1-16	16-25th
Logical Memory delayed Recall	8.2 (3.9)	1-18	25-37
Processing Speed			
SDMT (z score)	-1.8 (1.3)	-.4.3 - .61	2nd-4th
TMT-A (seconds)	52.2 (22.2)	19-108	
(z score)	-2.3 (2.4)	-9.6 - .88	1-2nd
TMT –A (errors)	.05 (.22)	0-1	-
Executive Functioning			
TMT-B (seconds)	122.4 (78.4)	40-357	
(z score)	-3.9 (5.1)	-16.17-1.51	<0.1st
TMT-B (errors)	.92 (1.9)	0-9	-

Age-adjusted scaled score reported apart from RCFT (Ray Complex Figure Test) where T-scores reported and SDMT and TMT where z-scores reported. TMT errors = number of errors. One participant excluded for TMT B due to z score being -41.4 (extremely abnormal)

4.3.2 Sensitivity of PM measures to brain injury

4.3.2.1 Simple computerised Tasks

Participants' performance on the simple computerised PM tasks is summarised in Table 4.4. Data from the Number and Picture tasks were combined in order to form composite score of overall PM functioning.

Table 4.4: Comparison of performance of patients and control groups on the simple computerised tasks

Computerised Task Condition	ABI Group		Control Group	
	Accuracy (%) (SD)	Reaction Time (ms) (SD)	Accuracy (%) (SD)	Reaction Time (ms) (SD)
Ongoing (OG)	95.3 (6.1)	1043.4 (605.7)	98.5 (1.1)	724.8 (109.0)
Prospective memory (PM)	88.7 (12.5)	1924.1 (3043.0)	95.9 (3.1)	1023.0 (214.3)
PM Targets only	59.9 (33.0)	1687.6 (760.0)	74.6 (25.7)	1126.0 (308.4)
OG Targets only	91.2 (11.7)	1936.8 (3257.7)	97.3 (1.8)	1015.0 (208.8)

Accuracy scores reported as percentage (%) of total responses correct. Reaction times reported in milliseconds (ms).

Both the patient and control groups had higher overall accuracy (95.3% and 98.5%) and faster reaction times (1043.4ms and 724.8ms) in the ongoing condition compared with the PM condition (88.7% and 95.9%, 1924.1ms and 1023ms) respectively. The mean PM target accuracy of 59.9% correct in the patient group and 74.6% correct in the control group indicates that the level of difficulty was appropriate for both groups with no ceiling or floor effects being present. Due to violation of parametric assumptions, a Mann-Whitney U-test was performed to assess group differences in performance. The patient group was not found to be significantly less accurate in the ongoing condition (U = 228, z = -1.56, p = .119, r = -0.21). This was also true for the PM condition overall accuracy, (U = 226, z = -1.60, p = .110, r = -0.22), accuracy to PM targets (U = 235, z = -1.43, p = .153, r = -0.19) and accuracy to ongoing targets (U = 239.5, z = -1.39, p = .178, r = -0.19).

Although performance accuracy was not found to significantly differ between groups in any of the conditions, the patient group had significantly longer reaction times in both the ongoing condition (U= 168.0, z = -2.67, p < .05, r = -0.36) and all measures in the PM condition (overall: U = 151, z = -2.98, p < .05, r = -0.40, on PM trials: U= 131, z = -3.35, p < .05, r = -0.45 and on OG trials: U = 157, z = -2.87, p < .05, r = -0.39). The longer reaction times in the patient group, compared with the control group, may reflect the impact of brain injury on general processing speed as suggested by the patient group's neuropsychological profile (Table 4.3) and/or compensatory mechanism for achieving a greater accuracy in performance.

In order to control for the speed of responding in both the OG and PM conditions, an overall performance composite score was calculated due to violations of assumptions required for ANOVA and unsuccessful transformation of data to normality. The composite score was calculated by subtracting OG performance from PM condition performance (OGPM difference score) using a z-score approach with inverse z-used for reaction time measures as described in greater detail in chapter 2. Higher overall performance score indicates poorer performance in the PM condition in comparison with the ongoing condition. All correlations involving the simple computerised tasks have been reported using the overall performance composite score. Neither HADS scores nor WTAR FSIQ were found to correlate with performance on the simple computerised tasks.

The mean overall performance score for the patient group was 0.19 (SD = 1.66) and -0.47 (SD = 0.31) for the control group with the difference between groups being non-significant (U = 285.0, z = -.50, *p* = .62, r = -0.1).

Visual inspection of PM target accuracies in the number and picture tasks over time independently indicate that the patient group shows somewhat greater gradual decline over time, particularly in the number task, compared with the healthy controls (Figure 4.2).

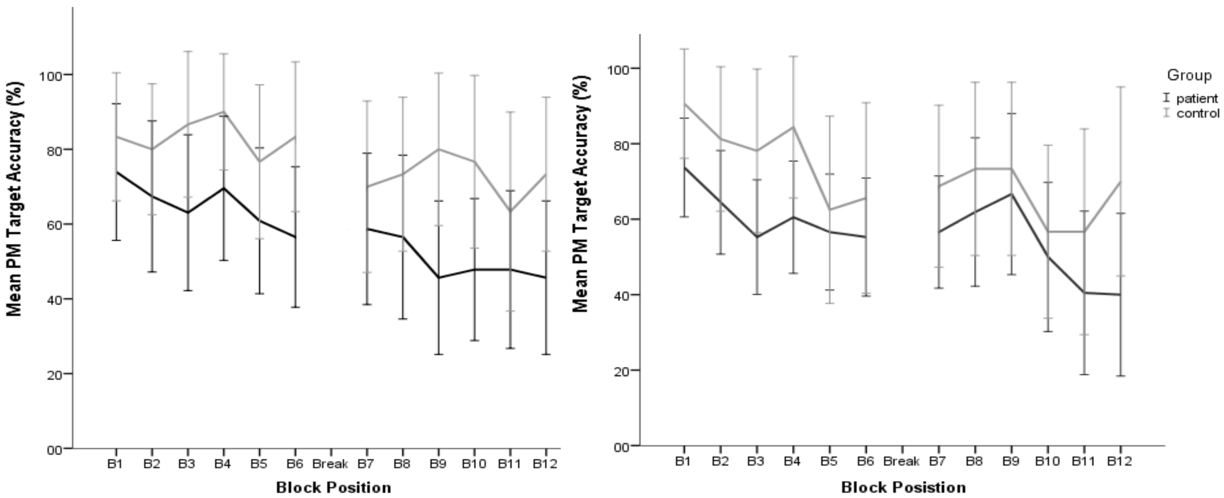

Figure 4.2: Accuracy to PM targets in the number task (left) and picture task (right) over time in the patient and control groups. Grey lines represent patient group and black lines control group. Error bars represent 95% confidence intervals.

After controlling for performance in the OG condition and reaction times in the PM condition (OGPM difference score), the ABI group was found to show significantly poorer overall performance in the Number Task compared with the control group (U = 197, z = -2.13, p < .05, r = -0.29). The level of performance decay (PM block 2 accuracy minus PM block 1 accuracy) shown by the ABI group was not however greater than the level of performance decay shown by the control group (U = 220, z -1.72, p = .085, r = -0.23). In the Picture Task, no significant differences between groups were evident on overall performance (U = 303, z = -.02, p = .99) or on performance decay (U = 279, z = -.48, p = .63, r = -0.07).

4.3.2.2 The Modified Hotel Test

Participants' performance on the modified Hotel Test is summarised in Table 4.5.

Table 4.5: Comparison of performance of patients and control group on the modified Hotel Test

mHT Measure	ABI Group (n = 39)		Control Group (n = 16)	
	Raw Score (SD)	Percentage Score (SD)	Raw Score (SD)	Percentage Score (SD)
Tasks Attempted	3.3 (1.5)	65.1 (30.7)	4.3 (0.9)	85.0 (17.1)
Number of correct bell rings	5.1 (3.6)	51.3 (35.9)	9.3 (1.3)	93.1(12.5)
Time deviation (seconds)	799.1 (451.5)	-	480.9 (301.8)	-
Number of clock checks	1.4 (1.9)	-	2.1 (2.5)	-
mHT Total PM Score	8.4 (4.5)	116.2 (56.2)	13.8 (1.5)	178.1 (21.5)

Tasks attempted denotes total number of tasks attempted out of 5 and number of correct bell rings out of 10. Percentage score for tasks attempted and number of correct bell rings is total percentage out of 100%. mHT modified Hotel Test and PM denotes prospective memory. Percentage score for total PM score is total out of 200%.

The control group showed near ceiling performance on the mHT attempting 4.3 tasks and remembering to ring the bell for 9.3 executives on average, while the patient group attempted 3.3 tasks and remembered to ring the bell for 5.1 executives on average. Mann-Whitney U-test revealed that the patient group showed significantly poorer performance on the following measures of interest on the modified Hotel Test: number of tasks attempted (U = 201.5, z = -.2.12, p < .0.05, r = -0.29), number of correct bell rings (U = 83.5, z = -4.31, p < .05, r = -0.58), and total PM score (%) (U= 102.0, z = -.391, p < .05, r = -0.53. The patient group also had a greater time deviation score compared with the control group (U = 184, z = -2.38, p < .05, r = 0.32). Although the patient group made fewer clock checks than the control group (1.4 vs. 2.1) this difference was not statistically significant (U = 249.0, z = -1.22, p = .22, r = -0.17).

Although the patient group had higher HADS scores these were not found to correlate with performance on the mHT, hence these were not controlled for. WTAR FSIQ, on the other hand, was found to correlate with performance on the mHT in the patient group. Hierarchical Multiple Regression model was constructed to assess whether the WTAR FSIQ (*Model 2*) contributed unique variance over and above the presence of ABI (*Model 1*) with mHT Total PM score as the dependent variable. Using the enter method, a significant model emerged ($F_{(1,\ 53)} = 18.25$, $p < .001$) explaining 25.6% of the variance (R^2). The inclusion of WTAR FSIQ into model 2 resulted in an additional of 14.4% variance on mHT performance being explained (R^2 change = .144). A summary of Regression results is presented in Table 4.6.

Table 4.6: Multiple Regression Results

	B	**SE B**	**β**
Model 1			
Constant	178.13	12.22	
Group	-61.97	14.51	-.51**
Model 2			
Constant	-15.37	55.98	
Group	-47.24	13.81	-.38*
WTAR FSIQ	1.79	.51	.40*

$R^2 = .256$ for Step 1, $\Delta R^2 = .144$ for Step 2 ($p < .05$). * $p < .05$; ** $p < .0.01$

4.3.3 Convergent Validity

The convergent validity of the simple computerised tests and the mHT in the patient group (n=39) was assessed using correlational analyses and are reported in Table 4.7.

Table 4.7: Relationship between Measures on the mHT and Simple Computerised PM Tasks in patients with ABI

Correlations **Spearman's *rho***	**OGPM Difference Score** **ABI Group (n = 39)**
Number of tasks attempted	-.21
Number of correct bell rings	-.34*
Total time deviation (seconds)	.22
Total number of clock checks	-.50**
mHT total PM score (%)	-.36*

mHT denotes modifies Hotel Test **correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

To investigate convergent validity of the mHT and simple computerised tests with clinical assessment measures of PM, patient group's performance was correlated with their performance on the CAMPROMPT. Participants' performance on the CAMPROMPT is summarised in Table 4.8.

Table 4.8: Performance of the ABI group on CAMPROMPT

CAMPROMPT Score (n = 38)	Mean Score ± SD	CAMPROMPT Maximum Score
Total Score	20.0 ± 8.5 Range 4-34	36
Time Based PM	9.0 ± 5.5	
Event Based PM	11.0 ± 4.6	

PM = Prospective memory

Wilcoxon signed rank test showed that the patient group did significantly better on the event based than time based PM tasks on the CAMPROMPT (T = 21.7, $p < .05$, r = -.37).

Considering the convergent validity of the simple computerised task and the CAMPROMPT, a significant correlation of large effect size was found between performance on simple computerised tasks and the CAMPROMPT total score (Table 4.9). This effect was also found independently for both the Number (*rho* = -.429, $p < .01$) and the Picture task (*rho* = -.47, $p < .01$).

Table 4.9: Relationship between CAMPROMPT and Simple Computerised PM Tasks

Correlations Spearman's *rho*	OGPM Difference Score
CAMPROMPT (n=38)	-.56**
Time based PM	-.541**
Event based PM	-.415**

PM = Prospective memory, ** Correlations significant at the 0.01 level (2-tailed).

To further confirm that this relationship was driven by simple computerised tasks sensitivity to prospective memory processes, a William's test was performed to assess whether the correlation between performance on the CAMPROMPT and performance to PM targets after controlling for speed was greater than the correlation between performance on the CAMPROMPT and ongoing condition after controlling for speed (Table 4.10). A significantly stronger relationship was found between CAMPROMPT and PM condition performance than between the CAMPROMPT and the OG condition performance (t (35) = 2.2, $p < .05$). The relationship between PM condition accuracy score and CAMPROMPT total score remained significant after partialing out FSIQ (Par rho = .48) and processing speed (par *rho* = .48) whereas the relationship with OG condition accuracy controlling for speed was significantly reduced after partialing out FSIQ (par *rho* = .193, p = .25) and processing speed (par *rho* = .179, p = .29).

Furthermore, the Number Task PM target accuracy, controlling for speed, was a found to be a better predictor of performance on the CAMPROMPT than the picture task (t (35) = 2.4, p < .05, r = 0.38).

Table 4.10: Relationship between CAMPROMPT and Simple Computerised PM Tasks (Speed accuracy score)

Correlations Spearman's *rho*	OG condition Accuracy controlling for speed	PM Target Accuracy in the PM Condition controlling for speed of responding		
		Total	Number	Picture
CAMPROMPT (n=38)	.438	.652	.693	.469

All correlations significant at the 0.01 level (2-tailed).

Regarding performance on the CAMPROMPT, good convergent validity of a large effect size was seen with performance on the mHT (Table 4.11) with the overall PM score on the mHT being the best predictor of overall performance on the CAMPROMPT. A trend, although non-significant, was seen towards a stronger relationship with time based CAMPROMPT tasks and performance on the mHT compared with event based CAMPROMPT tasks.

Table 4.11: Relationship between CAMPROMPT and mHT

Correlations Spearman's *rho*	mHT PM Total (% score)	mHT Number of Tasks attempted	mHT number of correct bell rings	mHT Total Time Deviation	mHT number of clock checks
CAMPROMPT Total Score (n=38)	.72 **	.49 **	.68 **	-.51 **	.66 **
Time Based Tasks	.70**	.46**	.65**	-.47**	.54**
Event Based Tasks	.45**	.33*	.41**	-.35*	.48**

**correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

4.3.4 Ecological Validity

Mean scores for the self-rated and informant-rated questionnaires are presented in Table 4.12. Two individuals in the patient group failed to return self-rated questionnaires.

Table 4.12: Questionnaire data descriptive statistics

Questionnaire Measure		ABI Group		Control Group
		Informant Rating (n=39)	**Self –Rating (n=37)**	**Self-Rating (n=16)**
PRMQ	Total	50.4 ± 16.7	51.3 ±16.8	34.4 ±6.7
	Range	16-80	18-80	25-49
	PM	26.4 ±8.8	26.5 ± 8.8,	19.2 ± 3.8
	Range	8-40	8-40	13-28)
	RM	24.1 ± 8.2,	24.8 ± 8.3	15.2 ± 3.6,
	Range	8-40)	9-40	10-21
GMQ Total Score		191.8 ± 84.8	196.3 ± 196.3	96.7 ± 63.5
	Range	7-335	27-340	20-201
HADS				
	Anxiety	–	9.2 ± 4.9, 2-19	4.9 ± 3.8, 0-13
	Depression	–	7.2 ± 4.2, 0-17	2.4 ± 2.8, 0-12

PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire, HADS = Hospital Anxiety and Depression Scale

Scores on the informant rated PRMQ indicate that the patient group's PM and RM abilities were in the below Average/Borderline range (T = 36, CI 32-44 and T = 36, CI 32-45) indicating greater than average general memory difficulties. This was similar to patient reported PM and RM functioning (T = 37, CI 33-46 and T = 38, CI 33-48). The control groups' self-reported PM and RM abilities were in the normal average range (T = 52, CI 45-59 and T = 57, CI 49-63). The correlation between informant and self rated PRMQ (r =.740, p < .001) in the patient group was high.

Independent T-tests revealed that the patients reported significantly more self-reported prospective and retrospective memory difficulties (t (51) = 4.2, p < .01, r = 0.51) than the control group (t (51) = 5.85, p < .01, r = 0.63) on the PRMQ. It was further noted that difficulties with self-cued PM tasks (26.6, SD = 8.9) were more common than difficulties with environmentally cued PM tasks (24.9, SD = 8.6) in the ABI group (t (35) = 3.0, p < .01, r = 0.45). This was also true when informant ratings of self- (25.9, SD = 8.9) and environmental cued (24.5, SD = 8.8) PRMQ scales were used (t (34) = 3.3, p < .01, r = 0.49).

Informant and self ratings of memory and goal management difficulties as measured by the GMQ were also of a similar level (t (36) = .53, p = .602, r = 0.09) indicating good levels of insight and awareness in the patient group. The relationship between informant and self-rated GMQ was significant (r = .593, p < .001) though lower than that of the PRMQ.

The patient group reported feeling significantly more depressed (U = 100.5, z = -3.9, p < .05) and anxious (t (53) = 3.15, p < .05, r = 0.40) than the control group as measured by the HADS.

4.3.4.1 *Ecological Validity* of the Simple computerised tasks

Results of the correlational analyses in relation to the ecological validity of the simple computerised tasks are presented in Table 4.13.

Table 4.13: Relationship between simple computerised tasks and Everyday Functioning

Correlations (Spearman's *rho*)		OGPM Difference Score		
		Patients		Controls
		Self	Other	
PRMQ	**Total**	.46**	.39*	-.08
	PM	.44**	.35*	.06
	RM	.52*	.43**	-.35
GMQ		.58**	.33*	-.04

PRMQ = Prospective and Retrospective Memory Questionnaire, PM Scale = Prospective memory Scale, RM = Retrospective memory Scale, GMQ = Goal Management Questionnaire, OGPM = ongoing and prospective memory condition, **correlation is sig at the 0.01 level, * correlation is sig at the 0.05 level (2-tailed).

In the patient group, performance on the simple computerised PM tasks showed significant correlation of medium to large effect size with both self- and informant rated memory failures (PRMQ total score self, *rho* = .46, p < .01; other, *rho* = .39, p > .05) as well as with informant rated goal management difficulties (GMQ total score *rho* = .58, p < .01) with those showing better performance on the tasks also reporting less memory slips and goal management difficulties in everyday life. Medium-to large effect size correlations were also seen independently in the Number and Picture tasks for all self-rated measures. Informant ratings only reached significance (medium-to large effect) for the Number task but not for the Picture task.

4.3.4.2 *Ecological Validity* of the modified Hotel Test

The results from the correlational analyses with regards to performance on the mHT are presented in Table 4.14.

Table 4.14: Relationships between questionnaire measures and the mHT

Correlations / mHT / Questionnaire		PM Total (%)	Number of Tasks attempted	Number of correct bell rings	Time Deviation (secs)	No of clock checks (rho)
PRMQ-Rel	**Total**	-.32 *	-.35 *	-.24	.37 *	-.39 *
	PM	-.27	-.30	-.20	.32 *	-33 *
‘	**RM**	-.40 *	-.43 **	-.28	.44 **	-.46 **
GMQ- Rel		-.35 *	-.29	-.33	.29	-.27

Rel denotes informant rated version, Spearman's *rho* used for all analyses as assumptions of normality not tenable. **correlation is sig at the 0.01 level * correlation is sig at the 0.05 level (2-tailed).

Controlling for potential confounds

Exploratory analyses were performed to assess the degree to which other variables may be contributing to the relationship between simple computerised tasks and reports of everyday functioning.

Of demographic variables, only age was found to significantly correlate with the overall performance on simple computerised task overall performance in the PM condition (rho = .39, p > .05). Age also correlated with GMQ self-rated total score. Non-parametric partial correlational analyses were performed to assess the contribution of age on the relationship between simple computerised PM tasks and GMQ self-ratings. After controlling for age, the relationship between PM tasks and GMQ self total score (par rho = .56, p < .001) remained significant. None of the neuropsychological measures were found to significantly correlate both with the overall performance on the computerised tasks and questionnaire measures.

The CAMPROMPT was also noted to posses good ecological validity with self-rated goal management difficulties measured on the GMQ (*rho* = -.45, p<.01) and self-rated prospective and retrospective memory difficulties (PRMQ total score, -.39, p > .05). Informant ratings on the PRMQ (total score) were also significantly correlated with performance (*rho* = -.34, p < .05). No significant relationship was seen with informant rated goal management difficulties (*rho* = -.29, p = .82).

4.4 Discussion

Summary of main findings

This study assessed the convergent and ecological validity of simple computerised PM tasks in a group of patients with ABI of mixed aetiology. There were three main findings: (1) Simple computerised tasks were found to show moderate convergent validity (medium to large effect size) with the mHT and good convergent validity (large effect size) with the clinical PM assessment tool CAMPROMPT, (2) the mHT, and one of the simple computerised tasks, was shown to be sensitive to the effects of brain injury and (3) the simple computerised tasks were shown to correlate with self- and informant reports of everyday memory functioning and goal management difficulties in the patient group.

Ecological, convergent validity and sensitivity to brain injury

Tests used to assess PM in clinical practice tend to utilise complex multi-element tasks that require integration of several cognitive processes such as planning, RM and attention. ABI typically causes impairments in a range of cognitive functions depending on aetiology and injury severity making it difficult to determine which cognitive functions have been most impacted. The positive relationship found between performance on simple computerised tasks and the mHT is encouraging given that the mHT is designed to measure PM in the context of a complex multi-element task whereas the simple computerised tasks are considered to be a purer measure reflecting the underlying PM process.

The number of clock checks measure on the mHT showed the strongest relationship with performance on the simple computerised tasks with those showing better performance on the simple computerised tasks also making more clock checks on the mHT. This finding is in line with results presented in Chapter 2 where older participants were found to make significantly fewer clock checks compared with the younger individuals. This adds to the evidence suggesting that ageing and brain injury may to disrupt PFC functions that support tasks with greater self-initiation demands or stimulus independent processing (Burgess et al., 2005, 2006b, 2007, 2008). This suggests that clock checking may reflect internal goal reviewing or maintenance of future intentions likely to be required for successful performance on the simple computerised tasks.

Despite the fact that the mHT and simple computerised tasks were found to have good convergent validity with one another, the simple computerised tasks were not found to be sensitive to brain injury when both Picture and Number tasks were assessed together, contrary to expectations. A possible explanation of this finding might be that the patients included in the study represent a sample with mild ABI, with the level of PM impairment not being severe enough for the tasks to be sensitive to their difficulties. However, given the long duration of the mean PTA in the patient group and the majority being on the impaired range on the SDMT, which can be seen as a proxy of overall injury severity, this is unlikely to be the case in the current sample. Given that the Number task was found to be sensitive to PM difficulties following brain injury, this account can be excluded.

Both informant- and self-reports of everyday functioning as measured by the PRMQ suggests that the patient group is in the below average or borderline range with regards their everyday PM- and RM functioning. Given that the ABI group appeared to have, relatively good insight into their cognitive difficulties, as suggested by the level similarity of the self- and informant-rated questionnaire responses, the ABI may have deployed a greater conscious cue monitoring approach on the Picture task, which was perceived to be more difficult of the two tasks. Greater cue monitoring approach is likely to enable sustaining greater levels of accuracy than may be possible or efficient in everyday life, where the delay between creating a prospective task and its execution tends to be longer and filled with other unrelated tasks. This may also explain the greater sensitivity of both the mHT and CAMPROMPT where a constant monitoring approach is not possible.

Another plausible explanation for this the finding is that patients with ABI do not show impairment in all types of PM situations but are most impaired on tasks where the need to perform an intended action places greater demand on self-initiated processes or where a constant monitoring approach cannot be utilised. A closer inspection of self- and informant PRMQ ratings showed that the ABI group experienced significantly greater difficulty in performing self-cued PM tasks compared to environmentally cued PM tasks. Patients with Parkinson’s disease have also been shown to report greater self-cued but not environmentally cued PM lapses on the PRMQ with significantly poorer performance on a laboratory PM requiring greater self-initiation demand (non-focal cues) compared to a condition where the response is directly triggered by the cue (Foster, McDaniel, Repovš and Hershey, 2009).

According to the Gateway theory (Burgess et al., 2007, 2008), stimulus independent (self-initiated) and stimulus oriented (environmentally cued) attending have different neural underpinnings. Simple computerised PM tasks utilise an event based PM paradigm where the task instructions are relatively directly linked to the performed action hence the stimuli may trigger the PM intention in a stimulus oriented processing manner (e.g. when I see two even numbers together, I will need to press the third button).

Lesion location may be another factor mediating performance on PM tasks given that those with rostral PFC lesions (area 10) have been found to shown significantly poorer performance on the original version of the Hotel Test compared with healthy controls and patients with lesions outside this brain region (Roca et al., 2011). Performance on the Hotel Task was also found to correlate with volume of damage in lateral right BA10. No lesion location data were available to assess the extent and spatial coverage of each participant's lesion, hence it was not possible to further assess differences in performance on simple computerised tasks and the mHT between those whose lesions involved areas within and outwith the rostrolateral PFC.

Recently, Volle, Gonen-Yaacovi, de Lacy Costello, Gilbert, and Burgess, (2011) found that patients with ABI, regardless of lesion location did not show impaired performance on event-based computerised PM tasks relative to the control group. However, they did find that patients with lesions in the right prefrontal region, approximating Brodmann area 10 showed impaired performance on time-based PM tasks. The extent to which time- and event-based tasks make demands on self-initiated or environmentally cued processing may differ with time-based tasks posing greater demand due to a participant having no external prompt of cue to indicate when to press a button. Similarly, the patients in the current study showed significantly better performance on event-based than time-based tasks on the CAMPROMPT

A study investigating patients with schizophrenia has reported poorer performance on time-based task requiring self-initiated retrieval as opposed to event based PM task (Shum, Ungvari, Tang and Leung, 2004). By contrast, Cheng, Wang, Xi & Niu and Fu (2008) found patients with PFC lesions to be impaired on event based tasks but not on time based tasks. Given the discrepancy in the reported findings in the literature and time based PM tasks having been argued to place greater demand on self-initiated PM processes (Craik 1986; Einstein et al., 2005), future studies should investigate the interplay between self and environmentally cued PM tasks in patient populations to enable assessment of the neural underpinnings of PM following brain injury and to allow assessment of neural changes following rehabilitation interventions aimed at improving prospective memory.

Patient Z.P (Uretzky and Gilboa 2010) with damage to the right PFC region has been reported to be in the severely impaired range on the PRMQ (t = 11) and experience frequent PM lapses in everyday such as forgetting to perform critical turns when driving to new destinations and instead driving by known, automatic driving routes, forgetting to turn off the gas when cooking or starting activities but forget to finish them (e.g., boiling water for tea but forgetting to prepare it). Hence the complexity and number of distracting events during task performance may partly explain the sensitivity of the mHT. The sensitivity of the simple process based PM Number task to detect PM difficulties in the current ABI sample is encouraging given that it utilises an event-based PM paradigm.

The strong relationship seen between the simple computerised tasks and the CAMPROMPT and the mHT and the CAMPROMPT is striking despite their seemingly different methodologies. This suggests that both tasks are capable of capturing much of the same cognitive processes underpinning successful PM performance.

Considering the ecological validity of simple computerised tasks and the mHT, the simple computerised tasks were found to show significant correlations between self-rated memory functioning (medium- to large effect size) and goal management difficulties (large effect size) in the patient group. The relationship between self-reported goal management difficulties and task performance was found to remain significant after controlling for age, which was found to correlate with both measures. This suggests that those who showed better performance on the simple computerised tasks also showed less frequent PM and goal management lapses in everyday life. No relationship was seen between task performance and everyday functioning in the control group. Informant ratings were also found to show significant correlation with task performance on the simple computerised PM tasks with somewhat stronger correlations seen with the Number- than the Picture task.

Informant reported everyday functioning in the ABI group as measured by the PRMQ and GMQ also predicted performance on the mHT with those reporting fewer lapses also showing better performance. Furthermore, CAMPROMPT was also found to have good ecological validity with self-reported functioning showing significant correlations of medium- to large effect size with questionnaire measures with informant rated measures showing medium but significant effect with everyday memory but not goal management functioning. This finding is in line with previous research suggesting a moderate relationship between the PRMQ and performance on the CAMPROMPT in older adults with a cognitive impairment (Foley, 2007).

Strengths

This is the first study demonstrating that both simple computerised PM tasks and the mHT possess good ecological and convergent validity in patients with ABI. The mHT was confirmed to be sensitive to the effects of brain injury as suggested by previous research findings using the original Hotel Test (Manly et al., 2002; Roca et al., 2011). The Number PM task was also found to show good sensitivity. Both tasks, in particularly the mHT, were found to show good convergent validity with existing clinical measures of PM; an area often overlooked is research studies making the comparison of findings from different studies difficult. The simple computerised PM tasks were not found to show significant inter-correlations with most demographic and neuropsychological assessment measures such as speed of processing suggesting good sensitivity to specific processes associated with PM rather than general injury severity for example.

Another strength of this study is the representativeness of the sample in relation to clinical practice. The patient group comprised of range of abilities, brain injury severity, time post injury and co-morbidities, which enhance the generalisability of the findings. The demographic composition of the sample also reflects that seen in clinical practice with men being two to three times more likely to have a traumatic brain injury than women (Headway UK).

Limitations and Future Directions

Although inclusive participant selection increases the generalisability of the findings, this is also a limitation due to the wide range of aetiologies and abilities making it harder to pinpoint who is more likely to suffer from PM impairment following brain injury and to what extent. Future studies should compare patients with TBI and stroke or haemorrhage to assess whether aetiology has a differential contribution to who is likely to experience greater PM difficulty in everyday life.

Inclusion of patients with wide variation in time since injury is useful in informing the effects of brain injury on PM functioning but may be less efficient in developing paradigms for assessing the initial need for PM rehabilitation interventions following brain injury.

A further limitation of the study is that the simple computerised tasks were not designed to separate self-initiated and stimulus oriented processing. Future studies should investigate these in more detail given that the ABI group was found to be impaired on the Number task but not on the Picture task yet reporting difficulties in everyday functioning and showing significantly poorer performance on the mHT. This is the second study (see Volle et al., 2011) to demonstrate that event based computerised tasks as they stand have good convergent validity but very in their sensitivity to detect PM difficulties following brain injury. With further validation, the Number task may be suitable for studying the neural basis of PM in patients with ABI.

Future neuropsychological assessment of PM should focus on theory driven approaches and development of tasks with good ecological validity that allows fractionation of the EF processes associated with PM to a greater extent than what most tasks currently offer.

Conclusions

The findings suggest that the process based simple computerised PM tasks show good level of convergent validity with complex multi-element tasks of PM; namely the mHT and the CAMPROMPT. The Number PM task and the mHT were sensitive to brain injury. The simple computerised tasks, mHT and the CAMPROMPT all showed modest ecological validity with questionnaire measures of everyday functioning. Given the potential for use in the brain imaging environment, the Number PM task may be suitable for assessing the neural basis of PM in patients with ABI.

Chapter 5

Behavioural effects of brief Goal Management Training with Implementation Intentions on performance on simple computerised tests of prospective memory

Abstract

Background and aims: Deficits in prospective memory (PM) affect the ability to carry out future intentions, compromising independent functioning. PM complaints are common following neurological illness yet the evidence-base in support of PM interventions is limited. This study investigated whether brief Goal Management Training combined with Implementation Intentions (GMTii) can improve performance on simple computerised PM tasks developed for use in neuroimaging and known to correlate with everyday functioning.

Method: Thirty neurologically healthy individuals were randomly assigned to GMTii or control training. Participants completed a computerised task pre- and post-training that involved carrying out an ongoing task into which a PM task was embedded. In addition, a novel task similar in nature was completed post-training to assess generalisability of any effect.

Results: The overall performance of the two groups did not differ significantly pre-training. Post-training, the GMTii group demonstrated significantly better performance on the familiar computerised PM task compared to the control group, with the GMTii group showing less performance decay over the duration of the task compared to the control group. The GMTii group also showed better performance on a novel task compared with the control group.

Discussion and Conclusions The results indicate that brief GMTii can reduce the occurrence of PM slips on PM tasks designed for use with neuroimaging methods. This suggests that these measures may be useful outcome measures, affording the opportunity to study the impact of neural activation changes following GMTii interventions.

5.1 Introduction

Several studies have been successful in demonstrating transfer of effects following physical training to other similar activities with running found to improve cycling performance (Millet, Candau, Barbier, Rouillon and Chatard, 2002) and stair climbing improving running performance (Loy, Holland, Mutton, Snow, Hoffmann and Shaw, 1993) for example. Demonstrating transfer of skills following cognitive training has proved more challenging (Owen et al. 2010; Sohlberg, White, Evans and Mateer, 1992). Demonstrating that cognitive interventions lead to behavioural improvements and assessing whether their effects generalise to other similar but untrained tasks and everyday functioning are central issues in cognitive rehabilitation.

A recent meta-analysis (Martin, Clare, Altgassen, Cameron and Zehnder, 2011) assessing the effects of memory training in healthy older adults and older adults with mild cognitive impairment (MCI) suggests that cognitive training interventions do lead to improvements when compared to no-treatment control groups but do not tend to be superior to active control groups. Another meta-analysis on memory based training programs also suggests that training programs tend to produce only small effects with lack of transfer of training effects (Papp et al., 2009 – see also Lustig et al., 2009 and Noack et al., 2009). This has also found to be the case in the working memory literature (see Melby-Lervåg and Hulme, 2013 for a review) A recent study has also reported a reduction in self-reported everyday cognitive failures in addition to significant improvement on trained tasks following computerised working memory (WM) training in a patient with ABI. Due to lack of a control group, we cannot be certain of its effectiveness in improving everyday functioning (Johansson and Tornmalm, 2012).

The current treatment of choice for prospective memory impairment is the use of passive external memory aids (e.g. calendars, diaries, post-it notes and pagers) as a method of compensation (Cicerone al., 2005) but external aids, with active reminders, such as NeuroPage® (Wilson, Evans, Emslie and Malinek, 1997; Wilson, Emslie, Quirk and Evans, 2001) or Google calendar (McDonald, Haslam et al., 2011), are proving most successful. A limitation of external aids is that they tend to give reminders for single tasks and require preparation or programming in advance. Cognitive training approaches, on the other hand, provide a promising alternative to external aids and repeated practice as they aim to teach an individual a strategy that can be applied in certain situations, which removes the need to remember to carry a device. A challenge that this brings is that the individual needs be able to recognise situations where strategies can be used and remember to apply them at the correct moment. As with computerised training programs the challenge is to ensure that any effects generalise to other similar tasks and result in improvements in functioning in everyday “real-life” rather isolated improvement in performance on the trained tasks or in the laboratory setting.

The evidence base for improving prospective memory through compensatory cognitive training approaches remains limited but promising, although very few have used computerised paradigms to assess their effectiveness.

Improvement in older adults’ prospective remembering in the laboratory has been reported following a broad spectrum intervention encouraging the use of internal strategies in favour of external aids together with psychoeducation regarding the impact of mood on memory, relaxation training, behaviour modification and cognitive restructuring of automatic thoughts (Villa and Abeles, 2000). Improvements on laboratory tests in older adults (Levine et al., 2007; van Hooren et al., 2007) have also been reported following Goal Management Training (GMT) in addition to improved meal preparation skills in an individual with ABI (Levine et al., 2000). More recently another RCT using an expanded version of GMT (Levine et al., 2011) found an improvement in performance on the Sustained Attention to Response Task (SART). Positive transfer of training effects was observed on the Tower Test, although no significant changes were seen on self-reported goal management ability.

Despite the relative effectiveness of complex cognitive interventions, assessing the mechanism through which improvements in performance occur is challenging as they are likely to tap into several associated cognitive functions simultaneously. Studies focussing on a single strategy or subcomponents of complex interventions have also reported improvements in performance on prospective memory tasks. Auditory alerts presented during performance on a multi-element task have been shown to aid the ability to manage multiple goals when they are used as cues for reviewing future goals (Manly, Hawkins, Evans, Woldt and Robertson, 2002) although studies have failed to find an effect on performance on a virtual reality task (Sweeney, Kersel, Morris, Manly and Evans 2010; Brown, 2009). Receiving a content free text message simply reading ”STOP” following brief Goal Management Training focussing on learning to pause current activity and review stored goals (Fish et al., 2007), has been shown to improve brain injured individuals’ ability to remember to phone to an answer phone service at pre-set times over a four week period. More recently Rous (2012) and Gracey et al. (2012) also found some preliminary evidence of transfer of training effects to real life tasks using a similar approach for adolescents and patients with acquired brain injury.

Another cognitive strategy that has been shown to improve realisation of a range of future intentions, from losing weight to taking medication, is Implementation Intentions (Gollwitzer, 1993; 1996). Implementation intentions (I.I.) work by strengthening the cue–action association during the encoding phase (Chasteen et al., 2001). Therefore future intention recall is more likely to be supported by automatic cognitive processes as opposed to generic goal intentions, which are instead supported by more self-generated cognitive processes. Use of implementation intentions has been shown to benefit MS patients on a game called the Virtual Week (Rendell and Craik, 2000) in the laboratory (Kardiasmenos et al., 2008). Each time a patient was assigned a task to be completed in the future, they were told either to use rote-rehearsal or implementation-intentions. Patients' PM performance was found to be significantly better in the implementation-intention condition compared to the rote-rehearsal condition. The I.I. is somewhat similar to the 'mental blackboard' concept that is used in GMT. Kardiasmenos et al., (2008) also reported that MS patients were less likely to use mental visualisation strategy in the rote-learning condition than control participants. Mental imagery has been shown to improve the ability to keep appointments (Kaschel et al., 2002) and performance on laboratory tasks of prospective memory Potvin et al., (2011).

5.1.1 Rationale of the current study

Although Goal Management Training has been shown to improve performance on laboratory and real life tasks requiring PM, little is known about the mechanism underlying it. Previous research suggests that the prefrontal cortex plays a role in PM. However tasks that have been previously used in the assessment of the effects of goal management ability have tended to be complex multi-element tests that also tap into other related cognitive functions and are not compatible with current brain imaging technology. It is therefore necessary to develop tests that can be used to assess the neural basis of cognitive training. Tests need to be suitable to be completed in the movement-constrained fMRI scanner environment. They also need to tap into the same underlying cognitive construct as other known measures of PM functioning that capture the kinds of situations that individuals with impaired PM functioning have difficulty with.

The ability to effectively maintain future intentions is one component of successful goal attainment. The ability to protect these intentions from distracting information is also likely to improve realisation of future goals. Targeting these specific cognitive abilities may therefore lead to improvements in performance that may generalise to broader domains of goal-directed functioning. The ‘STOP’ (and think) and ‘mental blackboard’ principles of GMT are designed to aid encoding and maintenance of intentions whereas implementation intentions can minimise the detrimental effects of distractions by strengthening the link between cue and the action of the intention that needs to be performed. Assessing whether brief GMT combined with implementation intentions (GMTii) can improve performance on simple computerised tasks that require prospective remembering allows for some components of successful goal management to be evaluated. This may later allow us to better assess the behavioural and neural mechanisms of simple interventions aimed at improving prospective goal attainment through the use of neuroimaging techniques such as fMRI. Most previous studies that have found Goal Management Training to improve performance have used a comprehensive version delivered over several weeks (Levine et al., 2000, 2007, 2011; van Hooren et al., 2007) or brief GMT where participants have been assessed over a longer period (Fish et al., 2007) giving participants longer to learn to apply these strategies. Studies assessing the immediate effects of brief GMT have so far failed to find a significant effect in patients with acquired brain injury (Brown, 2009; Wood, 2011). Whether brief GMT is able to produce immediate improvements in performance on computerised tasks requiring prospective memory and be suitable for use in the fMRI environment in neurologically healthy individuals is not yet known and was the focus of this study.

5.1.2 Aims and Hypotheses

Aim

The aim of this study was to investigate whether brief Goal Management Training with Implementation Intentions (GMTii) can produce improvements in performance on simple computerised tasks that require prospective memory.

Hypotheses

Primary hypothesis: The GMTii group will show greater improvement in performance on the computerised task requiring prospective memory post-training compared with the control group.

Secondary hypotheses: The GMTii group will perform better on a novel PM task compared with the control group.

It is further expected that the effects of training will be greater in the second block of each computerised task that follows a brief break filled with an unrelated activity.

5.2 Methods

5.2.1 Participants and Recruitment

Thirty-two young healthy individuals with no history of psychological or neurological illness were recruited from the University of Glasgow via advertising posters. Participants received a payment of £6 for taking part in the study. Two individuals were excluded from the sample following completion of the study for not following the task instructions correctly in the condition involving prospective memory. These individuals have not been included in the results reported. Thus the final sample comprised 30 individuals (15 male and 15 female), 14 of whom were in the intervention group and 16 in the control group. Their mean age was 22.3 years, (SD 4.5). On average, they had spent 15.6 years (SD 2.2) in full-time education.

5.2.1.1 Inclusion and Exclusion Criteria

Participants were included in the study if they were between 18 and 40 years of age, wrote with their right hand and spoke English as their first language. Exclusion criteria applied to those individuals who had a neurological illness or had sustained a head injury that had resulted in a loss of consciousness or had a history of a major psychiatric, psychological or substance abuse problems or had received treatment for psychological problems within the six months prior to taking part.

5.2.2 Measures and Materials

Participants completed two different simple computerised PM tasks. The tasks were based on tasks used by Burgess et al., (2003) and are described in more detail in Chapter 4. (Number processing, Picture processing). The tasks were presented using E-Prime (Psychology Software Tools, Inc., USA). The number task was completed pre- and post-training. The picture task was completed post-training only. Both tasks had three conditions: baseline (low cognitive load), ongoing task (greater cognitive load) and prospective memory load (identical to ongoing task but with an additional prospective memory instruction). Participants completed 10 practice trials at the start of the ongoing condition and 12 practice trials including three PM targets before the start of the PM condition in both tasks. All tasks were time limited in duration. The ongoing condition lasted 2.5 minutes pre- and post-training and was followed by 30-second baseline block pre-training. Pre-training, the PM condition lasted three minutes and was preceded by a 30 second baseline block. Post-training, a 30 second baseline block also preceded the PM condition but the PM condition duration was six minutes with an additional 30 second break after three minutes during which the participants completed the baseline task. The 'break' was included in order to see whether cognitive training can reduce the number of PM slips following a delay filled with unrelated activity.

5.2.3 Research procedures

The research procedure is summarised in Figure 5.1.

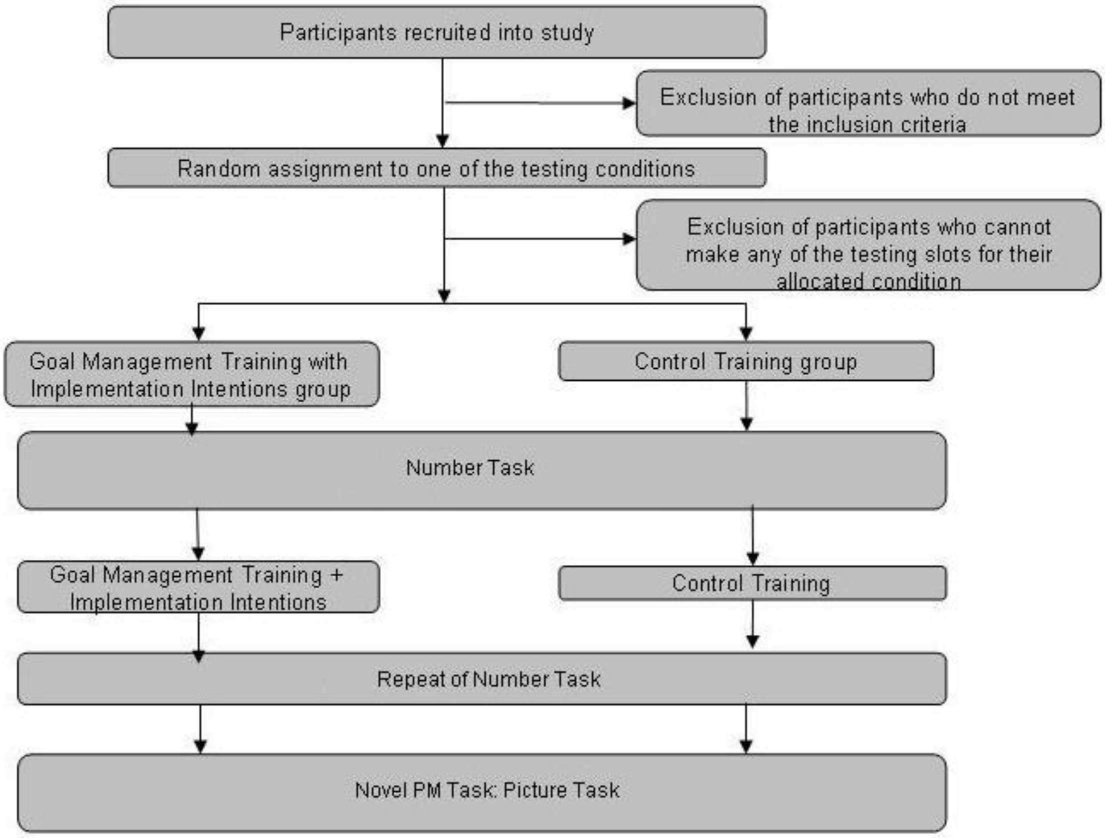

Figure 5.1: Research procedure flowchart

Participants were randomly assigned into a training group (cognitive training or control group) at the point of recruitment. Randomisation was done using online software (http://www.jerrydallal.com/random/random_block_size.htm). Half of the participants were allocated to Goal Management Training with Implementation Intentions (GMTii) and half to the control training condition. Participants gave written consent before taking part and completed a short practice block before starting each task.

Testing took place in small groups (1-4 individuals) over a single session lasting approximately an hour. All participants completed the number task prior to training in order to assess the similarity of the two training groups pre-training. The number task was followed by either GMTii or control training. Both training sessions lasted approximately 20-25 minutes and followed the training handouts (Appendix K and L). All participants completed the number and picture tasks following the end of the training session. Before commencing the computerised tasks post-training, the GMTii group was told that they may find it useful to use the newly learned strategies while doing the computerised tasks but they were not told when or how the strategies would be best used or applied on these specific tasks.

5.2.3.1 Goal Management with Implementation Intentions Training

In the GMTii, participants were introduced to the idea of everyday memory slips through examples and were asked to rate their own prospective memory ability. They were then taught the key aspects of GMT and Implementation Intentions using examples from everyday life (e.g. remembering to post a letter, avoiding getting caught up when answering an exam question, passing a message onto a friend) and asked to apply different strategies to hypothetical abstract and everyday life scenarios presented on the training handout. Before starting the scenarios, they were also given an additional PM task to do where they had to remember to circle a word describing an item of luggage (suitcase) when they came across it in the handout. The word was placed in the last paragraph of the handout in order have a longer delay between the task instruction and carrying out the task. The training handout was built around concepts taken from the abbreviated GMT manuals used by Fish et al., (2007) and Brown, (2009) as well as the GMT Handbook (Robertson et al., 2000). The strategies covered during GMTii training were as follows:

Strategy 1: **'Stop and think'**. Participants were advised that this would help in drawing full attention to the task on hand and in thinking through (planning) the steps/goals of the task. Participants were told that this would be useful when creating an intention to do something later on or when taking a break from something that they are doing.

Strategy 2: **'If X happens I will do Y'** as opposed to my aim is to do Y. This will help to strengthen the association between the cue and the intention thus increasing the likelihood of something being remembered.

Strategy 3: **'Mental blackboard** Participants were introduced to the idea of using their mental blackboard (working memory) to mentally write out things they have to do. Things to do can be written on the 'mental blackboard' but it has limited capacity.

Strategy 4: **'Checking'**. Participants were taught that regularly checking their mental blackboard will help maintain intentions in mind.

The different strategies included in the GMTii intervention are expected to address different stages of the prospective memory processes proposed by Ellis (1996) as previously shown in Figure 1.1. 'Stop and think' was believed to aid initial encoding of the intention and maintenance over a longer delay filled with unrelated activities. Findings presented in chapter 3, showed that accuracy to PM targets decays over time when a brief break filled with an unrelated task is added to a task. Implementation intention strategy 'if x happens I will do Y' was believed to ease the planning stage but also to help trigger the initiation of the intended action by making the link between the cue and the action more explicit. The mental blackboard strategy was believed to minimise performance decay over time though regular checking and evaluation of performance.

5.2.3.2 Control Training

The control group received training that was similar in length to GMTii but did not introduce participants to cognitive strategies associated with GMTii. Participants were asked to work through a series of lateral thinking puzzles and to come up with possible solutions or explanations to the puzzles (e.g. "A man lives on the twelfth floor of an apartment building. Every morning he takes the elevator down to the lobby and leaves the building. In the evening, he gets into the elevator, and, if there is someone else in the elevator -- or if it was raining that day -- he goes back to his floor directly. Otherwise, he goes to the tenth floor and walks up two flights of stairs to his apartment"). Participants were told that the purpose of the exercise was to get them to think outside the box and they were asked to rate their creative thinking ability prior starting the puzzles. Participants were given a cue card for each question that they were free to consult if they felt that they could not think of a solution to a question. They were also to free to move onto the next question if they did not find the cues helpful.

5.2.4 Ethical Approval

This study was reviewed and approved by the University of Glasgow, Faculty of Medicine Ethics Committee.

5.3 Results

Data analyses were carried out using PASW Statistics 18 (SPSS, Chicago). Prior to analysis, variables were screened for outliers and their normality checked using the Shapiro-Wilk test. Performance of the two groups was compared using two-tailed independent t-tests for normally distributed variables and Mann-Whitney U tests for those violating the assumption of normality. Group x time interactions were assessed using repeated measures ANOVA or change scores where assumptions were violated and transformation to normality was not possible.

Two individuals in the GMTii group were excluded from the analysis as they had PM target accuracy scores of 0 both pre- and post-training. This would make it feasible to assume that the task instruction for the PM number task had not been correctly understood and participants therefore treated the task as an ongoing condition rather than a PM task.

5.3.1 Pre-training

Performance on the computerised tasks pre-training is summarised in Table 5.1.

Table 5.1: Descriptive Statistics Pre-training per Group

Condition	Group			
	Control (n=16)		GMTii (n=14)	
	Mean ± SD		Mean ± SD	
	Accuracy (%)	Reaction time (ms)	Accuracy (%)	Reaction time (ms)
Ongoing	98.4 % ±1.0	618.5 ± 162.7	98.4% ± 1.1	656.5 ± 106.0
PM	96.0 % ± 3.2	825.8 ± 228.1	96.4% ± 2.9	884.8 ± 161.0
PM targets only	73.1% ± 24.7	894.7 ± 211.6	80.4 ± 13.8	939.2 ± 160.7

Ongoing = overall performance in the ongoing condition, PM = Overall performance in the prospective memory condition, PM targets = performance to PM targets only in the prospective memory condition

Mann-Whitney U test was performed to assess whether the two groups were comparable pre-training. The two groups had identical accuracies (98.4%) in the ongoing condition (U = 111.0, z = -.04, p = .97). Both groups had similar overall accuracy in the PM condition with 96% for the control group and 96.4% for the GMTii group (U = 105.0, Z = -.30, ns, r = -.05). There was also no significant difference in the accuracy to PM targets in the PM condition between the two groups (U = 97.0, z = -.64, ns, r = -.12). Further, there were no between group differences in the reaction times in the ongoing condition (U = 79.0, z = -1.4, ns, r = -.03), PM condition overall (T (28) = -.806, p = .43) or reaction times to PM targets (t (28) = -.64, p = .53, r = 0.12) pre-training. Given that groups did not differ significantly pre-training, it would seem reasonable to assume that any post-training differences in performance, if any, are likely to be due to the effects of the cognitive training intervention assuming that the effects of practice will be similar in both groups.

5.3.2 Post-training

A summary of overall performance in each condition, post-training, is given in Table 5.2.

Table 5.2: Descriptive Statistics Post-training per Group

Condition	**Group**			
	Control (n=16)		**GMTii (n=14)**	
	Mean ± SD		Mean ± SD	
Ongoing	Accuracy	Reaction Time	Accuracy	Reaction Time
Number Task	97.0 % ± 2.5	567.8 ± 183.4	97.6 % ± 1.8	592.7 ± 113.3
Picture Task	95.1 % ± 5.1	633.6 ± 87.9	96.8 % ± 0.03	652.8 ± 111.4
Prospective Memory				
Number Task	95.4% ± 3.0	691.7 ± 203.9	96.4% ± 1.7	754.1 ± 156.2
PM targets only	60.8 % ± 23.1	763.1 ± 186.2	74.6 % ± 15.8	846.1 ± 166.1
Picture Task	92.9 % ± 5.0	807.9 ± 149.6	95.4 % ± 1.9	841.4 ± 154.2
PM targets only	57.3 % ± 19.2	913.0 ± 240.8	73.00 ± 12.7	931.3 ± 179.3

PM denotes prospective memory; Reaction times are reported in milliseconds

Post-training, there were no differences in the ongoing condition accuracy in the Number task (U= 102, z = -40, p = .69, r = -.07) or Picture task (U = 95.0, z = -.73, p = .47 r = -.13) or reaction times on either task (U = 78, z -1.41, p = .16, r = -0.27 and t (28) = -.53, p = .60, r = 0.1 respectively) between the two groups.

Neither differences in PM target accuracy nor reaction times were significantly different between groups (U = 70, z = 1.8, p = .08, r = .33 and t (28) = -1.3, p = .21, r = 0.24).

To assess the effects of brief cognitive training whilst accounting for performance pre-training, repeated measures ANOVA or a pre-post training change score was calculated. The change score was used instead of repeated measures ANOVA if parametric assumptions were violated given the relatively small sample size. Given that both accuracies and reaction times in the ongoing condition were similar between groups, performance in the ongoing condition was not controlled for. The pre-post training change score was calculated as change in PM target accuracy post-training minus PM target accuracy pre-training. Positive scores indicate improvement in performance from pre- to post-training while negative scores indicate poorer performance post-training compared to pre-training.

5.3.2.1 Number Task

Both groups showed reduced accuracy to PM targets on the Number task post-training compared to pre-training (Figure 5.2). The GMTii group's accuracy to PM targets in the PM condition decreased from 80.4% (SD 13.8) pre-training to 74.6% (SD15.8) post-training, while the control group went from 73.1% (SD 24.7) pre-training to 60.8% (SD 23.1) post-training. The overall decrease in PM target accuracy was therefore 5.7% (SD 13.3) for the GMTii group and 12.3% (SD 24.5) for the control group. However the pattern of decrease was not significantly greater in the control group compared with the GMTii group ($t(28) = -.89$, $p = .38$, $r = 0.17$).

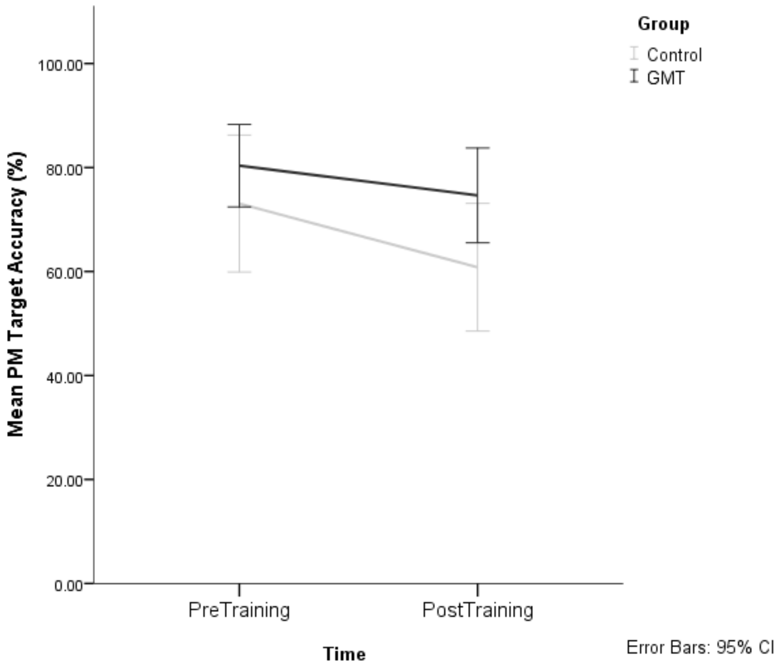

Figure 5.2: Mean Number Task accuracy to PM targets pre- and post-training by group. Error bars represent 95% confidence intervals.

Repeated measures ANOVA revealed no significant differences in the pattern of change in reaction times to PM targets (Figure 5.3) from pre- to post-training between groups ($F(1, 28) = .73$, $p = .40$).

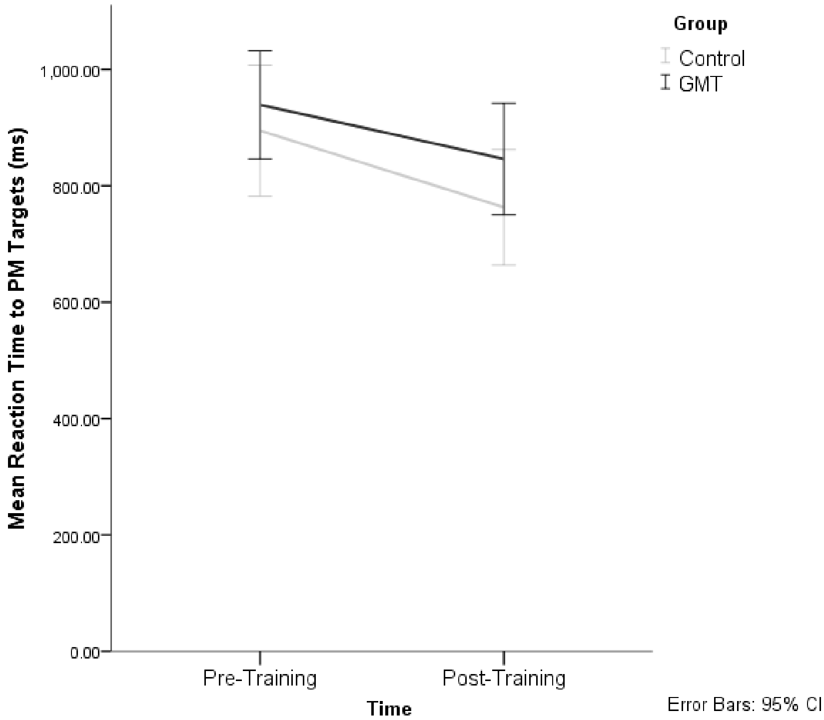

Figure 5.3: Mean change in Number Task PM target reaction times from pre-training to post-training by group. Error bars represent 95% confidence intervals.

To test whether the effects of training would be more evident in the second block following a brief break filled with an unrelated task, the performance of the two groups was compared in blocks 1 and 2, post-training by calculating a performance decay score. A summary of mean PM target accuracies is presented in Table 5.3 and Figure 5.4. The drop score was calculated by taking away the mean PM target accuracy in block 1 from the PM target accuracy in block 2.

Table 5.3: Mean PM target accuracies in the Number task block 1 and block 2 Post-training per Group

Condition	Group			
	Control		GMTii	
	Accuracy (%)	Reaction Time (ms)	Accuracy (%)	Reaction Time (ms)
	Mean ± SD		Mean ± SD	
N PM1 Block Accuracy	68.8% ± 22.5	786.2 ± 171.0	73.1% ± 20.0	832.9 ± 149.7
N PM2 Block Accuracy	52.9% ± 27.8	740.0 ± 210.8	76.4% ± 17.4	859.4 ± 191.8

N PM1 = Number task performance to PM targets only in the first prospective memory condition block; N PM2 = Number task performance to PM targets only in the second prospective memory condition block.

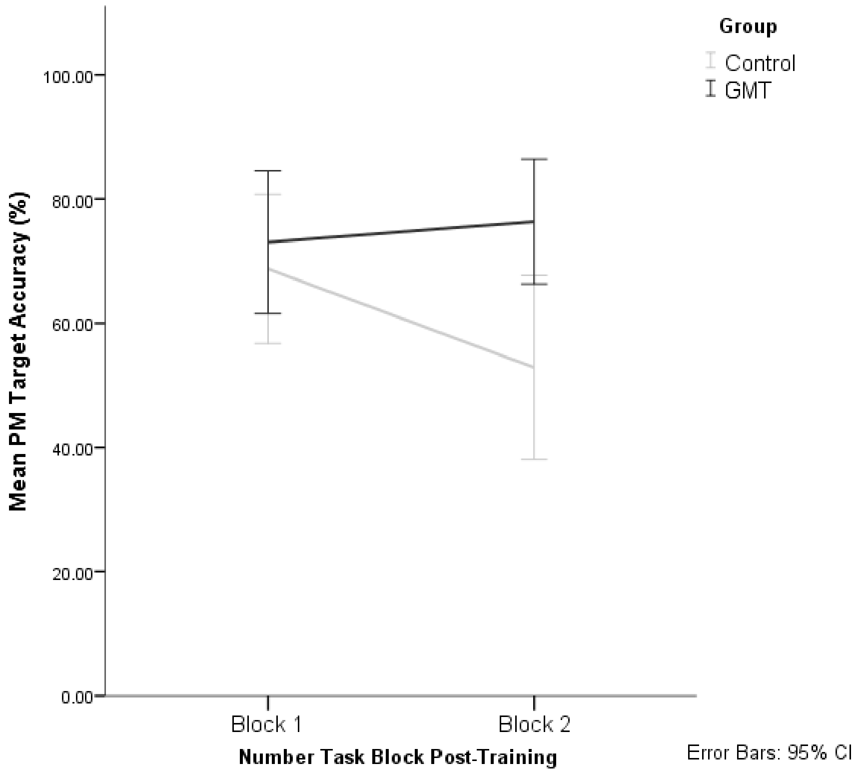

Figure 5.4: Performance of the GMTii and control groups on the Number Task before and after a brief break filled with unrelated task post-training. Error bars represent 95% confidence intervals.

The GMTii group showed a 3.3% (SD 19.7) increase in mean PM target accuracy from block 1 to block 2, whereas the control group showed a decrease of 15.9% from block 1 to block 2. This difference between groups was highly significant ($t\ (28) = -2.6$, $p < .05$, $r = 0.44$).

A closer inspection of reaction time group x time interaction (Figure 5.5) suggested that greater accuracy in the second PM block shown by the GMTii may have been at a cost of increase in reaction times ($F = (1, 28) = 4.72$, $p < .05$).

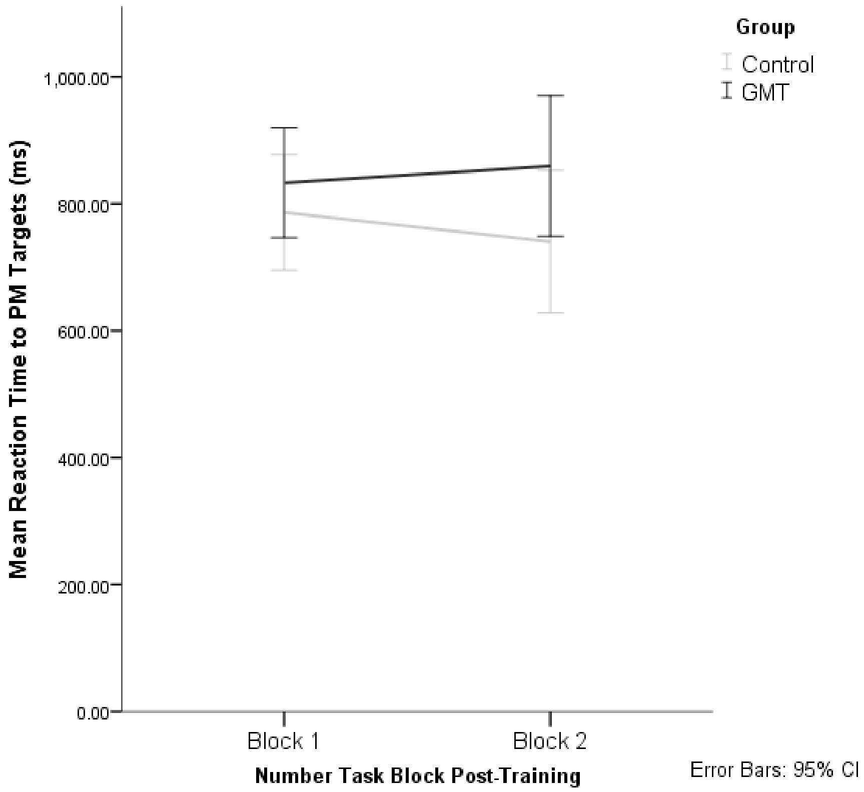

Figure 5.5: Mean change in Number Task prospective memory (PM) target reaction times from before to after a brief break filled with an unrelated task post-training times by group. Error bars represent 95% confidence intervals.

5.3.2.2 Novel Task

The GMTii group had a significantly higher PM target accuracy (73.0%, SD 12.7) compared to the control group (57.3%) in the novel PM picture task (t (28) = -2.68, p < .05, r = 0.45). This remained significant even after controlling for accuracy to PM targets in the pre-training number task (F (1, 27 = 5.45, p < .05). The significantly greater accuracy to PM targets in the GMTii group was observed despite both groups having similar reaction times in both the PM condition overall (t (28) = -.60, p = .55, r = 0.11) and to PM targets (t (28) = -.23, p = .82, r = 0.04). Both groups also had similar accuracies (U = 95.0, z = -.73, p = .47, r = -.13) and reaction times (t (28) = -.53, p = .60, r = 0.10) in the novel picture task ongoing condition.

Performance in blocks 1 and 2 of the picture task is summarised in Table 5.4.

Table 5.4: Mean PM target accuracies and reaction times in the novel Picture task block 1 and block 2 Post-training per Group

Condition	Group			
	Control		GMTii	
	Accuracy (%)	Reaction Time (ms)	Accuracy (%)	Reaction Time (ms)
	Mean ± SD		Mean ± SD	
P PM 1 Block	66.7% ± 27.7	951.1 ± 268.2	76.8% ± 23.0	1036.1 ± 275.3
P PM 2 Block	45.8% ± 27.3	929.8 ± 215.0	71.0% ± 23.7	875.4 ± 203.8

P PM1 = picture task performance to PM targets only in the first prospective memory condition block; PM2 = picture task performance to PM targets only in the second prospective memory condition block.

Both groups showed decreases in PM target accuracy from block 1 to block 2 (Figure 5.6) with the GMTii group's accuracy declining by 5 % (SD 37.6) and the control group's accuracy by 20.9% (SD 31.7). Accuracy to PM targets in block 1 did not significantly differ between groups ($t\ (28) = -1.1$, $p = .29$, $r = 0.05$) but the GMTii group had significantly higher PM target accuracies in the Picture task block 2 post-training ($t\ (28) = -.268$, $p < .05$, $r = 0.45$) compared to the control group. The purpose of the GMTii was to prevent performance decay from block 1 to block 2. The control group showed significant performance decay from block 1 to block 2 ($t\ (15) = 2.65$, $p < .05$, $r = 0.45$), where as the GMTii did not ($t\ (13) = .58$, $p = .57$, $r = 0.11$). However the group x time interaction effect was non-significant ($F = (1, 28) = 1.44$, $p = .24$).

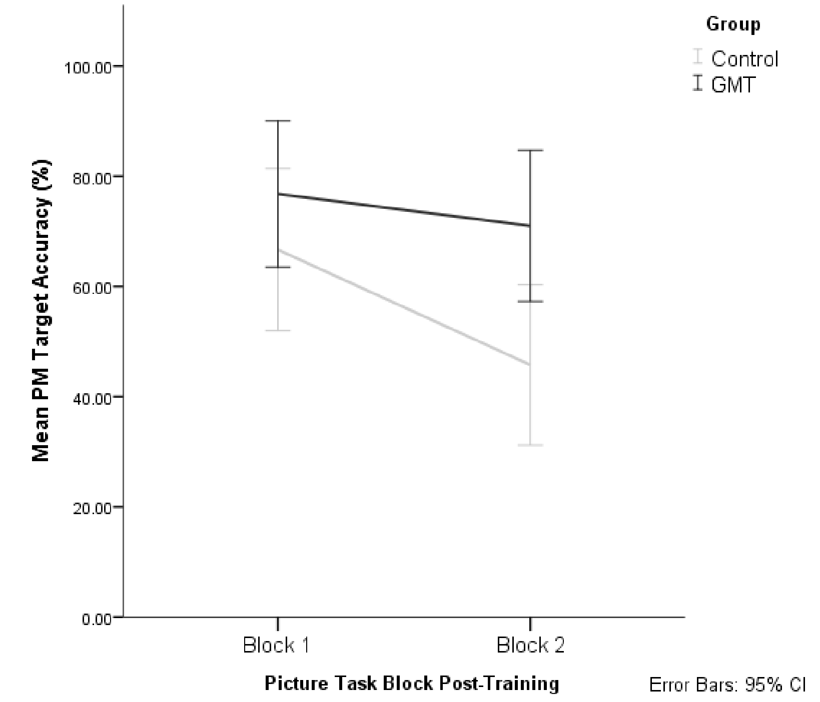

Figure 5.6: Performance of GMTii and control groups on the Picture Task before and after a brief break filled with unrelated task post-training. Error bars represent 95% confidence intervals.

No significant differences in reaction times between groups (Figure 5.7) were observed following assessment of the group x time interaction (F (1, 28) = 3.3, *p* = .8) or separately in either the 1st (t (28) = -.86, *p* = .40, r = 0.16) or 2nd PM block (t (28) = .71, p = .49, r = 0.13). Analysis of reaction times over time for each group individually showed significant reduction in mean reaction time to PM targets from block 1 to block 2 for the GMTii group (t (13) = 2.7, *p* < .05, r = 0.45) but not for the control group (t (15) =.43, *p* = .68, r = 0.08).

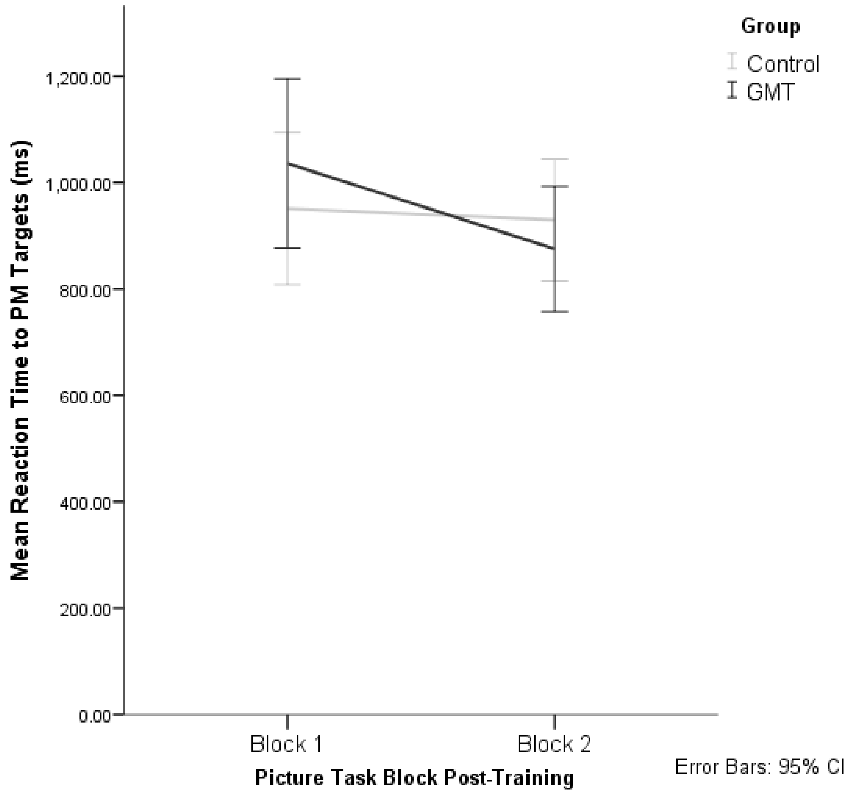

Figure 5.7: Mean change in Picture Task PM target reaction times by group from block 1 to block 2. Error bars represent 95% confidence intervals.

5.4 Discussion

This study investigated the behavioural effects of brief cognitive training that was designed to improve goal oriented prospective remembering on simple computerised prospective memory tasks following Goal Management Training with implementation intentions.

Brief GMTii was not found to improve overall performance on simple computerised prospective memory Number Task but was found to be effective in reducing performance decay on the familiar task. The GMTii group was also found to demonstrate better overall performance on the novel PM task and did not show significant performance decay from block 1 to block 2. The control group, on the other hand, did show significant performance decay over time.

Effects of GMTii on familiar Number Task

Both Goal Management Training and Implementation intentions are theoretically derived interventions that are aimed at improving goal attainment though automating goal directed responses (Gollwitzer, 2006), raising awareness of attentional lapses and reinstating cognitive control when behaviour is mismatched to the ongoing goal hierarchy (Levine et al., 2011).

Goal Management Training emphasises maintenance of sustained attention of goal states and output monitoring over time. One area where an intervention effect was clearly evident was in relation to performance decay, which reflects attentional drift in performance over time. Without any intervention, simple computerised tasks are known to be susceptible to performance decay in young healthy adults (Baylan and Evans, 2011). This supports previous findings of GMT, which demonstrated a reduction in errors of omission (i.e., not responding to go items) on the SART (Levine et al., 2011). The SART errors of omission score is a measure of attentional drift and loss of top-down control (O'Connell et al., 2009).

Reduction in performance decay on the familiar Number task suggests that the GMTii group may have benefited from the use of mental blackboard and STOP strategies of GMT and engaged in greater goal monitoring particularly during the second PM block. Significantly greater increases in reaction times from the first to the second PM block in the GMTii group, compared with the control group, further suggests application of these strategies. The observed increase in reaction times concurs with previous findings, with significantly longer speed of completion having been found on the proofreading and room layout tasks on the Simulated Real-Life Tasks (SRLTs) following GMT in healthy older adults (Levine et al., 2000). This slowing down is believed to be caused by the application of GMT principles rather than general slowing per se.

Performance on tasks is often expected to improve with practice, and enhanced performance on the simple computerised tasks without a break with practice has been previously reported (Burgess et al., 2003). The present study found that this was not the case when performance in the PM condition was briefly interrupted with another task. In contrast, both groups showed some decline in overall performance from pre- to post-training. Previous studies assessing the overall effects of GMT have shown that PM is most vulnerable to slips following breaks when initial high level of attention to task has slightly faded. Fish et al. (2007) showed that participants achieved greatest levels of success in remembering to phone an answer phone system at the correct time in the first few days following brief cognitive training but that level declined by midweek. A similar effect has been observed by (Gracey et al., 2012). The lack of overall effect on the Number task in the present study may be related to the ease of the task used, with the benefits of GMT principles only becoming evident in the second block of the task when the natural performance decay occurs. It is also possible, that due to the demands of the ongoing task, participants are only able to utilise the GMTii strategies during the brief break between blocks. McDaniel, Einstein, Graham and Rall (2004) have shown that presenting a small blue dot on the corner of a computer screen as a reminder of the prospective memory intention improves performance following interruptions compared to when no reminder is shown but interruptions are present.

In the light of the current finding, performance decay change from pre-training to post-training may be a more sensitive outcome measure for assessing the overall effects of GMTii. Due to there being no pre split block pre-training, the overall effects on performance decay cannot be assessed and a future study should address this issue.

Transfer of the effects of GMTii to a novel task

Very little good quality evidence in support of neuropsychological interventions for executive functioning deficits exists (Levine et al., 2008), with the evidence assessing the generalisability of any effects being particularly limited.

The issue of generalisability remains an issue for research trying to demonstrate the efficacy of different cognitive training intervention programs. If the effects of GMTii can generalise to other tasks, the GMTii group would be expected to show better performance on a novel PM task. In the present study, the GMTii group showed significantly better overall performance to PM targets on the novel PM task compared to the control group. Their accuracy to PM targets was significantly higher despite having comparable reaction times with the control group in both the ongoing and prospective memory conditions. Therefore, this finding cannot simply be attributed due general slowing down. One possible explanation of this finding is that the GMTii group benefited from the use of the implementation intention strategy on the novel task. The novel task is likely to require a greater degree of planning than the trained task due to a greater number of possible PM target combinations that may be encountered. The use of implementation intentions may have strengthened the association between the PM cue (middle two rows) and the action (press M) allowing the use of relatively automatic PM processes, which is reflected in maintenance of reaction times as compared to increase in reaction times following utilisation of GMT principles.

Contrary to the familiar Number task where performance during the first block followed a similar pattern between groups, some differences in PM target accuracy on the novel task between the two groups begin to emerge already half way through block one, which in turn may explain significant effect in the overall performance between groups.

The positive effects of GMTii on performance decay on the Number task suggested utilisation of top-down approach on the task. Top down approaches are considered being more likely to promote generalisation of function in a rehabilitation context. The purpose of GMTii was to prevent performance decay from block 1 to block 2. This study found some evidence of GMTii being effective in preventing performance decay on the novel task. Analysis of reaction time data revealed that the GMTii group had significantly faster reaction times in the second than first PM block compared with the control group. This suggests that the process of applying GMT principles may have started becoming more automatic; however, this may not have been the case for all participants in the GMTii group. A closer inspection of the data suggests that eight participants (58%) in the GMTii group either maintained accuracy to PM targets or improved in the second PM block compared to only three participants (19%) in the control group. Taken together, the findings suggest that performance decay is a good indicator that participants continue to maintain intentions over time.

Limitations

Although GMTii was effective in reducing performance decay in the novel task in GMTii group, the effect was somewhat smaller than that seen in the practiced task and may reflect aspects of the training intervention, which may not have been specific enough to allow extensive transfer to take place. Participants were not explicitly advised when to use the strategies or prompted to think about how these could be applied on the novel task, particularly with regards to breaks. Although participants practiced the strategies using a worksheet that cued them to which strategy to apply, the only self-initiated practice they were given was to remember to circle a word describing an item of luggage towards the end. Much of the success on strategy use depends on the ability to recognise when strategies can be applied and whether a participant successfully initiates its use at an appropriate moment. Individuals with executive dysfunction have particular difficulty in applying abstract rehabilitation strategies to other tasks without being provided with specific training in doing so (von Cramon and Matthes-von Cramon, 1994). Although the participants in this study did not suffer from difficulties in the executive function domain, the short length of the intervention may not have allowed them time to utilise the strategies as well as may have been possible following more extensive training. Previous studies suggest that task-specific training is unlikely to spontaneously generalise to other everyday tasks (Cicerone and Wood, 1987; von Cramon and Matthes-von Cramon, 1994). Allowing participants to practice identifying useful situations using a hands-on task in a more generic manner could have highlighted the usefulness of implementation intentions during the planning stage, the suitability of breaks in reviewing goals and allowed them to focus on task performance when strategy use is not of additional benefit. Grant, Ponsford and Bennett (2012) recently assessed the usefulness of GMT in improving financial management in a group of TBI patients with executive difficulties. They placed greater emphasis on practicing GMT principles to hypothetical everyday activities than previous studies (Levine et al., 2000; von Cramon and Matthes-von Cramon, 1994) and found it to improve aspects of day-to-day financial management with indication of transfer of its effects with some individuals.

Performance on the computerised tasks was assessed immediately after the end of training, giving participants no time to process and reflect on the strategies before having to use them. The strategies taught during the brief training may themselves have been overwhelming to some participants given the short time-frame participants had to learn the strategies. The presence of significant effects following brief GMTii in this study is encouraging given that other studies administering brief GMT have failed to find significant effects on performance or transfer of training effects (Brown 2009; Wood, 2011). Future research using brief training protocols should aim to simplify strategies by highlighting characteristics of situations that benefit from their use. They should also aim to increase self-initiation though generic strategy application practices to aid the effects of brief GMT interventions and their transfer to novel tasks.

Another limitation of the study design is that it due to its short duration it does not allow for assessment of change in self perceived goal management difficulties or transfer of training effect onto tasks in real life. Patients experiencing difficulties with PM, their families and caregivers are likely to be more interested in outcomes that generalise to real world improvements in functioning. So far, only a handful of studies assessing the effect of GMT administered over several weeks have demonstrated some improvements on real life performance such as meal preparation, financial management and shopping. (Levine et al., 2000; Willis et al., 2006; Grant, Ponsford and Bennett, 2012).

Strengths and Future research

The current study has demonstrated the simple computerised PM tasks to be sensitive to measuring the effects of GMTii and have therefore potential to be used in the fMRI environment. This expands up the possibility of using these measures to study the neural basis of improved performance following GMTii training. This study has further demonstrated that performance does not improve with repeated exposure, which is often found to be the case with neuropsychological assessment tools.

The findings suggests that neurologically healthy young adults do not spontaneously use breaks to reactivate their intentions, but that they interfere with prospective remembering causing participants to disengage from the task demands (Einstein et al., 2003; McDaniel et al., 2004). Application of very brief Goal Management Training with Implementation intentions can prevent performance decay and allow individuals to refresh their intended actions when they are able to identify situations where to use them.

Future research should focus on understanding which aspects of cognitive training interventions are most important in producing behavioural improvements and in which circumstances that they can result in improvements on familiar tasks as well having the capability to produce the best transfer effects on untrained tasks. They should also investigate the neural and cognitive mechanisms in order to further the development of clinically useful cognitive training interventions.

This study supports earlier findings that participants show greater performance in PM tasks early on (Baylan and Evans 2011; Gracey et al., 2012). Future studies assessing the effectiveness of interventions aimed at improving prospective memory should consider ignoring small amount of data collected early in the tasks, or calculate performance decay in order to account for greater attention paid to tasks early on. Immediate utilisation of GMTii principles following training which was very short in duration may be indicative of its usefulness in preventing slips in short term intentions following interruptions on simple tasks that do not reach the level of importance to be written down in a calendar or diary.

Although brief GMT showed some evidence in improving performance on simple tasks that do not require breaking goals into subgoals, its ability to improve performance on complex tasks has not been assessed.

Conclusions

Taken together, the findings from this study, suggests that very brief GMTii is able to reduce performance decay on a trained task and overall performance on a novel PM task. The preliminary findings suggests that it is most effective following brief interruptions to ongoing performance on a task but that the intervention would benefit from being better targeted to enhance the effect and to aid transfer to similar but untrained tasks.

Chapter 6

Assessment of the neural effects of brief Goal Management Training with Implementation Intentions using functional Magnetic Resonance Imaging (fMRI)

Background and aims: Several studies have reported changes in brain activation following physical or cognitive training interventions using fMRI but as yet no study has reported neural changes following prospective memory training in neurologically healthy individuals.

The overall aim of this study was to determine the underlying functional neural activation mechanisms that support improvements in prospective remembering (PM) following brief cognitive training.

Method: Twenty seven young adults were randomised into either brief Goal Management Training with implementation Intentions (GMTii) aimed at improving prospective remembering or to a control training condition.

Results: The findings indicate that the pattern of functional neural activation changes within Brodmann area 10 differed between the GMTii and control group. In addition to neural activation changes, behavioural improvements in performance were seen on simple computerised PM tasks in the GMTii group but not in the control group.

Discussion and conclusions: This study provides evidence for the effectiveness of brief Goal Management Training with Implementation Intentions that are associated with detectable changes in the underlying functional neural activations using fMRI.

6.1 Introduction

Until only a few decades ago it was commonly believed that the human brain displayed little if no plasticity beyond childhood. This view has since been challenged and there is now a growing body of evidence suggesting that the adult brain can change as a result of learning and experience. The prospect of brain plasticity in adulthood offers an exciting avenue for research into recovery and reorganisation of function following brain injury. Understanding the neural basis of cognition and mechanisms by which improvements occur, may aid the development of rehabilitation interventions aimed at enhancing a given function (Chen et al., 2006, 2011; Kennedy et al., 2008; Levine et al., 2008).

Several researchers have reported structural and functional changes in the brain following acquisition of new skills and/or information, but relatively little is still know about the mechanism of how these changes occur. This chapter will assess the neural effects of brief cognitive training aimed at improving prospective remembering using fMRI and examine whether any neural changes are associated with behavioural improvements in performance in neurologically healthy individuals.

6.1.1 Structural and functional effects of experience

Structural changes in the brain resulting from experience were first reported in animal studies in 1960’s, which found that rats raised in groups in an environment enriched with ‘toys’ and a wooden maze had greater cerebral cortex volume compared to rats raised alone in standard cages (Rosenzweig, Krech, Bennett and Diamond, 1962). In humans, it was noted that experienced London taxi drivers had significantly greater posterior hippocampi grey matter volume than control participants, which correlated with years of taxi driving (Mcguire et al., 2000). These structural differences between experienced and inexperienced taxi drivers are likely to have resulted from the experience of navigating London and reflect the long term effects of "The Knowledge" training, which involves memorising the complex layout of London’s streets over four years, given that concomitant changes in memory profile were observed in trainees who qualified, but not in control participants or trainees who failed to qualify (Woollett and Maguire, 2011). These changes appear to reflect a more general pattern of change with experience given that increases in hippocampi grey matter volume have also been reported in other skilled occupations such as piano tuners with the number of years of experience correlating with volume of change (Teki et al., 2012).

Another approach to examine the effects of learning and experience is to investigate the functional changes that occur in the neural processes underlying cognitive skills that learning or experience is likely to change or enhance. Behavioural improvements coupled with structural and functional changes are often reported following musical training (see Herholz and Zatorre, 2012 for review). Greater level of activity in the primary auditory cortex coupled with increased grey matter volume has been reported in musicians compared to non-musicians (Schneider et al., 2002). Both structural and functional observations also highly correlate with a behavioural measure of musical aptitude. In the music domain, training related changes are known to relate to the specific type of musical instrument practiced with string players showing increased cortical representation for the fingers of their left hand (Elbert, Pantev, Wienbruch et al., 1995) whilst piano players show a greater recruitment of both hand areas (Lotze et al., 2003). Training induced functional changes in the brain have been observed even following brief musical training. Non-musicians who were taught to play a familiar melody on the piano over five days showed BOLD increases in the motor network including ventral pre-motor and parietal areas while listening to the trained melodies compared to the untrained ones (Lahav et al., 2007). This is presumed to reflect the underlying mechanism of change caused by co-activation of motor areas during auditory perception reflecting new sound-action (piano-keystroke) associations.

6.1.2 Functional effects of cognitive training and practice

Functional neuroimaging studies investigating learning-induced changes associated with different types of practice or training in neurologically healthy individuals have reported different patterns of changes in the BOLD signal, primarily in terms of increases or decreases (Kelly and Garavan, 2005; Kelly et al., 2006). In neurologically healthy individuals, practice alone has been shown to predominantly produce decreases in functional brain activation (Kelly and Garavan, 2005) but some studies have also reported increases in activation following repeated practice where task difficulty has been increasing over time (Olesen et al., 2004). Studies using patient populations have also reported increases in activations following training or practice suggesting that patients may have to work their brains harder to attain a similar behavioural outcome to neurologically healthy individuals. In neurologically healthy individuals decreases tend to be associated with increase in neural efficiency (Garavan, 2000; Sayala, Sala and Courtney, 2006) or utilisation of greater automatic processing.

A handful of studies that have investigated changes in brain activation following cognitive training utilising cognitive strategies for memory now exist. Miotto et al. (2006) found that following semantic cognitive training, the number of words healthy individuals were able to recall significantly increased while significant increases in activation were seen in the right dorsolateral PFC using fMRI. The dorsolateral PFC is believed to be associated with semantic processing as activations were seen during conditions where subjects may have tried to apply a semantic organisational strategy but not in one that did not need a semantic strategy. The pattern of activations shown by patients following semantic training has been shown to differ from that shown by neurologically healthy individuals (Miotto et al., 2013; Strangman, 2009).

6.1.3 Effects of training and practice in the prospective memory domain

Neural changes associated with cognitive training or rehabilitation interventions in the prospective memory domain, are relatively unexplored in both young healthy adults and in patient populations. Several behavioural studies have indicated that multisession Goal Management Training (GMT) can improve performance of the elderly and patients with neurological illness on ill-structured tasks requiring the ability to manage goals and subgoals (Levine et al., 2000, 2007, 2011; van Hooren et al., 2007). The findings supporting the usefulness of brief GMT are mixed with some studies reporting improvements in performance (Fish et al., 2007; Baylan and Evans, 2012) while others have failed to find an overall effect (Brown et. al., 2009; Wood et al., 2011; Carstens, 2011). Chen et al., (2011) investigated the neural effects of 5-week Goals training in a group of 12 patients with ABI. The training, targeted at improving goal-directed attention regulation and derived from the GMT principles was found to enhance neural processing of goal-relevant information relative to non-relevant information in the visual cortex. Neural changes in the prefrontal cortex however, depended on individual baseline state with lower pre-intervention scores predicting greater changes in a positive direction and higher pre-intervention scores predicting greater changes in a negative direction. This pattern was not seen in the education control condition.

Umeda et al., (2006) administered PM training to two brain-injured patients for three months and found that patient Y.O, who had a brain lesion outside the PFC showed improvements in PM following training with better recall for time, whereas patient T.K, who had lesions in the right medial frontal lobe only improved in his ability to recall content suggesting that the right frontal areas may play an important role in PM.

Whilst few studies have examined the neural impact of cognitive training for PM, a number of studies have examined the neural basis of PM. The neural basis of PM has been investigated using PET. These studies have used computerised PM paradigms where a PM task is embedded into an ongoing activity (Burgess et al., 2001; 2003; Okuda et al., 1998) and fMRI (den Ouden et al., 2005; Gilbert, 2011; Gilbert et al., 2009; Hashimoto, Umeda, and Kojima, 2010; Haynes, Sakai, Rees, Gilbert, Frith, and Passingham, 2007; Okuda et al., 2007; Okuda, Gilbert, Burgess, Frith and Simons, 2011; Poppenk et al., 2010; Reynolds, West and Braver, 2009; Simons et al., 2006). Performance during PM condition, relative to the ongoing condition, tends to be associated with activations in rostrolateral PFC (Burgess et al., 2011). Studies have found a consistent pattern of activations within Brodmann's area 10 with medial BA10 activations normally seen during performance in the ongoing task relative to a PM task and lateral activation within BA10 during conditions involving delayed intentions or PM. Increased medial PFC activations have also seen on studies using prospection where participants are required to describe their own future intentions as opposed to tasks requiring recalling of their personal past experiences (Okuda et al., 2003; see also Burgess et al., 2011 for review). To date, only one study (Burgess et al., 2003) has investigated the neural correlates of practice using a prospective memory paradigm. Accuracy was found to increase with repetition following immediate repetition of the same task but no significant changes in neural activation within BA10 at the whole brain level were found. When a smaller ROI was created around the activation peaks for the PM-ongoing condition contrast identified by Burgess et al. (2001), a reduction in activation from first to second PM task repetition was seen within BA11.

To date, only one study has investigated the neural basis of implementation intentions, another strategy found to improve prospective remembering. Gilbert et al., (2009) asked participants to perform a computerised PM task both under goal intention and implementation intention (if X, then do Y) instructions with the order of tasks counter balanced across participants. Participants' accuracy to PM targets was better in the implementation intention condition compared with the goal intention condition, and this was not found to compromise the speed of responding to the ongoing trials in the PM task. Greater activation was seen in the lateral BA10 (also BA10/11, BA45/46) bilaterally in the goal intentions condition compared with the implementation intention condition. By contrast, greater activation in the medial BA10 was seen in the implementation intention condition compared with the goal intention condition. The results of this study can be taken to suggest that the goal intentions condition (self-initiated condition) requires a greater degree of self initiated processes than the implementation intention condition (cued condition). Similarly, Simons et al., (2006) reported greater medial BA10 activations during a cue identification condition compared to an intention retrieval condition during which more lateral activations were found to be present bilaterally.

More recently, Cullen, Brennan, Manly and Evans, (2012) reported increases in activation within the right lateral BA10 when participants were required to self-initiate switching of tasks on a computerised multi-element task (CMET) as opposed to being prompted to switch tasks. The CMET is a multi-element task designed to assess goal neglect. It may therefore be possible to postulate that if an intervention combining GMT with implementation intentions (GMTii) is driven by an increase in self-initiated maintenance of delayed intentions, then this should result in increased activation in brain areas responsible for self-initiated behaviour, whereas if changes are driven by greater automated processing of implementation intentions, then changes should be seen in areas responsible for more automated PM processes.

6.1.4 Aims and Hypotheses

Aims

The main purpose of this study was to assess the behavioural and neural changes associated with brief Goal Management Training with Implementation Intentions (GMTii).

Hypotheses

Primary: Compared with the control training group, the GMTii group was expected show greater improvements in PM target accuracy and significant increases in activation within Brodmann’s area 10 from pre- to post training.

Secondary: No significant differences in the pattern of activation within area 10 were expected to be present between groups pre-training.

It was tentatively speculated that post-training, the difference in the GMTii group, activation in area 10 would be significantly greater in following a brief interruption during task performance compared with the control group.

6.2 Method

6.2.1 Participants

Forty two participants were initially recruited to the study. Of these, six were excluded after initial screening. They were excluded due to having metal in their body thus not suitable for being scanned (n=2), previous head injury that had resulted in loss of consciousness (n=1), not speaking English as first language (n=1), being left handed (n=1) or receiving treatment for psychological difficulties (n=1). A further four participants failed to show up at their testing session or cancelled their time slot due to overlapping time commitments. In addition, two individuals completed the initial screening and the Goal Management Questionnaire (GMQ) but failed to arrange a time slot for an fMRI scan.

Thus 30 participants (12 male, 18 female) between the ages of 18.8 and 28.9 years (mean = 22.4 years; SD = 2.2) completed the training and scanning. Participants had spent 16.6 years in full-time education on average (SD = 2.0) and had a mean WTAR FSIQ score of 113.6 (SD = 4.3). Five participants in the control group and nine participants in the GMTii group had had an MRI scan previously. Half of the participants were allocated to GMTii training and half control training condition. Following completion of the study, a closer inspection of individual data revealed that three participants had not fully adhered to task instructions in the PM condition and were therefore excluded from the analysis. Thus the final sample comprised 27 individuals.

6.2.2 Inclusion and exclusion criteria

Inclusion criteria: Participants were included in the study if they were right handed, between 18 and 45 years of age and spoke English as their first language.

Exclusion criteria: Individuals with neurological illness, history of psychiatric or psychological problems that had required continued treatment by a professional or were currently receiving treatment we excluded. Those unable to undergo an fMRI scan were also excluded.

6.2.3 Recruitment

Participants were recruited from the University of Glasgow using posters and through the Department of Psychology subject pool. Participants were initially recruited to complete the GMQ and those willing and suitable underwent fMRI scanning. Participants were given a copy of the study information sheet prior to deciding whether to take part. Written informed consent was also obtained from all participants prior to starting the experiment.

6.2.4 Measures

6.2.4.1 Pre-experimental screening measures

Goal Management Questionnaire (GMQ; Robertson, Levine and Manly, 2000; Levine et al., 2012) was used to assess the level of self-reported goal management difficulties experienced in everyday life. This was completed prior to arranging a time slot for their fMRI scan.

6.2.4.2 Background Measures

Participants completed the Wechsler Test of Adult Reading (WTAR; Wechsler, 2001) as an estimate of their general intellectual ability.

6.2.4.3 Experimental Measures

Participants completed the Number Task (modified from Burgess et al., 2003) pre- and post-training. The stimuli were projected onto a screen in direct view of participants, who responded by pressing buttons on a response pad with their right and left index fingers and their right middle finger. The task comprised of two conditions, ongoing and prospective memory, in both of which participants were presented with two digits ranging from 1-9 with the digits presented together always being two different numbers. In the ongoing condition, participants were asked to indicate which one of the two numbers was greater by pressing the button on that side of the screen using their index fingers. In the prospective memory condition, in addition to deciding which of the two numbers was greater, they were asked to press a different button on trials where two even numbers were presented together. Thus the two conditions differed only by virtue of the task instruction. Participants performed the Number Task in a blocked fashion together with the baseline condition. The Number Task block configurations in each condition are summarised in Figures 6.2 and 6.3.

Ongoing condition

The ongoing condition was presented in a blocked fashion with the baseline condition (Figure 6.2). The duration of each ongoing block was 25 seconds and there were a total of eight OG blocks. A one second instruction screen that read ‘number task’ was presented before the start of each OG block. The inter stimulus interval (ISI) varied randomly between 150 and 350 milliseconds.

Baseline condition

In the baseline condition, subjects were asked to make a motor response to visual stimuli as fast as they could by pressing the button on the side that the red star appeared on each trial (Figure 6.1). The red star alternated between the left and the right side of the screen on each button press with the ISI varying randomly between 300 and 700 milliseconds. The stars were used instead of the ‘seesaw’ (see chapter 4) in order to remove the motion effect perceived by tipping the seesaw. The baseline block was 8 seconds long in all scans regardless of whether it alternated with the ongoing or prospective memory condition (Figure 6.2). A one second instruction screen (‘catch the red star’) was presented before each baseline block.

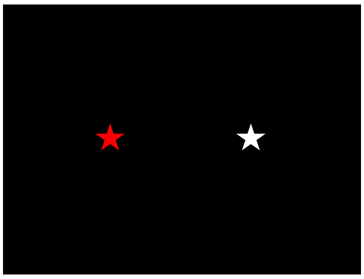

Figure 6.1: Baseline condition stimuli

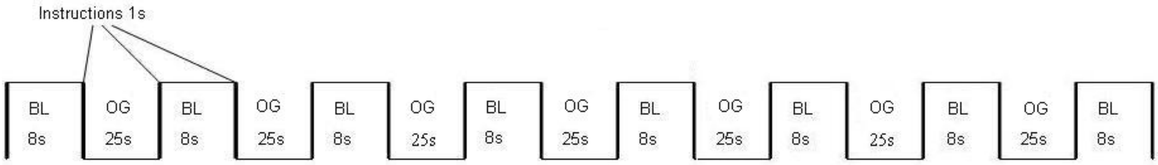

Figure 6.2: Boxcar of ongoing-baseline condition block sequence

Prospective memory condition

In the PM condition (Figure 6.3), the duration of the PM block was 25 seconds. The ISI varied randomly between 150 and 350 milliseconds.

A one second instructions screen (stating 'number task') was presented before the start of each block. There was a brief break lasting 30 seconds half way through the PM condition. During the brief break, subjects performed a simple task in which they were asked to decide whether a given animal had two legs or four legs. The PM block before the break will be referred to as 'PM block 1' and the block after the break as 'PM block 2'. Participants completed a total of 20 PM blocks of which ten were presented before the brief break and ten after the brief break. Half of the blocks contained one PM target and half the blocks two PM targets. In the PM blocks containing one target, the PM target was presented at a randomly selected point between the 3rd and 21st second of the block. In the blocks containing two targets one was presented at a randomly selected point between the 3rd and 10th second of the block and the other between the 14th and 21st second of the block). In total, participants encountered 30 PM targets during the experiment.

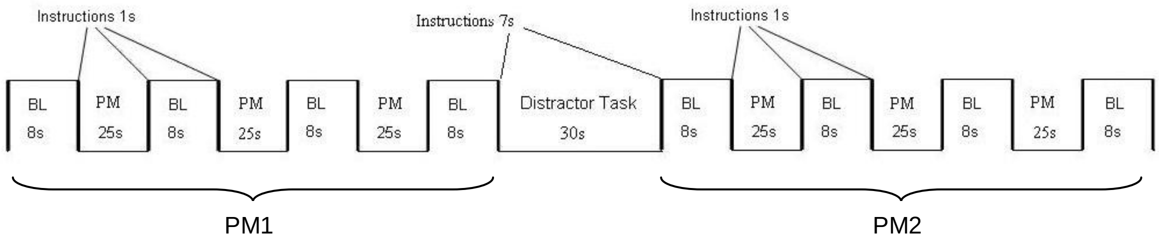

Figure 6.3: Boxcar of prospective memory-baseline condition block sequence showing the distractor task in the middle.

6.2.5 Cognitive Training Methods

Participants were randomly allocated into one of the training groups. They received either Goal Management Training with Implementation Intentions (GMTii) or no training (control training). Participants were blind to the cognitive training aspect of the study prior to taking part in the study as they were told that the study was to assess the effects of practice on computerised tasks performed in an fMRI scanner. The control training group remained blind to the purpose throughout the study. Both groups were debriefed at the end.

6.2.5.1 Goal Management Training with Implementation Intentions

Half of the participants received GMTii lasting approximately 60 minutes. Learning of the strategies occupied approximately half of this time (Appendix M). First, participants were introduced to the idea of everyday memory slips through general examples or examples from their everyday life. They were asked to think what makes them vulnerable to PM slips (e.g. when in a rush, when getting distracted or when working on autopilot). They were then taught three simple strategies derived from Goal Management Training

(Robertson, Levine and Manly, 2000; Levine et al., 2012) and Implementation Intentions (Gollwitzer, 1993; 1996) and asked to work through paper and pencil exercises where these strategies could be used. Compared to an earlier study presented in Chapter 5, emphasis was made on being able to recognise when it was and was not appropriate to use the strategies (e.g. breaks between activities provide a good opportunity for checking your mental blackboard). The examples consisted of both hypothetical and everyday life situations and were identical to those used in the study reported in Chapter 5. Before starting on the paper and pencil exercise, participants were (verbally) given an additional PM task to do where they had to remember to circle a word describing an item of luggage (suitcase) when they came across it in the handout. The word was placed in the last paragraph of the handout in order have a longer delay between the task instruction and carrying out the task. If the participant failed to circle the word, their memory for this task was checked and they were asked to think if one or more of the strategies introduced to them could have helped them to remember this. Following learning of the strategies during training, participants completed a modified version of the Hotel Test (Manly et al., 2002). The GMTii group was instructed to try and use the newly learned strategies during it.

The GMTii consisted of the following strategies:

Strategy 1: **‘Stop and think’**. Participants were told that this would help in orienting attention to the task on hand, encourage task setting (planning). They were told this may be useful way to ‘refresh memory’ during natural breaks in tasks.

Strategy 2: **‘When X happens I will do Y’** (as opposed to my aim is to do Y). Participants were told that using this strategy is likely to help strengthen the association between the cue to act and their intended action thus increasing the likelihood of something being remembered. They were also advised that this strategy would be most useful before starting a task and during breaks.

Strategy 3: **‘Mental blackboard**. Participants were introduced the ‘mental blackboard’ concept in order to aid monitoring performance and future intentions, namely encourage them to switch attention between the external environment and internal thoughts/mental blackboard. This switching was believed to allow for comparison and evaluation of current performance to be made against future goals stored on the mental blackboard particularly during breaks in the task.

6.2.5.2 Control Training

The control group completed training similar in length to GMTii. During control training, participants were not introduced to cognitive strategies aimed at improving prospective memory. Instead, participants were asked to work through series of lateral thinking puzzles and to come up with possible solutions or explanations to the puzzles (Appendix N). Participants were given a cue sheet that they were free to consult if they found it difficult to find a solution to a given puzzle. They were also allowed to skip to the next puzzle if they could not come up with a solution to a puzzle. Participants in the control group also completed the modified Hotel Test during the training session using standard instructions as described in chapter 2 earlier.

6.2.6 Research Procedure

The experimental research procedure is summarised in Figure 6.4.

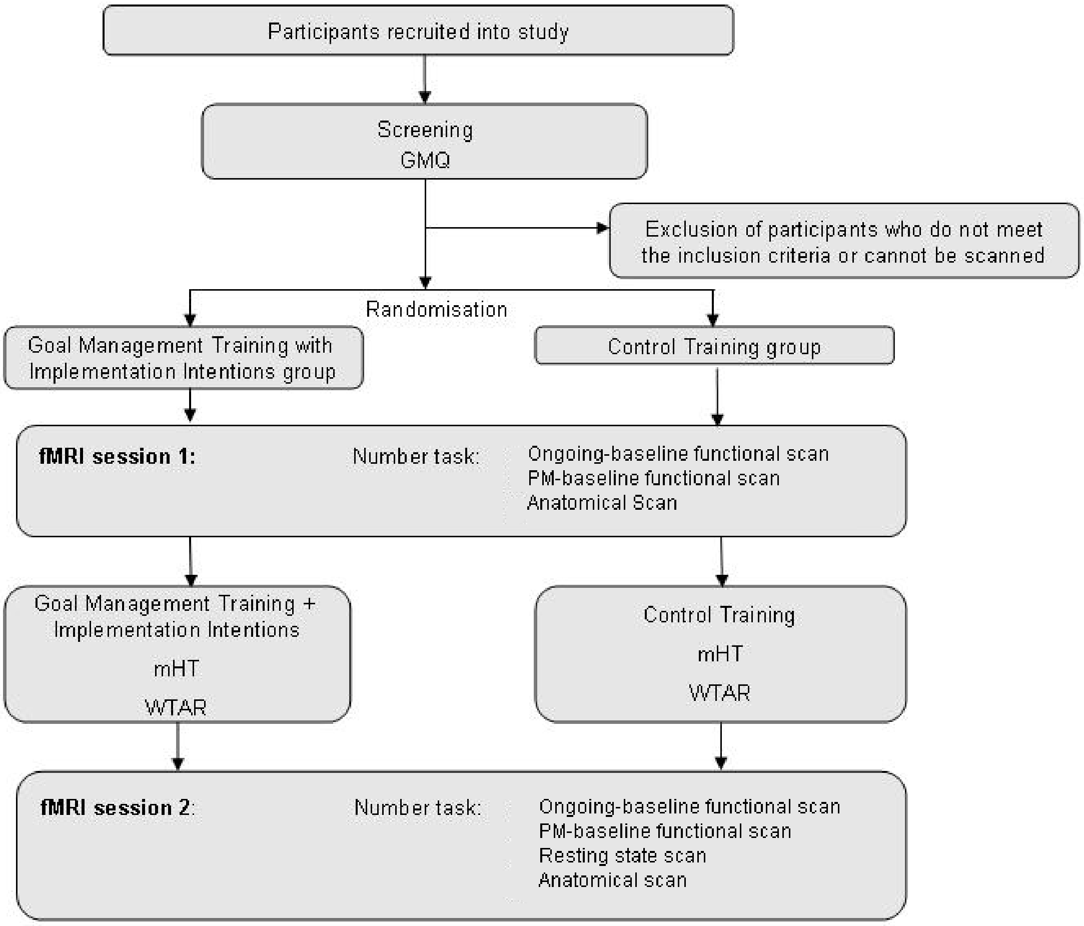

Figure 6.4: Research procedure flowchart

Participants were screened to assess their suitability for the study including their suitability for an fMRI scan. Those not meeting the inclusion criteria were excluded. Participants also completed the Goal management questionnaire (GMQ).

Participants were randomly allocated to either GMTii training or control training condition at the point of recruitment. The randomisation of participants was done by drawing a condition from a box. Participants were randomised into groups in pairs where the first participant was allocated to the condition drawn (e.g. GMTii) and the next participant to the condition not drawn (e.g. control). A participant from each condition was normally tested during each morning or afternoon scanning session in order to keep the time of testing between groups as similar as possible. On a few occasions where a participant cancelled their allocated time slot with very short notice (< 24hrs), their slot was allocated to a new participant who had not yet been randomised into a group in order not to waste scanner or researcher time.

All testing took place during one session lasting approximately 2.5-3 hours. First, participants underwent two functional MRI scans (ongoing condition followed by PM condition) and a high resolution anatomical scan. In the PM conditions, instructions were delivered to participants via computer screen and only given verbally if it was clear that the participant had not understood them correctly during a short practice block prior scanning. The stimuli were presented using E-prime 2.0 (Psychology Software Tools Inc., USA) onto a screen in view of the participant.

The first set of brain scans was followed by a training session lasting approximately one hour. During the training session, participants underwent either GMTii training or control training. Participants also completed the WTAR and the modified Hotel Test (see chapter 2 for detailed description) during the training session. The GMTii group was instructed to use the mHT as a way of practicing the skills they had learned during the training session where as the control group completed the mHT as per standardised instructions.

Immediately following the training session, participants underwent a further two functional MRI scans followed by a 5-minute resting state scan and an anatomical scan of their brain. Prior to starting the PM condition post-training, the GMTii group was briefly shown a reminder of the strategies they had learned during the training session (Figure 6.5). Participants were not explicitly told how to use the strategies during the task.

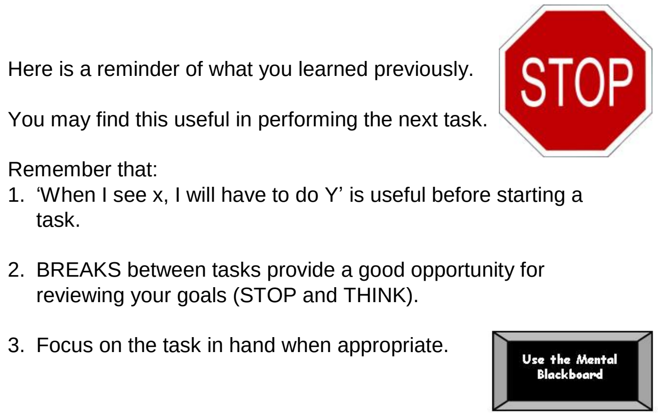

Figure 6.5: Training strategy reminder screen shown to the GMTii group prior starting the PM condition post-training.

6.2.7 Imaging methods

Scanning was performed on a 3-Tesla Siemens Tim Trio MRI scanner. Functional scans were acquired using T1* weighted eco-planar imaging (EPI) sequence (TR = 2.34s; echo time [TE] 30ms, matrix size: 64mm x 64mm; voxel size: 3mm x 3mm x 3mm). Each volume comprised 36 axial slices (2 mm thick; separated by 1 mm gap) covering the whole brain. The images were oriented at approximately 10 degrees to the anterior commissure-posterior commissure plane covering the whole brain. Functional magnetic resonance images (fMRI) were acquired during four runs of which two took place pre-training and two post-training. The first and third runs comprised of 122 volumes and second and fourth run 324 volumes. Field maps (long TE = 7.38ms, short TE = 4.92) were also acquired in addition to T1* weighted anatomical scans (matrix size 256 x 256, voxel size: 1mm x 1mm x 1mm) using 3D mprage sequence that were obtained pre-training and post-training.

6.2.8 Data analysis

6.2.8.1 fMRI data analysis

The fMRI data was preprocessed and analysed using Statistical Parametric Mapping (SPM8) software (http://www.fil.ion.ucl.ac.uk/spm/software/spm8, University College London, UK). The functional images were first realigned to the first image acquired in each scanning session. Images acquired during each time point were then co-registered with the subject's own T1-weighted structural image for that time point, segmented, spatially normalized to Montreal Neurological Institute (MNI) space, and spatially smoothed using an isotropic 8-mm full-width half-maximum Gaussian kernel.

The preprocessed images were analysed at an individual level with a general linear model and contrast images were created for each contrast of interest. These were then used in group level random effects analyses. A one sample t-test was carried out for whole group comparison pre-training and two sample t-test to assess the similarity of the two groups pre-training. A flexible factorial model with three factors (subject, group and time) was used to assess group x time interactions.

6.2.8.2 Region of interest definition

An anatomical mask was created for Rostrolateral PFC (area 10), a priori region of interest (ROI). The mask was defined using the xjView predefined Brodmann maps for area 10 (http://alivelearn.net/xjview) and were used to perform small volume corrections (SVC) on functional data unless otherwise stated. The contrasts were corrected for multiple comparisons within this brain region using a threshold of $p < 0.05$ for family wise error (FWE) and voxel size of 5 continuous voxels following a whole brain analysis at uncorrected $p < .001$. Activations outside BA10 are only reported where they reached a whole-brain threshold corrected at FWE $p < .05$ with a minimum of 5 continuous voxels.

6.2.8.3 Behavioural Data Analysis

Behavioural data analyses were carried out using PASW Statistics 19 (SPSS, Chicago). Descriptive statistics were calculated for demographic characteristics of the sample and for variables of interest. Between group characteristics were compared using two- tailed independent t-tests for normally distributed variables and Mann-Whitney U tests for those violating the assumption of normality. Group x time interaction was assessed using repeated measures ANOVA where parametric assumptions were met or where transformation of the data to normality was possible. Change scores and non-parametric statistics where used where assumptions were violated or transformation was not possible.

6.2.9 Ethical Approval

The study was approved by the University of Glasgow, Department of Psychology ethical review board. All participants gave written informed consent before taking part in the study. Participants who successfully completed the fMRI scan received a payment of £18 for taking part in the study.

6.3 Results

A total of thirty participants completed all measures. Three participants (two from the GMTii group and one control participant) had unusually low accuracies to PM targets in the prospective memory condition (from 20% to 37%) pre-training compared to the rest of the subjects suggesting that they may not have fully adhered to the task instructions. Individuals with a PM target accuracy less than 50% were therefore excluded from the analyses given that it can be questioned whether their neural activations would be reflective of normal PM processes in healthy individuals. This figure was decided based on findings from earlier studies utilising a similar paradigm. The final sample comprised 27 individuals.

Participant characteristics are summarised in Table 6.1

Table 6.1: Sample characteristics

Variable	GMTii Group (n=13) Mean ± SD	Control Group (n=14) Mean ± SD
Age (years)	23.5 ± 2.6	21.5 ± 1.5
Gender (count)	7 males / 6 females	4 males / 10 females
Education (years)	17.5 ± 1.9	15.6 ± 1.7
WTAR FSIQ	112.5 ± 4.7	114.2 ± 4.4
GMQ Total Score (max 340)	126.2 ± 59.8	123.1 ± 51.4

WTAR FSIQ = Wechsler Test of Adult Reading full scale intelligence quotient; GMQ = Goal Management Questionnaire

The GMTii group was found to be, on average, two years older (t (25) = -2.5, $p < .05$) and having spent just under two years longer in full time education (t (25) = -2.6, $p < .05$) than the control group. The groups did not differ with regards their mean WTAR FSIQ (U = 65.5, z = -1.24, $p = .21$, r = -0.24) or their mean GMQ total score (U = 75.0, z = -.78, $p = .44$, r = -0.15. The mean GMQ total score lies slightly below the midpoint of the minimum (0) and maximum (340) total score. Although no normative data exists for the GMQ, overall, the sample is likely to experience low or average level of difficulties in managing goals in everyday life.

6.3.1 Behavioural Data

6.3.1.1 Pre-training

Performance on the computerised tasks pre-training is summarised in Table 6.2.

Table 6.2: Performance of the GMTii and control groups on the simple computerised tasks pre-training

Computerised Task Condition	GMTii Group (n = 13)		Control Group (n = 14)	
	Accuracy ± SD	**Reaction Time ± SD**	**Accuracy ± SD**	**Reaction Time ± SD**
Ongoing	93.1 ± 2.0	587.6 ± 102.0	93.0 ± 2.4	559.9 ± 80.1
Prospective memory	91.2 ± 2.0	724.0 ± 176.9	92.4 ± 1.9	677.9 ± 124.5
PM Targets only	67.4 ± 12.3	853.3 ± 215.1	77.1 ± 11.7	829.7 ± 138.3
OG Targets only	92.8 ± 2.1	715.3 ± 172.2	93.4 ± 2.1	668.6 ± 123.0
PM Blocks				
Block 1 PM Targets only	70.5 ± 14.8	886.2 ± 244.7	76.0 ± 14.5	860.1 ± 161.6
Block 2 PM Targets only	64.2 ± 13.7	820.4 ± 188.9	77.6 ± 14.3	799.4 ± 120.7

Accuracy scores reported as percentage (%) of total responses correct. Reaction times reported in milliseconds (ms). PM = Prospective memory, OG = ongoing

The two groups had similar reaction times and levels of accuracy in both the ongoing (U= 81.0, z = -.49, p = .63, r = -0.09 and U = 88.5, z = -.12, p = .90, r = -0.02) and PM condition overall (U = 74.0, z = -.83, p = .41, r = -0.16 and t (25) = 1.5, p = .15, r = 0.29). Their reaction times and accuracies to PM targets (U = 89.0, z = -.1.0, p = .92, r = -0.19 and U = 52.5, z = 1.9, p = .06, r = 0.37) and OG trials in the PM condition (U = 75.0, z = -.78, p = .44, r = -0.15 and t (25) = .73, p = .47, r = 0.14) were also similar. They further had similar reaction times and accuracies in the first PM block (U = 66.5, z = -1.2, p = .23, r = -0.02 and t (25) = -.33, p = .74, r = 0.07) and reaction times in the second PM block (U = 89.0, z = -.10, p = .92, r = -0.02) but the control group was significantly more accurate in remembering to respond to the PM targets (77.6% vs.64.3%) in the PM2 block (t (25) = 2.5, p <. 05, r = 0.45). However, no significant difference in the performance decay score was seen between the two groups (t (25) = 1.3, p = .20, r = 0.25), indicating that one was not significantly poorer at remembering to execute their intentions over time. The performance decay score (block 2 minus block 1) is a measure of deterioration in performance over time. A graphical summary of performance in block 1 and block 2 is depicted in Figure 6.6.

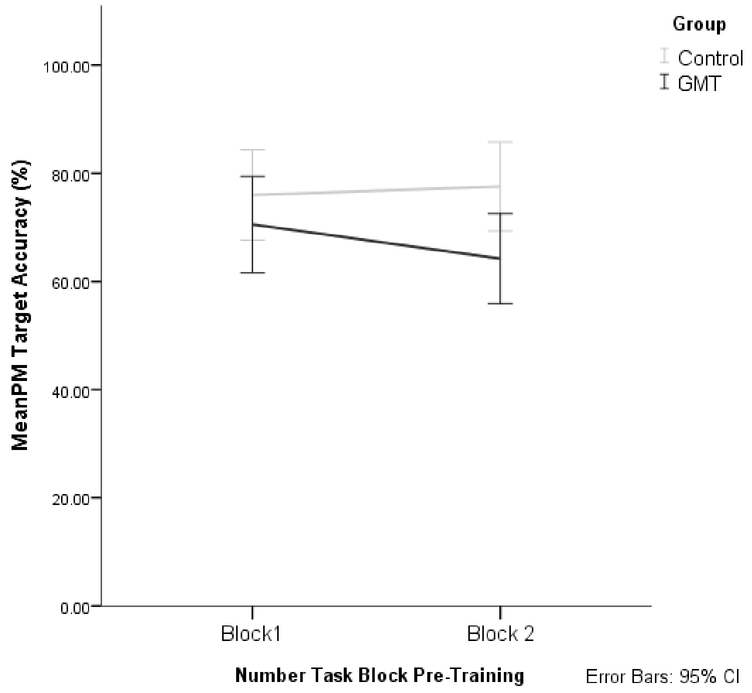

Figure 6.6: Change in the mean PM target accuracy from PM block 1 to PM block 2 pre-training. Error bars represent 95% confidence intervals.

6.3.1.2 Comparison of performance on the modified Hotel Test during training

Performance on the modified Hotel Test during training is summarised in Table 6.3.

Table 6.3: GMTii and control groups' performance on the modified Hotel Test

mHT Measure	GMTii Group (n = 13)	Control Group (n = 14)
	Mean Score ± SD	Mean Score ± SD
Number of Tasks Attempted	4.8 ± .4	4.4 ± .9
Number of Correct Bell Rings	8.8 ± 1.7	8.7 ± 1.2
Total PM Score	184.6 ± 19.4	174.3 ± 16.0
Time Deviation	280.6 ± 115.7	399.1 ± 254.2
Number of Clock Checks	4.9 ± 1.4	3.2 ± 3.2

Raw scores reported for all measures with the exception of Total PM Score for which a percentage score is reported. Time deviation reported in milliseconds (ms).

The GMTii group made significantly more frequent clock checks on the modified Hotel test compared with the control group (U = 46.5, z = -2.2, $p < .05$, r = -0.42). The two groups did not significantly differ on number of tasks attempted (U = 64.0, z = -1.6, p = .10, r = -0.31), total number of correct bell rings (U = 80.0, z = -.56, p = .58, r = -0.11), time deviation, (U = 68, z = -1.1, p = .26, r = -0.21), nor their overall total PM score (U = 56.5, z = -1.71, p = .09, r = -0.33).

6.3.1.3 Post-training

A summary of performance on the simple computerised tasks post-training is provided in Table 6.4.

Table 6.4: Performance of the GMTii and control groups on the simple computerised task post-training

Computerised Task Condition	GMTii Group(n = 13) Accuracy (SD)	GMTii Group(n = 13) Reaction Time (SD)	Control Group (n = 14) Accuracy (SD)	Control Group (n = 14) Reaction Time (SD)
Ongoing (OG)	93.2 ± 1.4	543.2 ± 78.6	94.2 ± 1.7	519.9 ± 63.7
Prospective memory (PM)	91.9 ± 2.1	697.3 ± 187.2	92.8 ± 2.2	610.3 ± 95.2
PM Targets only	77.5 ± 14.2	852.3 ± 289.4	74.9 ± 18.6	750.0 ± 96.4
OG Targets only	92.8 ± 1.9	686.5 ± 176.6	93.9 ± 1.9	602.5 ± 95.3
Block 1 PM Targets only	77.2 ± 14.7	856.6 ± 342.2	80.4 ± 19.6	752.4 ± 105.4
Block 2 PM Targets only	77.9 ± 17.0	847.9 ± 242.2	69.1 ± 18.9	747.7 ± 98.0

Accuracy scores reported as percentage (%) of total responses correct. Reaction times reported in milliseconds (ms).

Both groups had similar accuracies (t (25) = 1.64, *p* = .11, r = 0.31 and reaction times (t = -.85(25), *p* = .41, r = 0.17) in the OG condition post-training.

The GMTii group's accuracy to PM targets in the PM condition increased from 67.4% pre-training to 77.5% post-training while the control group went from 77.5% pre-training to 74.9% post-training (Figure 6.7). Both groups' accuracy to ongoing trials in the PM condition remained almost unchanged with the GMTii maintaining 92.8% from pre-training to post-training and the control group changed from 93.4% pre-training to 93.9% post-training.

The control group showed significantly greater decrease in reaction times from pre- to post-training in the PM condition overall (t (25) = -2.3, *p* < .05, r = 0.42) and to PM targets (Figure 6.8) compared to the GMTii group (U = 50.0, z = -1.99, *p* < .05, r = -0.36).

Following reciprocal transformation to normality, a repeated measures ANOVA revealed a significant group x time interaction for the PM condition overall (F (1, 25) = 6.31, *p* < .05) and to PM targets (F (1, 25) = 4.71, *p* < .05).

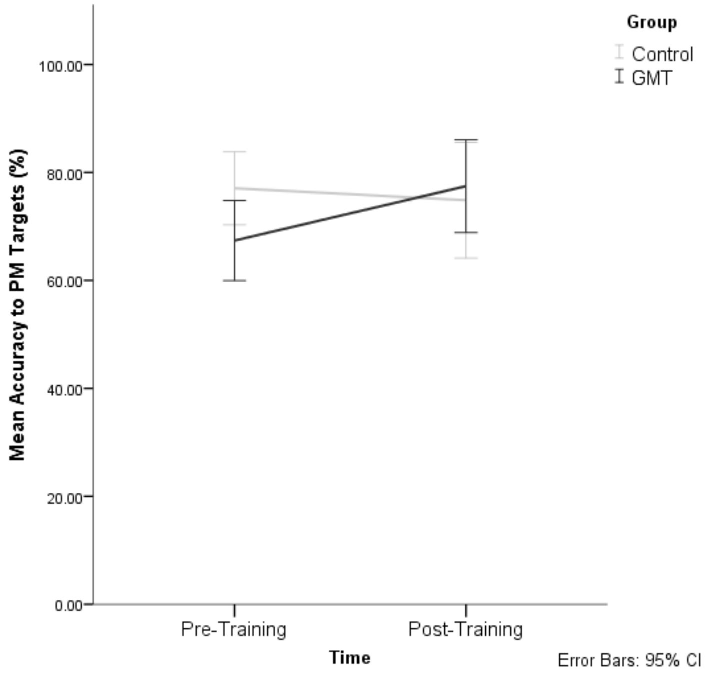

Figure 6.7: Mean PM target accuracy (%) pre- and post training for the GMTii and the Control Groups. Error bars represent 95% confidence intervals.

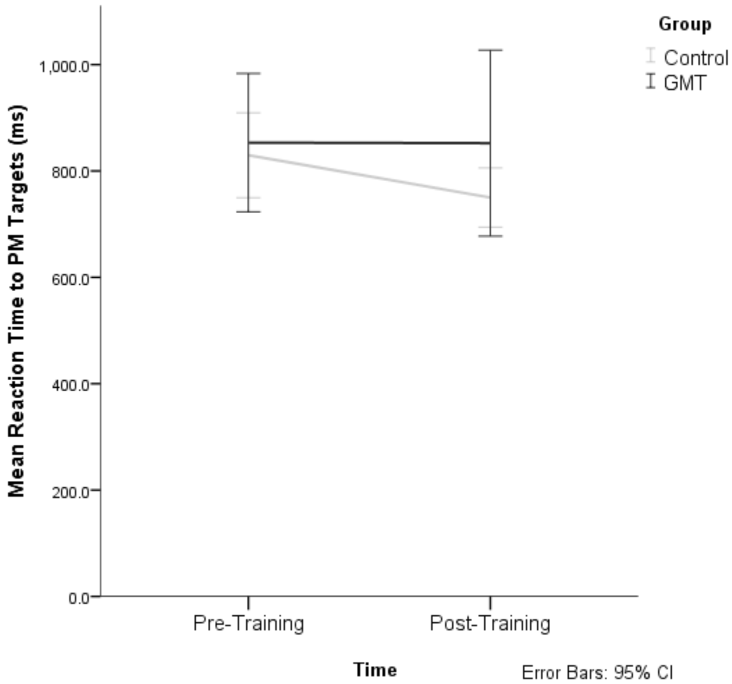

Figure 6.8: Mean reaction time (ms) to PM targets pre- and post training for the GMTii and the Control Groups. Error bars represent 95% confidence intervals.

To assess the effects of brief cognitive training whilst accounting for performance pre-training, a pre-post training ANOVA was conducted where data met assumptions of normality or where transformation of data to normality was possible. Otherwise change scores were calculated for both groups given the relatively small sample size. The change score was calculated as change in PM target accuracy post-training minus PM target accuracy pre-training. Positive scores indicate improvement in performance from pre- to post-training while negative scores indicate poorer performance post-training compared to pre-training.

The mean change score for the GMTii group was 10.1% (SD 6.9) and -2.2% (SD 12.5) for the control group. Mann-Whitney U test was used to assess whether this difference between groups was significant. The GMTii group was found to show significantly greater improvement from pre- to post-training compared to the control group (U= 38, z = -2.6, p< .05, r = 0.38).

To assess the pattern of change in a greater detail, performance in the two PM blocks post-training was analysed. A graphical summary of PM target accuracies in blocks 1 and 2 pre- and post-training is presented in Figure 6.9 and a numerical summary in Table 6.4.

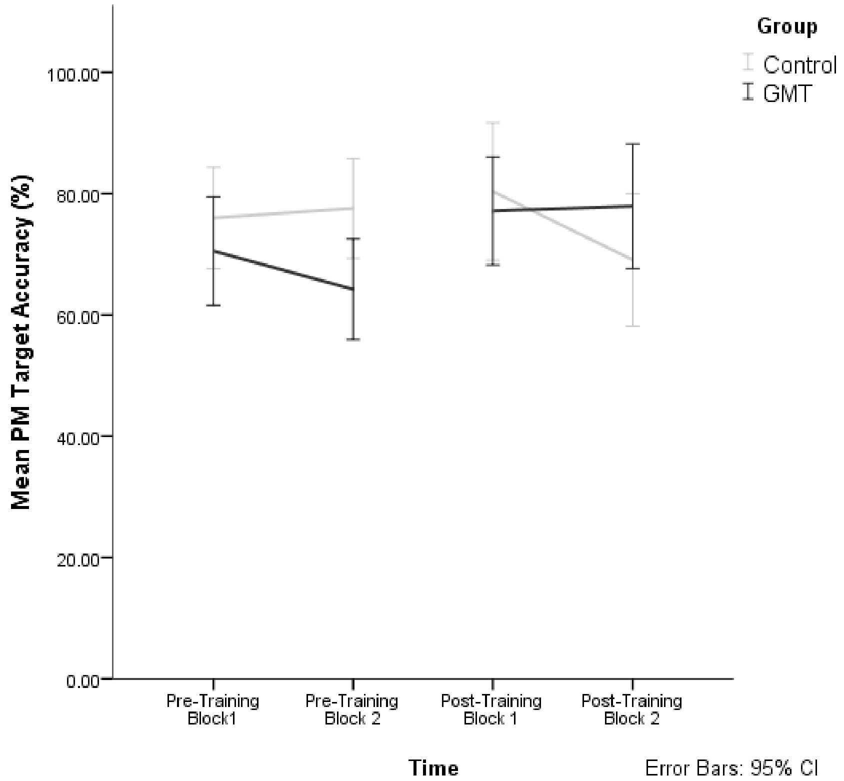

Figure 6.9: Mean PM Target Accuracy by PM block pre-training to post training for the GMTii and the Control Groups. Error bars represent 95% confidence intervals.

Compared to a pre-training performance decay score of -6.3% for the GMTii group and 1.6% for the control group (t (25) = 1.32, p = .20), the GMTii no longer showed performance decay (score of .8%) post-training compared to the control group (score of -11.3%) with the difference between groups being significant (U = 39.0, z = - 2.54, p < .05, r = -.049) (Figure 6.10).

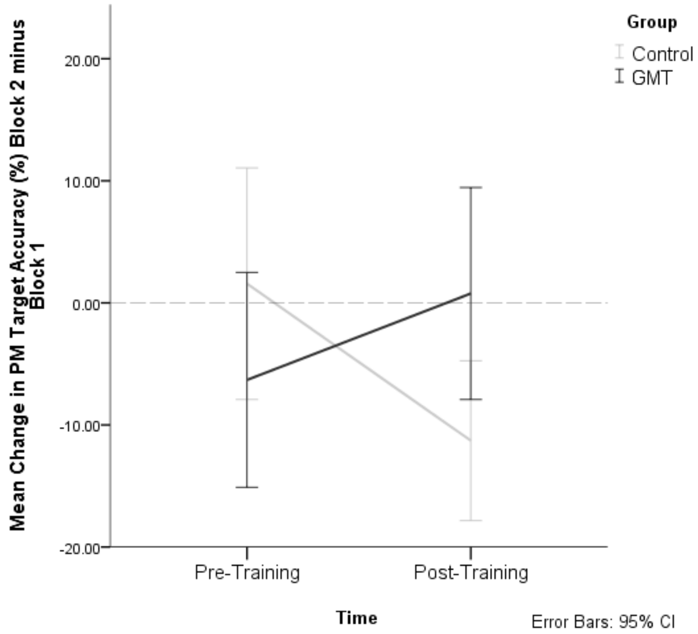

Figure 6.10: Change in PM target accuracy from block 1 to block 2 pre- and post-training shown by the GMTii and control groups. Error bars represent 95% confidence intervals.

6.3.2 Neuroimaging Data

6.3.2.1 Pre-training

The data was first collapsed across groups to investigate the general pattern of activation pre-training. The contrast between PM condition and ongoing condition revealed greater activity in both left (36, 47, 25; BA 10/46; Zmax 5.22, 187 voxels) and right Middle Frontal gyrus (-42, 38, 25; BA10/45; Zmax 5.08, 45 voxels) (Figure 6.11). Concomitant decreases were seen in medial Rostral PFC (-6, 59, 10; BA10, Zmax 5.59; 418 voxels) as shown in Figure 6.11. This pattern of changes in cerebral blood flow is in line with findings from previous studies (Burgess et al., 2003; Simons et al., 2006).

The pattern of activation within BA10 was compared between groups to ascertain that the two groups were comparable pre-training. No clusters survived FWE suggesting that the pattern of activation within BA10 did not significantly differ between groups pre-training.

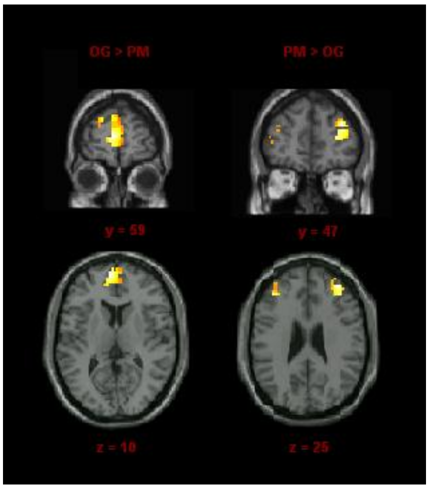

Figure 6.11: Overall patterns of decreases (left) and increases (right) in the PM condition relative to the OG conditions pre-training.

6.3.2.2 Post-training

A flexible factorial model was used to investigate the neural effects of brief cognitive training. In the time x group interaction contrast (Table 6.5) for the PM condition (prospective memory > ongoing), the GMTii group was found to show significantly greater activity in the right rostrolateral PFC (36, 47, 16; BA10) and left middle frontal gyrus (-33, 50, 28; BA10/46) compared to the control group (Figure 6.12, left panel). Increases were also seen in inferior, middle and lateral occipital cortex, superior parietal cortex and supplementary motor area.

Table 6.5: Brain areas showing significant increases for PM > OG contrast in the GMTii group post-training relative to pre-training as compared to the control group

			Coordinates				
Brain Region	**BA**	**Side**	***X***	***Y***	***Z***	***z* max**	**N voxels**
Rostrolateral Frontal Gyrus[1]	10	R	36	47	16	4.05	41
Middle Frontal Gyrus[1]	10/46	L	-33	50	28	4.10	15
Inferior Occipital	19	L	-30	-70	34	5.95	130
Cortex	48	R	27	-19	22	5.92	5
Superior parietal cortex	40	R	36	-49	55	5.85	328
Middle Frontal gyrus SMA	6	R	24	-7	52	5.84	20
Inferior occipital cortex	6	R	57	-28	40	5.75	114
Middle Occipital cortex	37	L	-51	-70	-5	5.68	14
Inferior temporal cortex	37	R	54	-58	-14	5.64	69
Lateral Occipital cortex	19	R	33	-76	25	5.40	44
	19	R	45	-76	7	5.35	26
Superior parietal cortex	2	L	-36	-46	64	5.36	8

Abbreviations; BA, Brodmann area; SMA, supplementary motor area; L, left; R, right. [1] Small Volume Correction at p<.001

The GMTii group also showed significant decreases in activation (ongoing > PM) compared to the control group in the middle rostrolateral BA10 (-21, 62, 19) on the left (Figure 6.11, right panel). Decreases were also seen in the right lateral globus pallidus and the lingual gyrus on the left.

Table 6.6: Brain Areas Showing Significant decreases for PM > OG contrast in the GMTii group post-training relative to pre-training as compared to the control group

Brain Area	BA	Side	Coordinates *X*	*Y*	*z*	*Z* Score	Cluster	*P* Values
Rostrolateral PFC	10	L	-21	62	19	4.04	28	0.023
Lateral Globus Pallidus		R	21	-7	-5	5.39	5	0.002
Brain Stem	35	L	-9	-13	-17	5.34	13	0.000
Cerebelum	27	L	-3	-43	-2	5.15	9	0.018

Abbreviations:; BA, Brodmann area; SMA, supplementary motor area; L, left; R, right ; [1] Small Volume Correction at p<.001

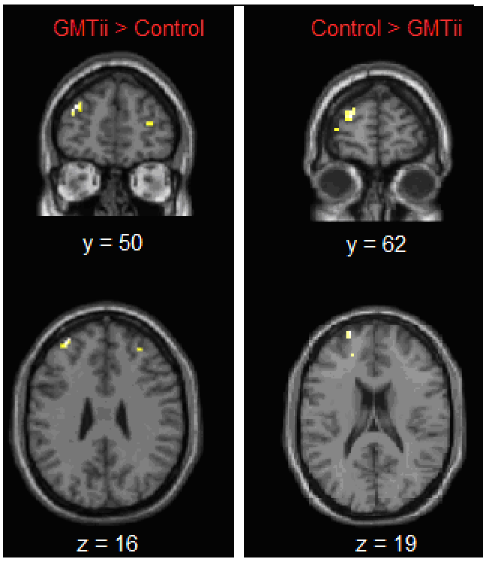

Figure 6.12: Left panel: Brain regions showing increased activation within BA10 for GMTii group over time compared with the control group. Right panel: Brain regions showing decreased activation within BA10 for the GMTii group over time and plotted on coronal and axial slices of a normalized T1-weighted scan.

The relative rCBF changes in these regions for by both groups are shown in Figure 6.13. It is clear from Figure 6.12 that the pattern of rCBF changes in the rostrolateral regions (36, 47, 16 and -33, 50, 28) shown by the GMTii group is almost the converse of those in the rostromedial region (-21, 62, 19). The rostrolateral regions shows higher blood flow in the GMTii group compared with the control group where as the rostromedial region show decreased blood flow compared to the control group.

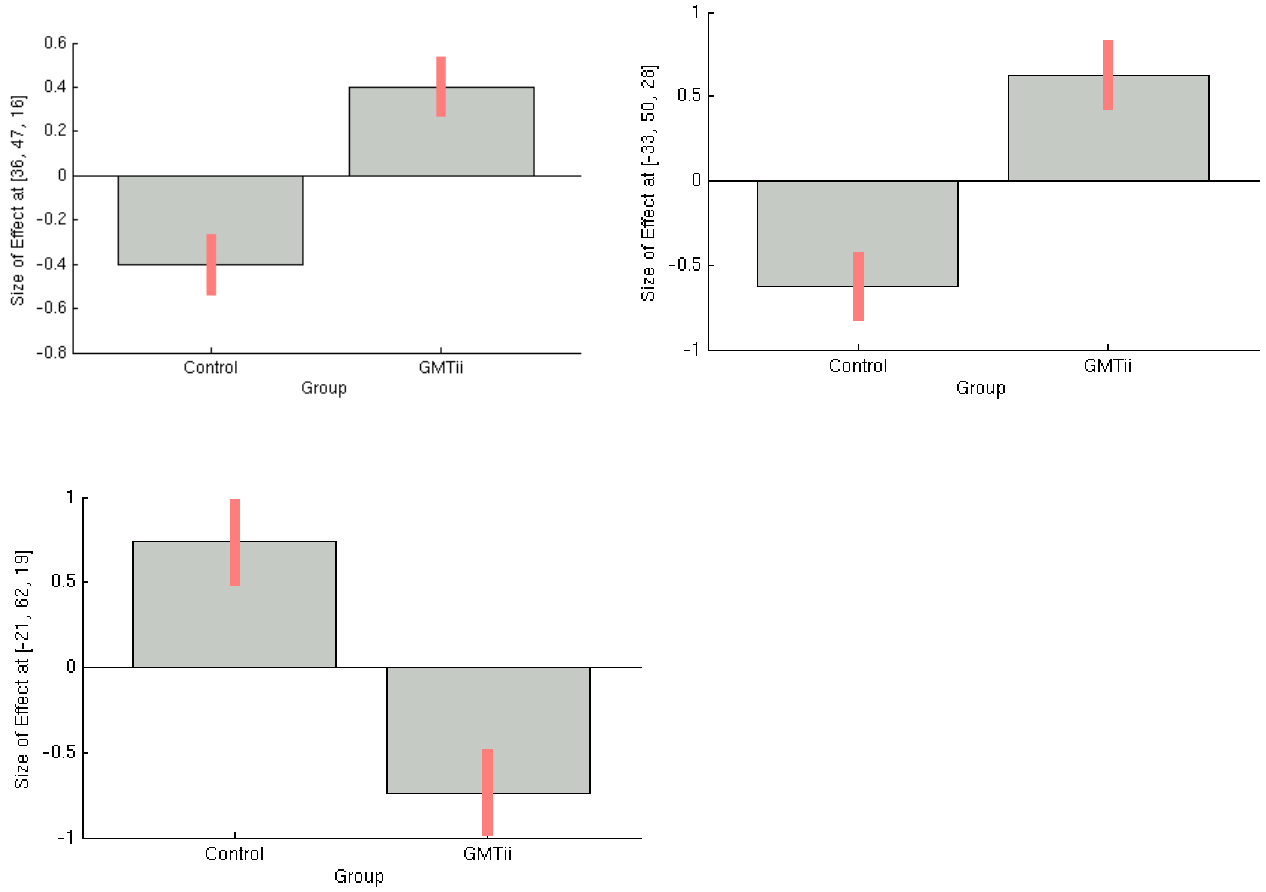

Figure 6.13: Relative blood flow changes in the right (top left), left (top right) rostrolateral and rostromedial (bottom) prefrontal cortex.

In an earlier study by Gilbert et al., (2009), the contrast between self initiated and cued PM conditions produced an activation peak in left ventrolateral PFC (BA 47), -38, 36, -10. To investigate whether the activation peaks for the interaction effect in the current study fall within a similar region, a 10mm sphere was created around the activation peak found in their study. A significant cluster with two peaks surviving FWE was found within this area (-36 29 16 and -39 32 19). However, given that the voxel size of individual peaks was only 1 voxel, the significance of this finding is questionable. Given that in the current study, the strongest effect was found in the right PFC study instead of the left PFC as in Gilbert et al.'s study, the laterality of their finding was ignored, and another 10mm sphere was created at the same coordinates on the right hemisphere (38, 36, -10). This revealed a significant cluster at 42, 41, -11 (BA47).

Block data post-training

To further investigate the pattern of change post-training, a contrast comparing the pattern of activation in the PM2 block to PM 1 block was created however, no clusters survived FEW within the BA10.

Correlation between behavioural change and neural changes

To assess whether behavioural changes were related to neural changes seen from pre-to post-training, change in PM target accuracy (post-training minus pre-training; where positive scores indicate improvement) was used as a covariate for changes in neural activation (post-training image minus pre-training image; where positive values represent greater increase in PM>OG contrast from pre- to post-training). As a group, the participants did not show a significant relationship between behavioural and neural changes within BA10 at the whole brain level. Within the GMTii group, improvement in PM target accuracy was correlated with greater activation in the left superior temporal pole (cluster size 40, coordinates -42, 26, -20, T = 7.43, p = 0.12 FWE post-training (PM>OG contrast) at whole brain level. SVC was used to create a 10mm sphere at Gilbert et al. 2009 peak co-ordinates, which revealed a significant cluster (cluster size 12, coordinates -39, 29, 17; T = 7.04, p < .05) surviving FWE correction.

6.4 Discussion

This study assessed the neural mechanisms underlying improvements in performance following brief cognitive training targeted at enhancing goal maintenance. The cognitive training was derived from the main concepts of Goal Management Training (Robertson, 1996; Levine et al., 2012) and Implementation Intentions (Gollwitzer, 1993).

Behaviourally, the GMTii group was found to show significantly greater improvement in their ability to respond to PM targets from pre- to post-training than the control group. They further showed greater reduction in performance decay post-training compared with the control group suggesting better maintenance of the PM intention over time and following a brief break filled with unrelated activity.

The two groups also showed a significantly different pattern of associated neural changes following training.

Neuroimaging Findings

Functional changes in brain activation were seen following brief Goal Management Training with Implementation Intentions within Brodmann area 10 previously shown to play a key role in successful realisation of future intentions and studies of prospection (Burgess et al., 2011). Compared with the control group, the GMTii group was found to show significantly greater increases in activation in the lateral BA10 bilaterally from pre- to post-training during the prospective memory condition. By contrast, significantly greater deceases were seen in the rostromedial BA10 from pre-to post-training during ongoing task performance.

Mechanism of Change - Medial vs. Lateral Prefrontal Regions

Previous studies of prospective memory have suggested differential functions for the lateral and medial areas of the rostrolateral PFC (area 10) in PM (Gilbert, Frith and Burgess, 2005; Gilbert, Simons, Frith and Burgress, 2006; Gilbert, Spengler, Simons, Frith and Burgess, 2006).

The gateway hypothesis of attentional control (Burgess et al., 2005, 2006b, 2007, 2008), offers a useful framework in understanding the current findings. The Gateway Theory makes a distinction between lateral and medial rostral PFC functions suggesting that rostromedial areas play a role in maintaining attention to external stimuli (stimulus-oriented processing) and rostrolateral areas in maintaining attention to internal cognitions (stimulus-independent processing) with the gateway acting as a switch between one’s external and internal goals.

Formation of future goals using Implementation Intentions is thought to allow for future intentions to be triggered relatively automatically by a relevant cue in the environment and is believed to rely on externally derived information processing. The use of implementation intentions has been previously shown to be associated with greater activations in medial PFC (BA10) compared to goals formed using goal intentions (Gilbert et al., 2009). Situations using cue identification (e.g. a post box) where detection of a cue signals the need to perform an action has also been shown to elicit medial rostral PFC activations compared with intention retrieval condition (e.g. posting a letter), which elicit greater bilateral BA10 activations (Simons et al., 2006).

The principal function of implementation intentions is to ease the access and triggering of intentions from memory by reducing the need to assess whether to act here or there, now or later (Gollwitzer, 1993) thus lowering stimulus processing demands. Prospective memory tasks with low stimulus processing demands have been shown to be associated with medial rostral PFC activations where as tasks with high stimulus processing demands have been associated with lateral rostral PFC activations (Gilbert, Simons, Frith and Burgess, 2006).

By contrast, Goal Management Training is a structured approach that relies on conscious application of internal strategies to prevent prospective memory slips. The initiation of strategy use is not necessarily triggered by cues in the external environment but rely on an individual's ability to self-initiate their use. Prospective memory tasks that place greater demand on self-initiated PM processing have been shown to activate rostrolateral PFC areas on PM paradigms (Cullen et al., 2012, Gilbert et al., 2005; 2009). It would therefore seem plausible to interpret the greater increases in lateral area 10 seen in the GMTii group following brief training as reflecting greater stimulus-independent maintenance of intentions or self-initiated processing of future intentions. One possible explanation of the finding is that it reflects greater attentional switching between internal and external cognitions (i.e. checking of internally-maintained prospective intentions and cues and performance of the ongoing task) given that participants learned to periodically 'refresh' their intentions by using stop & think and mental blackboard strategies of GMT. Use of increased attentional shifting is supported by behavioural observation during performance on the modified Hotel Test with the GMTii group making significantly greater number of clock checks compared with the control group. Increased clock checking may reflect switching between internal and external cognitions to support maintenance of intentions and suggest that participants have taken a moment to stop & think or to check their mental blackboard to review task goals although future studies will need to assess the significance of this finding. Enhanced maintenance of intentions following brief GMTii training is also supported by behavioural findings indicating greater reduction in performance decay from first to second PM block following a brief break filled with unrelated task that was not observed in the control group.

It is unlikely that the GMTii group has simply paid greater attention to PM targets, which could explain increase in activation in the lateral areas given that no cost in performance was observed to performance to ongoing trials in the PM condition. Einstein et al., (2005) found cost to performance to ongoing trials when greater emphasis was placed on the importance of the PM instruction.

Considering the role of lateral PFC areas in prospective memory, Umeda et al., (2011) found right dorsolateral prefrontal cortex (DLPFC) lesions to be the primary factor influencing PM task performance in patients with brain injury (Umeda et al., 2011) but it has also been shown to be associated with planning (Burgess et. al., 2000) and both time monitoring (Basso et al., 2003) and time based PM deficits (Volle et al., 2011) following brain injury. Studies using task switching paradigms (Sohn, Ursu, Anderson, Stenger and Carter, 2000) and ill-structured tasks (Gilbert et al., 2010; Goel and Grafman,, 2000) have also reported greater activity in right dorsolateral prefrontal cortex and it has further been proposed to have a function in selection from memory to guide a response in working memory (Rowe, Toni, Josephs, Frackowiak and Passingham, 2000).

Stuss' model of frontal lobe functioning (Stuss, 2008 and 2011) suggests that the right dorsolateral PFC plays an important role in monitoring where as the left lateral regions are involved with task setting (e.g. content of the to-be performed intentions). The Gateway theory does not make a distinction between the left and the right areas but simply argues that they are mainly concerned with internally-focussed information processing. Burgess et al., (2001) found greater right lateral frontal activation in a PM condition where no targets appeared ('expectation' condition) compared to when targets were being seen and responded to ('execution' condition) hence the right region is unlikely to involved with target recognition or execution but is likely to be involved in internally oriented intention maintenance or monitoring. Gilbert et al. (2009) on the other hand found greater activation in the left lateral area in a condition that required greater planning or self-initiation compared with a cued condition.

Improvement in PM target accuracy was found to be associated with increases in the left superior temporal pole/left inferior frontal gyrus approximating the region related to the goal intention condition in the Gilbert et al. (2009) study. According to Stuss (2011), Patient Z.P who suffered from PM and multitasking difficulties in everyday life and had a lesion covering fronto-polar regions on the right (BA10 and 9) was reported to be impaired on all aspects of cue monitoring and detection. By contrast, he was able to recall the cues and task instructions when questioned afterwards (Utretsky et al., 2010), presumably as his left PFC was still intact.

The area indentified in the current study (36, 47, 16) as eliciting greater activation in the GMTii group following training, bears striking similarity to area identified being key to

PM in a previous study (32, 52, 18) by Burgess et al., (2003) using similar computerised paradigm.

As part of GMTii training, participants were told that the use of implementation intentions is most useful prior to starting a task and when forming new intentions whereas GMT principles are most useful during task itself, which may explain greater lateral activation as opposed to greater medial activations found in this study. Greater medial BA10 activations have been reported on studies utilising strategies to reduce stimulus processing demands (O’Connor, Robertson and Levine, 2011; Okuda et al., 2011). O’Connor et al. (2011) exposed participants to brief auditory tones during performance on SART. Participants were instructed to use the tone to remind them to focus on what they were doing. The use of auditory alerts has previously been shown to be effective in improving performance on the Hotel Test (Manly et al., 2002). Performance on the SART normally elicits right DLPFC activations but this was found to be significantly reduced following the presentation of tones providing evidence for the lateral areas being involved with internally-oriented cognitive processing.

Another possibility is that the effects of implementation intentions can be seen outwith area 10. Gilbert et al., (2009) reported that activation in the premotor cortex (SMA) was associated with successful prospective memory performance in the implementation intentions condition. The GMTii group was found to show significantly greater activation in SMA following training compared with the control group, however, the effect was noted on the right SMA instead of the left region as would be expected in a right-handed sample. The SMA is thought to be involved in low-level motor planning (Parks-Stamm and Golwitzer, 2009).

Strengths, Limitations and Future Research

To our know knowledge, this is the first study to provide evidence of functional activation changes within the rostral prefrontal brain region in conjunction with behavioural improvements following brief Goal Management training with implementation intentions training in neurologically healthy young adults. A strength of this study is the inclusion of a control group, which is not always implemented as standard in functional MRI studies of cognitive rehabilitation.

Although brief GMTii was effective in improving performance and changes were seen in functional brain activation on a simple computerised PM task in neurologically healthy individuals, it remains unknown whether a similar pattern of change would also be seen in patient populations. Previous case reports described in the literature suggest that patients with right dorsolateral PFC lesions (Eslinger and Damasio, 1985; Evans et al., 1998; Goel and Grafman, 2000; Goldstein, Bernard, Fenwick, Burgess and McNeil, 1993; Shallice and Burgess, 1991; Uretzky and Gilboa, 2010) or BA10 lesions (Roca et al. 2011), in particular, have difficulty in coping with ill-structured real-world situations despite having normal IQ, supporting the current neuroimaging findings of the importance of dorsolateral PFC in situations requiring self-initiated future intentions. Future research should investigate the neural effects of Goal Management Training and Implementation Intentions in the elderly and in the patient populations.

Another limitation of this study was that it did not test the transfer of the training effects to a novel task. Transfer of training effect has been demonstrated in a previous behavioural study (Baylan and Evans 2012, Chapter 5). A further limitation of the study is that the maintenance of training effects beyond the day of training was not assessed and remains to be investigated.

Future research should try to further fractionate the neural basis of the components of cognitive training interventions and focus on understanding the transfer of training effects to novel tasks. For example, it would be useful to compare the neural effects of ‘refreshing’ intentions (conceptualised as stop & think and mental blackboard) to more encoding strengthening approach utilised in implementation intentions or auditory alerts.

Given that patients with prefrontal lesions are known to have greater difficulty in completing ill-structured tasks and the suitability of simple computerised PM tasks for assessing patient populations can be questioned (see Chapter 4 and Volle et al., 2011), future studies should focus on developing clinically useful assessment tools that are also suitable for measuring the neural changes associated with cognitive training interventions using current neuroimaging technology.

In conclusion, the findings from this study provide evidence that brief Goal Management Training with Implementation Intentions is effective in improving performance of computerised tasks of PM and results in detectable changes in underlying neural activation.

Chapter 7

General Discussion

Overview

The primary aims of this PhD thesis were to:

1. Develop paradigms suited for measuring the neural effects of brief cognitive rehabilitation interventions aimed at improving prospective remembering in a brain imaging environment

2. To assess the convergent validity of different PM paradigms both in clinical groups and in neurologically healthy individuals

3. To assess the ecological validity of different PM paradigms both in clinical groups and in neurologically healthy individuals

4. To assess the behavioural and neural effects associated with brief cognitive rehabilitation interventions aimed at improving prospective remembering using fMRI

In this final chapter, I will discuss the main findings presented in this thesis in relation to the existing literature, in terms of what they do (or still do not) add to our understanding of the assessment and rehabilitation of prospective memory both in neurologically healthy adults and in adults following acquired brain injury. The methodology and methods employed for this research will also be discussed, both in terms of their strengths and limitations, as well as the implications of the findings from this work for future research.

Summary of Main findings

The main aims of the first part of the thesis (Chapters 2-4) were to investigate the convergent and ecological validity of computerised assessment measures of PM and their sensitivity to the effects of ageing and brain injury.

Chapter 2 investigated age related changes in performance on computerised PM tasks and on a modified version of the Hotel Test (Manly et al., 2002) in a group of young and older neurologically healthy individuals. Older adults were found to show significantly poorer overall performance on both the computerised PM tasks and the mHT compared to the younger individuals. The computerised PM tasks and the mHT were found to have good convergent validity particularly in the older participant group. Performance on the computerised tasks was not found to be a good predictor of self-reported functioning in everyday life in either younger or older individuals.

It was hypothesised that the poor ecological validity may have been due to high target frequency on the computerised tasks or due to the task not capturing the demands of everyday PM situations. Qualitatively it was noted that when older participants took a brief self-paced break during computerised tasks, they verbalised and ‘reviewed’ how they had done on the tasks or what they had to remember to do next. Hence, Chapter 3 investigated whether change performance over time following completion of a brief unrelated task might be a better predictor of everyday functioning in neurologically healthy young individuals. A brief break filled with an unrelated task was found to have a negative effect on performance on the computerised tasks with the amount of performance decay from before to after the brief break correlating with self-reported memory functioning. The convergent validity of the computerised tasks was also found to be improved with the number of correct bell rings and clock checking showing a significant relationship with performance on computerised PM tasks.

Because the overall aim of this thesis was to develop paradigms suited for assessing the effects of brief PM rehabilitation interventions, the convergent and ecological validity of the computerised PM tasks was assessed in a group of patients with ABI, in Chapter 4, in order to ensure the findings would have some relevance to clinical practice. The computerised PM tasks were found to show good convergent validity with the mHT in the ABI group, though only the Number task was found to be sensitive to the effects of brain injury. In addition, the computerised tasks and, to a greater extent, the mHT, were found to show significant convergent validity of a large effect size with a commonly used clinical assessment measure the CAMPROMPT. The computerised PM tasks were found to show good ecological validity with both self and significant-other reports of everyday memory and goal management functioning in the ABI sample.

Having demonstrated that seemingly simple computerised PM tasks possess good convergent validity with a complex multi-element mHT in both neurologically healthy and impaired adults, the main aim of the second part of the thesis (Chapters 5 and 6) was to investigate the behavioural and neural changes associated with a brief PM intervention developed from the principles of Goal Management Training (Robertson 1996; Levine et al., 2000; 2012) and Implementation Intentions (Gollwitzer 1993; 1996).

Chapter 5 investigated whether a brief intervention aimed at reducing PM lapses would be successful in improving performance on computerised PM tasks compared to a control training intervention. The group that received GMT with Implementation Intentions training was found to show significant reductions in performance decay on the familiar Number PM task. The GMTii group was also found to show significantly better performance on a novel Picture PM task. The GMTii group was not found to show performance decay on the novel task whereas the control group did, suggesting that the intervention may have improved performance through better maintenance of the PM intention. The intervention was minimally revised to maximise the effects of maintenance before the neural changes associated with this brief training were investigated (Chapter 6). GMTii was found to improve both overall performance and to reduce performance decay in the trained group compared with the control group. Using fMRI, significant changes in neural activations within Brodmann’s area 10 were seen following brief training in the trained group compared to the control group.

The findings from this research have implications to the development of PM assessments and rehabilitation interventions of PM and are discussed briefly in the following sections.

Implications for Development of Assessments of PM

The findings presented in Chapters 3 and 4 suggest that performance on simple computerised tests of PM is likely to share similar underlying cognitive processes with performance on the mHT, given the good convergent validity demonstrated by these tests in both neurologically healthy adults and in patients with ABI.

Short laboratory assessments of PM and the role of attention

Computerised assessments of PM completed in the laboratory tend to be short lasting only several minutes during which many PM intentions to pre-set targets are executed. In everyday life, the frequency of intention execution varies greatly due to each individual's environmental demand but is likely to be less frequent with the delay between intentions longer and more variable. Fish et al., (2007) noted that on a real life task where participants were required to telephone and answer phone at set times, the initial PM performance (day 1) was much higher than performance on days 2-4.

The studies presented in the thesis indicate that participants may pay greater attention to the PM task initially with performance subsequently levelling off. First, considering the number of correct bell rings on the mHT, the accuracy to the first few bell rings appears to be much higher than accuracy to later bell rings particularly in the older participant group. Similarly, in Chapter 4, healthy individuals' performance is almost at ceiling on the first three stimuli on the task requiring participants to monitor for executives arriving at the Hotel before starting to fluctuate. As with older adults, patients' performance was maintained for the first two executives before starting to gradually level off. A somewhat similar effect was noted on the Number and Picture tasks for patients (Figure 4.2). Thus, ignoring a small amount of trials/data at the start of PM tasks when the level of attention devoted to the task may be considerably increased may be advisable, particularly in patient groups (neurologically healthy young individuals were found to show return to initial or close to initial levels on some tasks possibly reflecting better maintenance of the PM intention). This may also be true for clinical assessment and research utilising everyday measures of PM given the evidence from Fish et al., (2007) and Gracey et al., (2012).

Brief interruptions and maintenance of PM intentions

Performance decay (decrease in performance over time) may be another way of measuring PM performance and be more akin to everyday life where intentions often need to be performed following completion of other unrelated tasks or interruptions. For example, consider having to remember to post a letter on the way back from work in the evening. The intention is likely to be 'fresh' in memory in the morning when one has just placed the letter in the bag, but the intention to do this is likely to have weakened and moved from, in Oberauers's (2002) framework, the centre of direct access to the activated part of long term memory by late afternoon as it would have been replaced by other ongoing activities if not attended to or strengthened using associative links that will aid the triggering of the intention at the appropriate moment in time in the evening. Studies presented in Chapters 3, 5 and 6 suggest that participants do not necessarily spontaneously use breaks to review task goals or future intentions. Measures utilising brief breaks or interruptions may therefore be useful for studying the ability to maintain PM interventions or withhold distractions.

Clinical Assessment of Prospective Memory

Prospective memory has relevance to clinical practice in several disorders with PM impairments having been reported in a wide range conditions in adults from stroke and brain injury (Groot, Wilson, Evans and Watson, 2002, Brooks et al., 2004, Kliegel, Eschen, and Thöne-Otto, 2004; Shum, Valentine and Cutmore, 1999; Umeda, Kurosaki, Terasawa, Kato and Miyahara, 2011); dementia (Huppert et al., 2000; Maylor et al., 2002), Parkinson’s disease (Katai et al., 2003; Kliegel, et al., 2005) Multiple Sclerosis (Bravin et al., 2000), depression, (Rude, Hertel, Jarrold, Covich and Hedlund, 1999) to schizophrenia (Shum, Ungvari, Tang and Leung, 2004). Studies using paediatric samples have also reported impairments in PM following TBI (McCauley & Levin, 2004; Ward, Shum, McKinlay, Baker and Wallace, 2007) and autism (Altgassen et al., 2009). The results from objective measures and self and informant reports from Chapter 4 lend support to the presence of PM impairment following brain injury yet very few validated clinical measures of PM exist.

Process based vs. multi-element tasks of PM

The mHT and computerised PM tasks appear very different on the surface in that the mHT is a multi-element task requiring initiation of several unrelated PM tasks with and overall goal, whereas in the computerised PM tasks participants perform a simple ongoing task occasionally having to remember to respond to a pre-determined target. Nevertheless the convergent validity between them is striking. Given the choice, these two tasks serve different purposes. Clinically, the mHT offers qualitatively richer information about overall performance (e.g. Do they get caught up on a task?) and participants approach to the task (e.g. Do they plan?) compared to the simple computerised tasks. The mHT was further confirmed to be sensitive to brain injury and possess good convergent validity with the currently used clinical PM assessment tool CAMPROMPT. By contrast, the computerised tasks are quick to administer, do not require preparation and allow better fractionation of separate PM processes due to lacking the complex multitasking environment making them ideal studying theoretical models of PM and associated neural processes. Performance on the CAMPROMPT was also found to correlate with performance on the computerised tasks but to a lesser extent than with the mHT (Chapter 4).

Given that novelty is an important factor for tasks in the executive function domain, future research should further develop PM tasks that have high convergent validity to allow better measurement of change over time and changes associated with recovery or rehabilitation interventions but also allow them to be used as learning tools.

The results presented in Chapter 6 indicate that participants may have been able to use the GMTii principles to aid performance on the mHT given that the GMTii group made significantly more frequent clock checks than the control group and subsequently were better able to maintain PM intentions on the computerised tasks post-training. Future research could assess the usefulness of internal STOP strategy on performance on a complex multielement task. All three studies presented in the first part of this thesis suggests that clock checking may serve as a useful marker of goal maintenance given that it was found to strongly correlate with performance on the computerised task in neurologically healthy adults (Chapter 3) as well as in patients with ABI (Chapter 4).

Most participants engaged well on the mHT and reported enjoying it. Sorting playing cards was reported to be particularly enjoyable by many but was also a task participants felt they were more likely to get caught up on. Engagement may therefore facilitate PM assessment in that tasks that are better enjoyed may be better able to capture PM slips if it increases the likelihood of other intentions or of the overall goal of the task being neglected. A limitation of the mHT is that it may not be well suited for those with poor literacy skills. Future task development should aim to develop tasks that are suited also for those with poor literacy skills.

Recent years have seen an increase in the developments of complex PM multitasking tests utilising virtual reality (Jansari et al., 2004; Rand et al., 2005; Renison et al., 2012). Given the encouraging finding that process based computerised PM tasks were found to correlate with performance on the mHT, future research should continue to develop complex multi-element tasks during which separate components of multitasking can be assessed saving valuable clinical assessment time and aiding formulation. These should be built on theoretical models of PM that also have a neural basis such as the Stuss model of frontal lobe functioning (Stuss, 2011).

Ecological Validity

Ecological validity has long been a challenge in the assessment of executive functions and PM (Burgess et al., 2009) with performance tending to shown only modest if any relationship with everyday functioning. This remains a challenge in the light of present findings although the moderate ecological validity of the mHT and computerised tasks in the ABI sample is encouraging. As with task development, development of multi-domain questionnaire measures based on theoretical concepts could be explored with future research.

Implications for the development of rehabilitation interventions for PM

Findings from Chapter 5 and Chapter 6 suggests that brief Goal Management Training with Implementation Intentions can improve performance on computerised PM tasks in young healthy individuals with some evidence of transfer of the effect to a task very similar in nature. The behavioural findings presented in Chapter 6 are somewhat stronger that the findings seen in Chapter 5. The study presented in Chapter 6 placed greater emphasis on being able to identify times when it is good to apply strategies (i.e. brief breaks) without them interfering with a current task and using a multi-element test (mHT) to practice strategies compared to passive learning and completion of a worksheet as in a study presented in Chapter 5.

Completing the computerised PM tasks in the scanner environment was found to significantly reduce the accuracy to PM targets compared to when completed in an office environment. An alternative interpretation to this finding is that the interleaved task structure in Chapter 6 increases the likelihood of PM slips occurring due to the greater number of interruptions or completion of other unrelated tasks.

Although brief GMTii was found to be effective in improving performance in a group of neurologically healthy individuals, it is unlikely that brief training would be able to produce similar results in a group of adults with ABI. Any future studies should adjust the length of training to match the PM ability of patients before assessing the effects of a longer training intervention. Given that the GMTii strategies taught participants to better utilise brief breaks, this may reduce the need to learn the application of a strategy on each novel task but rather improve awareness of when to review intentions and place greater emphasis on the planning process of PM, which in turn may facilitate transfer to unfamiliar tasks.

Due to the methodological constraints of the fMRI technology, the study presented in Chapter 6 was only able to directly assess the contribution of GMTii on improving maintenance of PM intentions. Although participants were taught the implementation intentions strategy as part of the intervention, they were advised that it would be most useful before starting a task hence their use of this strategy was not directly measured and further research should aim to fractionate the different components of PM interventions further.

Theoretical Implications

The Stuss model of frontal lobe functioning (Stuss, 2011) and the Gateway theory (Burgess et al., 2007, 2008) offer a useful framework in understanding the behavioural and neural changes associated with brief GMTii reported in Chapter 6. Stuss' model is based on evidence from behavioural, lesion and imaging studies making it a good candidate for combining behaviour and neural underpinnings of PM. According to Stuss, the left dorsolateral PFC is involved with task setting and the right dorsolateral PFC with monitoring with area 10 involved with metacognition or coordination of executive capacities. Following brief training, compared with the control group, greater activation in the GMTii group was found in the lateral area 10 bilaterally that was coupled with decreases in the medial BA10. Stuss' explanation of the right lateral areas (BA 9/46) of the PFC adjacent to BA10 being responsible for monitoring, makes the current finding of increased maintenance of PM seem plausible but does not offer a direct guidance on the role of lateral areas of BA10.

The Gateway theory, created as an extension to the Norman and Shallice (1986) model, suggests a division of processes within area 10 with the lateral areas of area 10 being involved in self-initiated (endogenous) processing of information, and medial areas with stimulus-oriented (exogenous) processing of information. The finding from Chapter 6 may therefore suggest that the application of GMTii principles increases self-initiated or internal reviewing (stimulus independent) of future goals. The right lateral PFC has been suggested to play a role in time monitoring and time based PM (Volle et al., 2011), which has also been suggested to require greater stimulus independent processing and self-initiation of behaviour in the absence of direct environmental cues. Right dorsolateral BA10 lesions are also known to be present in several case reports in impaired PM functioning following brain injury (Eslinger and Damasio, 1985; Evans et al., 1998; Goel and Grafman, 2000; Goldstein, Bernard, Fenwick, Burgess and McNeil, 1993; Shallice and Burgess, 1991; Uretzky and Gilboa, 2010). It has also been suggested that right BA10 lesions have been associated with clock checking behaviour on the Hotel Test (Manes, personal communication). Future research should further investigate the role of the right and left BA10 in self-initiated maintenance and reviewing of future intentions.

Strength and Limitations

To my knowledge, the study presented in Chapter 6 is the first study to demonstrate functional activation changes associated with brief GMTii training in neurologically healthy individuals.

Another strength of the work presented in this thesis is that it has shown the mHT and computerised PM tasks to be valid measures of PM in neurologically healthy young and older adults and patients with brain injury and also to be related to an existing clinical assessment measure, the CAMPROMPT.

A limitation of the study presented in Chapter 6 is that it did not assess whether the neural activation changes would also transfer to a novel task similar in nature to the trained task.

Future Directions

Future research should investigate the generalisation of the GMTii principles and its relevance to psychological and neurological disorders beyond TBI. The long-term neural changes associated with GMTii whilst correlating them with changes in everyday functioning should also be investigated. Furthermore, future research should try to better understand the contribution of the left and right lateral PFC areas to prospective remembering.

Both longitudinal and cross-sectional fMRI studies have shown that the brain is able to reorganize to compensate for motor deficits following injury to the brain. (Calautti and Baron, 2003). Much less is known about the neural mechanism underlying improvement resulting from cognitive rehabilitation particularly in the executive function domain (Kim al., 2009). Future research should also investigate the neural effects of GMTii in patients with ABI or those with frontal and non-frontal lesions addressing methodological issues associated with measuring change in the injured brain allowing and ensuring adequate of number measurable PM events. A recent study by Miotto et al. (2013) suggests that the mechanisms underlying behavioural improvements following the application of semantic chunking strategy may be different following brain injury.

Robertson (2005) raised an important but often overlooked issue in understanding how cognitive rehabilitation works. Much of the research into recovery of function following brain damage operates on a neurophysiological level yet rehabilitation in clinical practice operates at a behavioural level, assuming that behavioural rehabilitation will have an effect on recovery on a neurophysiological level. He argued that what is lacking is a theoretical framework that can accommodate both behaviour and physiology, which will allow testing and improvement of the currently used behavioural rehabilitation interventions.

Current limitations and benefits of neuroimaging in cognitive rehabilitation

Although widely used in research, imaging procedures are, at present, of limited value in rehabilitation. There is no doubt that they can (a) identify specific lesions and areas of impaired functioning; (b) determine the severity of brain damage; (c) monitor change in brain functioning over time; (d) help with making medical decisions; and (e) predict which people are likely to remain with persistent problems after brain injury (Wilson, 2009). With continuously improving technology, brain imaging has the potential to advance the understanding of the functional changes underlying behavioural change with cognitive rehabilitation interventions and the neural mechanisms underlying recovery of function. Brain imaging can further aid the development of theoretically derived rehabilitation interventions aimed at compensating or ameliorating cognitive deficits.

Conclusions

In conclusion, the findings suggests that process based paradigms of PM can be sensitive to the effects of ageing and brain injury and possess good convergent validity with complex multi-element tests of PM. This work has also shown brief GMTii to be effective in reducing PM lapses on computerised PM tasks and to produce changes in functional activations in the brain. Further studies are needed to confirm the mechanism of the GMTii and the role of the dorsolateral PFC in stimulus-independent processing.

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Appendix A

GMQ-Self

Appendix not visible due to intellectual property rights.

Appendix B

Summary of younger and older adults Performance on the Letter, Number and Picture Task

Accuracies- Descriptive Statistics

Group		Mean	Std. Deviation	Group	Mean	Std. Deviation
Young	**Letter Task**			**Old**	**Letter Task**	
	LetterOGACC	95.3	2.5		97.5	1.9
	LetterPMACC	92.9	3.7		93.7	6.2
	LetterPMPMACC	89.4	7.2		88.3	20.4
	LetterPMOGACC	93.7	3.6		95.0	5.5
	Number Task				**Number Task**	
	NumberOGACC	93.7	10.6		98.2	1.4
	NumberPMACC	91.3	10.0		96.6	2.8
	NumberPMPMACC	79.6	14.4		89.9	12.5
	NumberPMOGACC	94.3	11.6		98.2	1.6
	Picture Task				**Picture Task**	
	PictureOGACC	94.4	3.0		96.7	3.1
	PicturePMACC	89.5	8.1		91.3	7.7
	PicturePMPMACC	73.4	17.4		74.0	22.7
	PicturePMOGACC	127.1	150.7		95.6	5.0

Reaction Times - Descriptive Statistics

Group		Mean	Std. Deviation	Group	Mean	Std. Deviation
Young	**Letter Task**			Old	**Letter Task**	
	LetterOG	765.8	123.6		929.7	251.0
	LetterPM	904.8	148.4		1218.3	227.7
	LetterPMPM	813.3	136.4		1059.7	333.9
	LetterPMOG	927.7	158.1		1242.8	235.0
	Number Task				**Number Task**	
	NumberOG	532.9	73.1		670.8	129.0
	NumberPM	740.4	114.8		1012.8	198.4
	NumberPMPM	768.0	119.2		994.2	226.5
	NumberPMOG	733.4	117.1		1017.4	194.8
	Picture Task				**Picture Task**	
	PictureOG	562.4	56.0		729.4	120.9
	PicturePM	873.2	147.5		1276.7	332.0
	PicturePMPM	859.9	156.6		1370.1	359.4
	PicturePMOG	838.3	233.2		1253.3	332.7

Appendix C

Letter of Invitation

Dear

We are writing to see whether you would be interested in contributing to a research project that is being carried out by the Section of Psychological Medicine, University of Glasgow.

The project looks at the effect of brain injury on memory. In particular we are studying difficulties with remembering to do things in the future (e.g. remembering to go to an appointment or to call a friend at a certain time or take medication on time and so on). People often say that they have more problems with these types of tasks following certain types of neurological illness or brain injury. We are looking for people with acquired brain injury (e.g. head injury or stroke) as well as people with no previous history of head injury or other neurological condition.

In summary, you would be initially asked to come to meet with us on two occasions during which we would ask you to carry out short 'paper and pencil' tasks, tasks using everyday materials, questionnaires and tasks on computer. This does not require previous knowledge of using computers. If you an individual with an acquired brain injury and are found to have significant difficulties in remembering to do things in your everyday life, you will be asked to take part in a single training session. If you continue to use the strategies that you have learned during this, it is possible that this may improve your memory for doing things in the future. Participant information sheets for both of these studies have been included with this letter.

We would very much appreciate your involvement in this research but understand that you may not wish to be involved or may have other commitments at this time.

If you are interested in taking part, please return the attached form in the free post envelope or call 0141 232 7566 or 074 2470 7546 to set up an appointment with Fiona, Satu or Andrew.

Even if you agree to take part you are completely free to withdraw from the project at any time without needing to give us a reason.

Yours sincerely,

Fiona Scott	**Satu Baylan**	**Andrew Wood**
Trainee Clinical Psychologist	PhD student	Trainee Clinical Psychologist

Jonathan Evans
Professor of Applied Neuropsychology

I..1.1 If you are interested in taking part in the study please fill out the tear-off slip below and return it in the freepost envelope provided.

I..1.2 A member of the research team will then contact you to give you more information / arrange your first meeting at a time that is suitable for you.

Alternatively, you may e-mail us:

Fiona Scott: f.scott.1@research.gla.ac.uk

Satu Baylan: s.baylan@clinmed.gla.ac.uk

Andrew Wood: a.wood.1@research.gla.ac.uk

Study on the Assessment of Prospective Memory and Planning

Name ……………………………………………………………………

Telephone Number ……………………………………………………...

Address …………………………………………………………………..

Please tick:

☐ **I would like to participate in this study/ would like more information on this study.**

Please return this reply slip in the freepost envelope provided or return to a member of your clinical team or group leader.

Appendix D

PARTICIPANT INFORMATION SHEET

Assessment of Everyday Executive Functioning in

Individuals with Acquired Brain Injury

Purpose of the study

Planning ahead and remembering to do things in the future (e.g. planning what to buy before going to the supermarket and remembering to post a letter on the way home) is difficult and most people make mistakes from time-to-time. This type of memory is called prospective memory. People often say that they have more problems with these types of tasks following certain types of neurological illness or brain injury. When clinicians assess for these problems, it is important that the tests they use are accurate (i.e. that they can measure this difficulty) and sensitive to these types of difficulties experienced in real life.

This research study will be investigating the usefulness of different tests of planning and prospective remembering of future actions, and will involve "pencil and paper", real life and computer tasks.

What does taking part involve?

If you decide to take part you will initially be asked to come along to meet with us on two occasions, for up to a maximum of two hours each. Those found to have difficulties with remembering to do things will be invited to take part in a third treatment session lasting a maximum of 2.5 hours. In these sessions, you will do the following:

Session One
You will be asked to complete some short tasks lasting a few minutes each. For example you will be asked to read out loud a list of words. This will be recorded for scoring purposes using an audio recorder. No other tasks will be recorded. The information from these will help us find out more about the current difficulties you experience in everyday life. You will then complete a task on the table top using everyday objects and two short tasks on a computer which involve making simple responses to images you see by pressing one of the response buttons. In addition, you will also be asked to complete short questionnaires concerning your day to day life.

<u>Session Two</u>

You will be asked to carry out two tasks involving some puzzle activities and "pencil and paper" tasks. Lastly, you will complete a task on a computer that involves you taking on the role of an office employee. This task simulates you doing a set of office activities such as setting up a meeting.

<u>Session Three</u>

If you are someone who has difficulty with remembering to do things in the future, you will be invited to take part in a training session. This aims to improve this type of memory and will involve practising different strategies and techniques such as imagery and repetition. You will also be asked to do two computer tests similar to the ones you did before. We have included a participant information sheet explaining this part of the study in more detail. If you decide to take part, you will be asked to give your consent again at the beginning of this session.

Does the research involve any medical examination or medication?

No.

Do I have to take part?

No. You are free to decide whether or not you wish to take part. This project is separate from any clinical services you may be receiving. Your decision has no effect on your access to, or care received from, these services. If you do decide to take part, you will be given this form to keep and be asked to sign a consent form. You are free to withdraw from the study at any time without giving a reason.

What happens to the information?

All information collected during this study will be kept in strict confidence. The data are held in accordance with the Data Protection Act, which means that we keep it safely and cannot reveal it to others without your permission. If we publish any findings from the study, this will be in the form where your results are combined with those of many other people and average scores are presented. We take great care not to publish any details from which you could be identified.

Will taking part have any advantages for me?

Our research is entirely experimental. Our aim is to improve understanding about the assessment of planning and prospective remembering and to try to ensure that tests are accurately measuring the specific real life problems often reported after a neurological illness or injury. If the tests completed as part of this study are similar to tests you may do as part of any NHS clinical care you may be receiving, with your permission, we can provide your clinical team with information on your test scores, which may be of help to them in planning your ongoing treatment. This will also avoid you doing unnecessary testing. If you take part in the training session, and continue to use the strategies that you have learned, it is possible that this may improve your memory for doing things in the future (e.g. remembering to attend appointments).

Are there any disadvantages or risks of taking part?

There are no significant risks or disadvantages for taking part. You may feel a little tired but there will be regular breaks during the study to minimise this.

Will you contact my GP?

With your permission, we will send your GP a short letter to let them know that you are taking part in the study. If you would like to see an example of the letter, please just ask a member of the study team. If you have a clinical team you are already involved with, we will, with your permission, let them know the results of your tests.

Who is funding the research?

This research is being funded by the Sackler Institute of Psychobiological Research and the University of Glasgow Doctorate in Clinical Psychology programme.

Who is conducting the research?

The study is being carried out by Fiona Scott (Trainee Clinical Psychologist), Satu Baylan (PhD Student) and Andrew Wood (Trainee Clinical Psychologist) from the Section of Psychological Medicine at the University of Glasgow. This research is supervised by Prof. Jonathan Evans (Professor of Applied Neuropsychology).

Who has reviewed the study?

This study has been reviewed by the West of Scotland Research Ethics Service REC.

If I have any further questions?

If you would like more information or would like to receive a summary of the main findings once the study has completed, please contact:

Fiona Scott or Andrew Wood
(Trainee Clinical Psychologists)
Section of Psychological Medicine,
Gartnavel Royal Hospital, 1055
Great Western Road, Glasgow, G21
OXH. Tel. 074 2470 7546
f.scott.1@research.gla.ac.uk
a.wood.1@research.gla.ac.uk

Satu Baylan,
(PhD Student)
Sackler Institute of
Psychobiological Research,
Southern General Hospital,
Glasgow, G51 4TF.
Tel. 0141 232 7566
s.baylan@clinmed.gla.ac.uk

If you would like to contact someone, who is not directly involved in the study, for general advise about taking part in research, please contact Dr Denyse Kersel, Clinical Director, Community Treatment Centre for Brain Injury on 0141 300 6313 or denyse.kersel@ggc.scot.nhs.uk.

Thank you for taking the time to read this information.

IS THE RESEARCH SAFE?

There are no significant risks or disadvantages to taking part. You may feel a little tired but you can take breaks during the experiment.

WHAT IF I CHANGE MY MIND?

Participation is entirely voluntary. You are free to withdraw at any time should you later decide that you do not wish to take part.

CAN ANYONE TAKE PART?

Due to the nature of the tasks you will be asked to complete, it would not be appropriate for you to take part if you have any of the following: a severe aphasia, severe visual or hearing impairment or learning disability, neurogenerative disorder (e.g. multiple sclerosis, dementia) or current or history of significant substance use problem.

WHERE THE RESEARCH IS BEING CONDUCTED?

It is possible to take part in one of our testing locations in Glasgow or in the Douglas Grant Rehabilitation Centre, at Ayrshire Central Hospital. Please contact the research team for information on current other testing locations.

HOW CAN I HELP?

To take part in our research, or simply to find out more please contact:

Fiona Scott, Satu Baylan or Andrew Wood

Telephone:
0141 232 7566 or
074 2470 7546
email:
f.scott.1@research.gla.ac.uk
s.baylan@clinmed.gla.ac.uk
a.wood.1@research.gla.ac.uk

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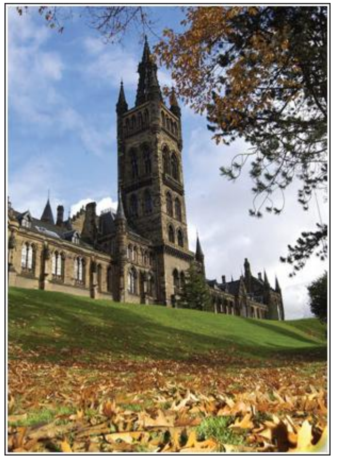
NHS Greater Glasgow and Clyde

University of Glasgow | Section of Psychological Medicine

Can you help with research into brain injury?



CAN YOU HELP?

After certain types of neurological illness or brain injury people often say that they have more problems with memory and particularly with remembering to do things at some point in the future (e.g. remembering to go to an appointment). This type of memory is called prospective memory. When clinicians assess for these problems, it is important that the tests they use are accurate (i.e. that they can measure this difficulty) and are reflect the kinds of difficulties experienced in real life.

We are looking for people who speak English as their first language and are between the ages of 18-65 with- or without acquired brain injury (e.g. stroke, head injury, encephalitis, brain tumour), who are interesting in taking part in a research study.

WHAT IS THE NATURE OF THE RESEARCH?

The aim of the research study is to investigate the usefulness of different tests of planning and prospective remembering of future intentions. We would ask you to come in on two occasions. You will be asked to complete short questionnaires concerning your day to day life. During your first visit we will ask you to complete some short tasks lasting few minutes each, such as reading out loud a list of words. The information from these will help us find out more about the current difficulties you experience in everyday life. You will then complete a task on the table top using everyday objects and two short tasks on a computer which involve making simple responses to images you see by pressing one of the response buttons.

During your second visit we will ask you to carry out two tasks involving some puzzle activities and “pencil and paper” tasks. Lastly, you will complete a task on a computer that involves you taking on the role of an office employee. This task simulates you doing a set of office activities such as setting up a meeting.

The study takes approximately 4 hours to complete in total. Testing takes place over two sessions broken into shorter blocks with rest breaks. If you take part as a healthy control with no history of brain injury, the study takes 1-1.5 hours to complete.

If you are someone who has difficulty with prospective remembering you may be invited to another session (approx. 2hrs) in which we are studying whether certain strategies can help people remember to do things. You are free to decide whether or not you wish to participate in this.

Appendix F

University of Glasgow

NHS Greater Glasgow and Clyde

Participant Reminder Letter

Dear

You recently received information on a research project being conducted by the Section of Psychological Medicine, University of Glasgow. This is a quick reminder to see if you are interested in participating in this study. If you would like to participate, or would like more information on the study you can return the tear-off slip below or discuss this with a member of the clinical team at your next appointment. Alternatively, you can contact a member of the research team on 0141 232 7566 or 075 3646 6149, or e-mail (see below). Remember, this study is voluntary; you are not obliged to take part and if you feel you would rather not, this will not affect your clinical treatment in any way. Even if you agree to take part, you are completely free to withdraw from the project at any time without needing to give us a reason.

Yours Sincerely,

Fiona Scott
Trainee Clinical Psychologist
f.scott.1@research.gla.ac.uk

Satu Baylan
PhD student
s.baylan@clinmed.gla.ac.uk

Andrew Wood
Trainee Clinical Psychologist
a.wood.1@research.gla.ac.uk

Study on the Assessment of Prospective Memory and Planning
Name ……………………………………………………………………
Telephone Number …………………………………………………
Address ………………………………………………………………

Please tick:

☐ **I would like to participate in this study/ would like more information on this study.**

Please return this reply slip in the freepost envelope provided.

Appendix G

University of Glasgow

NHS Greater Glasgow and Clyde

Letter of Invitation for Individuals with no history of brain injury

Dear

We are writing to see whether you would be interested in contributing to a research project that is being carried out by the Section of Psychological Medicine, University of Glasgow.

The project looks at the effect of brain injury on memory. In particular we are studying difficulties with remembering to do things in the future (e.g. remembering to go to an appointment or to call a friend at a certain time or take medication on time and so on). People often say that they have more problems with these types of tasks following certain types of neurological illness or brain injury. We are looking for people with acquired brain injury (e.g. head injury or stroke) as well as people with no previous history of head injury or other neurological condition.

If you have no previous history of head injury or other neurological condition, we would ask you to come to meet with us on one occasion during which we would ask you to carry out a task using everyday materials, and two tasks on a computer. This does not require previous knowledge of using computers. We would also ask you to complete a few short questionnaires about your everyday life. In total, this is expected to take 1-1.5 hours.

We would very much appreciate your involvement in this research but understand that you may not wish to be involved or may have other commitments at this time.

If you are interested in taking part, please return the attached form in the free post envelope or call 0141 232 7566 or 074 2414 2681 to set up an appointment with Fiona, Satu or Andrew.

Even if you agree to take part you are completely free to withdraw from the project at any time without needing to give us a reason.

Yours sincerely,

Fiona Scott
Trainee Clinical Psychologist

Satu Baylan
PhD student

Andrew Wood
Trainee Clinical Psychologist

Jonathan Evans
Professor of Applied Neuropsychology

I..1.3 If you are interested in taking part in the study please fill out the tear-off slip below and return it in the freepost envelope provided.

I..1.4 A member of the research team will then contact you to give you more information / arrange your first meeting at a time that is suitable for you.

Alternatively, you may e-mail us:

Fiona Scott: f.scott.1@research.gla.ac.uk

Satu Baylan: s.baylan@clinmed.gla.ac.uk

Andrew Wood: a.wood.1@research.gla.ac.uk

Study on the Assessment of Prospective Memory and Planning

Name ……………………………………………………………………

Telephone Number ……………………………………………………...

Address ………………………………………………………………….

Please tick:

☐ **I would like to participate in this study/ would like more information on this study.**

Please return this reply slip in the freepost envelope provided.

Appendix H

University of Glasgow

NHS Greater Glasgow and Clyde

CONTROL PARTICIPANT INFORMATION SHEET

Assessment of Everyday Executive Functioning in

Individuals with Acquired Brain Injury

Purpose of the study

Remembering to do things in the future (e.g. remembering to post a letter on the way home) is difficult and most people make mistakes from time-to-time. This type of memory is called prospective memory. People often say that they have more problems with these types of tasks following certain types of neurological illness or brain injury. When clinicians assess for these problems, it is important that the tests they use are accurate (i.e. that they can measure this difficulty) and sensitive to these types of difficulties experienced in real life.

This research study will be investigating the usefulness of different tests of prospective remembering of future actions, and will involve “pencil and paper”, real life and computer tasks.

What does taking part involve?

If you decide to take part you will be asked to come along to meet with us on one occasion, which will last between 1 and 1.5 hours.

First, you will be asked to read out loud a list of words, which will be recorded for scoring purposes. You will then complete a task on the table top using everyday objects and two short tasks on a computer which involve making simple responses to images you see by pressing one of the response buttons. In addition, you will also be asked to complete short questionnaires concerning your day to day life.

Does the research involve any medical examination or medication?

No.

Why have I been chosen?

This study tries to develop a better understanding of how people with and without brain injury perform on tests that require prospective remembering. You have been chosen because you have no history of brain injury or other neurological condition. This allows us to assess whether there is a difference on performance between those with and without brain injury.

Do I have to take part?

No. You are free to decide whether or not you wish to take part. Even if your friend of relative is taking part in the study as someone who has experienced a brain injury and you have agreed to complete questionnaires for them, you do not have to participate in the full study yourself. Your decision has no effect on your relative's access to, or care received from clinical services they may be receiving. If you do decide to take part, you will be given this form to keep and be asked to sign a consent form. You are still free to withdraw from the study at any stage without having to give a reason.

What happens to the information?

All information collected during this study will be kept in strict confidence. The data are held in accordance with the Data Protection Act which means that we keep it safely and cannot reveal it to other people without your permission. If we publish any findings from the study, this will be in the form where your results are combined with those of many other people and average scores are presented. We take very special care not to publish any details that could lead to an individual being identified.

Will taking part have any advantages for me?

Our research is entirely experimental and there is no direct benefit to you as you are taking part as a healthy control participant. Our aim is to improve understanding about the best way to assess prospective remembering and to try to ensure that tests are accurately measuring the specific real life problems often reported after a neurological illness or injury.

Are there any disadvantages or risks of taking part?

There are no significant risks or disadvantages for taking part. You may feel a little tired but there will be regular breaks during the study to minimise this.

Will you contact my GP?

No.

Who is funding the research?

This research is being funded by the Sackler Institute of Psychobiological Research and the University of Glasgow Doctorate in Clinical Psychology programme.

Who is conducting the research?

The research is being carried out by Fiona Scott (Trainee Clinical Psychologist), Satu Baylan (PhD Student) and Andrew Wood (Trainee Clinical Psychologist) from the Section of Psychological Medicine at the University of Glasgow. This research is supervised by Prof. Jonathan Evans (Professor of Applied Neuropsychology).

Who has reviewed the study?

This study has been reviewed by the West of Scotland Research Ethics Service REC.

If I have any further questions?

If you would like more information or would like to receive a summary of the main findings once the study has completed, please contact:

Fiona Scott or Andrew Wood
(Trainee Clinical Psychologists)
Section of Psychological Medicine
Gartnavel Royal Hospital, 1055
Great Western Road, Glasgow
G21 0XH Tel. 075 3646 6149
f.scott.1@research.gla.ac.uk
a.wood.1@research.gla.ac.uk

Satu Baylan
(PhD Student)
Sackler Institute of
Psychobiological Research
Southern General Hospital
Glasgow, G51 4TF
Tel. 0141 232 7566
s.baylan@clinmed.gla.ac.uk

If you would like to contact someone, who is not directly involved in the study, for general advise about taking part in research, please contact Dr Denyse Kersel, Clinical Director, Community Treatment Centre for Brain Injury on 0141 300 6313 or denyse.kersel@ggc.scot.nhs.uk.

Thank you for taking the time to read this information.

Appendix I

Participant Screening Form

Place of recruitment **Date ___________**

Headway group at ________________________________	
Momentum	
BIRT	
Community Treatment Centre for Brain Injury	
Community Stroke Services	
Douglas Grant Rehabilitation Centre	
CHSS Group at _________________________________	
West Dumbartonshire ABI team	
Other:	

Personal details

Name:			D.O.B:		Age:	
Address: Postcode:						
E-mail:				Gender	M	F
Telephone number:			Years in full-time education:			
Native English Speaker	yes	no	Dominant hand	L	R	

For experimental group

Significant other: _______________________ relationship___________________ Post questionnaires Y / N Address:____________________________________ ____	None
GP surgery ____ Who do you normally see?	

Page 1 is to be stored separate from page 2 with participant ID and medical history.

History	YES	NO
Neurological conditions (e.g. Head injury or stroke, Encephalitis, Brain tumour, Aneurysm, Epilepsy, Parkinson's Disease Dementia, Alzheimer's)		
Psychological and psychiatric condition (e.g. Depression, Anxiety disorder or Schizophrenia that has required treatment by a professional)		
Substance abuse How many units of alcohol on average do you take per week? (One standard (175ml) glass of wine = 2 units One pint of standard lager = 2.3 units Spirit & Mixer = 1 unit)	No of Units:	
Current medications whether prescribed or non- prescribed		

Can you: hear (normal speech) Y / N	Read (study information sheet, self) Y / N	Write Y / N

Participant type: patient ☐ control ☐

PATIENT GROUP ONLY	ABI	TBI
Nature of injury (Type, lesion location, where)		Open Closed
Time since injury		
1st memory after injury, how long after?(PTA) = **The time between loss of consciousness and return of continuous memory for day to day events**	____ hrs ____ days ____ months	
Do you remember being taken to hospital		
being in casualty		
being in intensive care unit		
being on the ward NSU/DHG/rehab		
being taken to other hospital		
going home from hospital		
special event (birthday/Xmas)		
GCS 0-15 (in coma, loss of consciousness, 30mins +, able to speak, move, open eyes)		

Additional notes:

Appendix J

Participant ID_________________

Date:_________________

COMPUTER FAMILIARITY QUESTIONNAIRE

This short questionnaire looks at how familiar you are with using computer technology in your day to day life. Please answer the following questions using the scale below:

1 = Strongly disagree

2 = Disagree

3 = Neither agree nor disagree

4 = Agree

5 = Strongly agree

Please circle one number for each question	Strongly Disagree		Neither Agree or Disagree		Strongly Agree
1. In general, I feel confident in my abilities to use a computer	1	2	3	4	5
2. I feel I have a good knowledge of computer technology	1	2	3	4	5
3. I use computers at least once a week for work or leisure activities.	1	2	3	4	5
4. I feel my abilities to use a computer are similar to other people my age	1	2	3	4	5

Thank you for taking the time to complete this questionnaire.

Appendix K

2A GMT WORKSHEET
RESEARCHER COPY

The purpose of the next exercise is to introduce strategies that you can use to improve how you use your memory. These can help you plan, organise and do everyday activities that need to be carried out sometime in the future.

Just before we start, I would like you to rate, by ticking one of the boxes, how good you would say that you are in remembering to do things that you intend to do? (E.g. keep appointments, remembering to take something with you) **(1min)**

Excellent ☐ Good ☐ Average ☐ Poor ☐ Bad ☐

In the first exercise, I would like you to think of times when you have forgotten to do something. Try and think why this may have been? What is it that makes you vulnerable to slips? I will give you a few minutes to have a think.

Exercise 1. I would like you to think of times when you may have forgotten to do the following and **try and think why** this might have been. What was the situation? What made you vulnerable to forgetting? (aims to get participants to think of slips) **(2 mins)**

1. Forgetting to buy something that you intended from a supermarket or going to another room to get something but forgetting to get what you intended to get?

   ____

   ____

2. Forgetting an appointment (e.g. doctor, dentist, meeting with tutor etc.) or forgetting to meet a friend (at the right time or right place)?

   ____

   ____

What sort of things did you write down? Prompt with further questions if necessary to get the similar to below (planning, autopilot, mental blackboard). Summarise.

I'm more likely to forget to do something when I:

- don't have time to stop & think (in a hurry)
- are working on 'autopilot' (not planning or thinking what you should be doing)

  OR
- Get distracted or caught up in another task – (Wiped out from your mental blackboard/too many things at once)
- Working on an autopilot (not keeping a check on how you are doing).

Exercise 2. Improving your chances of remembering to do something

4 simple strategies & when to use them:

1. **STOP & THINK** (grabs your attention)

Most things we have to do in our everyday life are routine or boring activities, ones that we may have done hundreds of times. Let's think you want to post a letter. We don't have to keep thinking "I need to post the letter" constantly in order to successfully post it, but we will need to think about it at some point. For the most part, we just do what we intended, and it works well. However, we are more likely to make mistakes if we slip into this kind of "automatic pilot" mode, There is a good chance you will forget to do something that you intended when you slip into this mode - for example, leave the house without the letter. One problem with the 'autopilot' is that it is not very flexible – if something goes wrong or if a situation is changed – the most automatic behaviour might be the wrong thing to do. This can easily happen if you get distracted from your original goal and don't take a moment to think what you should be doing. For example, you could think you have posted the letter, but then find it in your bag when you get home.

Other people are very good at stopping our automatic pilot when they say something to us. Ideally, we don't want to rely on other people being there to stop the automatic pilot or to wait for chance events to interrupt us – we want to take charge ourselves So, the best way to do this yourself is to say 'STOP!' – then check what you are doing, whether you are doing it right, and what other things you have to do.

What can you do to stop this from happening?

- When you realise there is something you have to remember to do later (i.e. when you create an intention to do something) you are more likely to remember to carry it out if you think through very clearly what you actually have to do and are not distracted by other things while making your plan.
- when you take a break from what you're doing, take a moment to remind yourself of what you still have to do

2. WHEN X HAPPENS DO Y

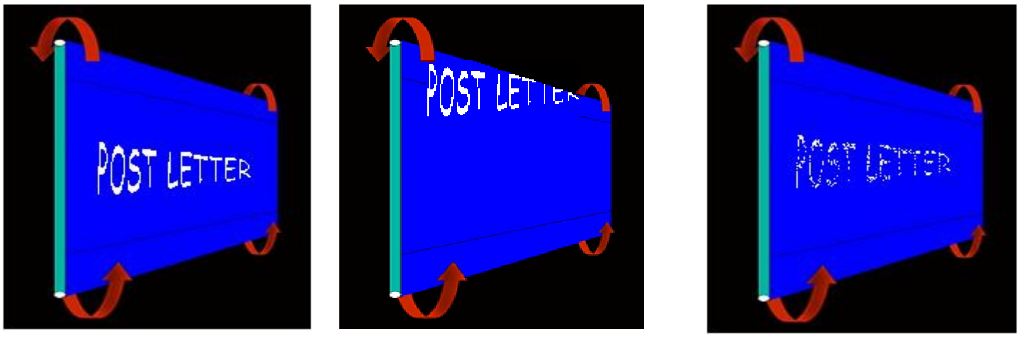
When you want to remember things that don't need to be done at a pre-set time, like going to the doctors' at 5pm but rather in response to an event that can take place at any time, such as a phone call, you can make your intention more specific. In doing so, the event (phone call) will work as a 'cue' that can help you to remember to do something. For example; You need to ask John about the price of X". John is likely to phone you later today. Think: "*When* John phones, I must ask him about the price." John might phone at any time, but when he does (the *event*); this will cue you to remembering this goal.

- you're much more likely to remember to do something if you specify exactly when you have to do it. So, rather than thinking 'must post this letter' you might say 'when I walk past the postbox at the end of my road on the way to the library tomorrow morning, I will need to post the letter'.

3. USE YOUR MENTAL BLACKBOARD

The way in which our brain stores our plans and intentions is a sort of “mental blackboard”, (refer to picture) like the old fashioned kind which rolls around to provide more space to write on. When we have something to remember to do, it gets stored for a short amount of time on this blackboard. Sometimes the information on one side gets pushed aside/rolled over, and although we can’t see it anymore, the information is often still there, we just need to roll the board over in order to find it. Also, there is only a limited amount of space on the blackboard - if too much information is stored there it becomes full, and some of it can get rubbed out; For example, when you get distracted by other things. If the board is left unchecked for a long time, it can fade. What can you do to prevent this from happening? You could keep checking the blackboard, but this may only work for a short amount of time. You could make the information more memorable by associating it with something that is important to you, or creating a mental picture of it. All of these things can help move the information into longer-term memory.

- things to do can be written on the ‘mental blackboard’
- check your mental blackboard regularly - what do I still have on my to do list? Works well any time after you’ve created an intention
- But remember, there’s limited amount of space on it!



4. CHECK HOW YOU ARE DOING

Now that you are aware that things on your mental blackboard can get rubbed off or fade, you can minimise this by getting into the habit of periodically stopping what you are doing. If you said “STOP” to yourself every now and then, and checked the blackboard – you are much more likely to remember what you should do.

- regularly check the mental blackboard! During activities or perhaps in natural breaks in tasks you can check the mental blackboard. What am I supposed to be doing? Have I gone off track or am I still doing what I was supposed to do? Have I remembered to do everything I needed to do?

Next, I would like you to work through a few examples so that you get a chance to practice these strategies. You will find this most useful if you can relate it to your everyday life at home, work or at the university - whether it is getting bigger tasks done like getting all information you need for a project or small everyday things such as remembering to take something with you when you leave the house.

I would also like to give you an additional task to do. When you come across a word that describes an item of luggage, I would like you to circle it. Try and use the techniques you’ve used to help you remember to do this.

Example 1. You have just started a job in a large zoo. It is 9am on your first day and the head keeper is explaining your duties to you. One of your daily tasks will be to feed the animals. You will have to do this as quickly as you can, but you can't start the feeding round until 2pm. You have responsibility for feeding the lions, giraffes, chimpanzees, camels, gazelles, emus, wolves and the meerkats. You have a truck in which you transport the various different meals for each of the animals. The head keeper explains that each type of animal has a different food, and each of the meals is in a different labelled container in the truck. However, the head keeper also explains that all of the animals with hooves need to have a bale of hay as well. The hay is kept in storage sheds behind each of the enclosures.

STOP & THINK Q. - What do I need to remember to do?

A. – Get a bale of hay in addition to food each time I get to an animal with hooves.

Q. - Which animals have hooves?

A. - _______________, _______________ & ________________

WHEN X HAPPENS DO Y

Think: When I go past the _________/ _________ / ________, I will need to give a bale of hay as well.

MENTAL BLACKBOARD IMAGINE! Picture yourself doing this OR imagine your mental blackboard reads “GET HAY”.

Before and during your delivery round you can also check the __________________________ to remind yourself what you still have to remember to do.

Example 2. Imagine you meet your friend <u>in the morning</u> and she gives you a piece of paper with a phone number written on it for you to give to your other friend. You will be meeting your other friend <u>later on that evening</u>. You have a busy day ahead of you at work/university.

WHEN X HAPPENS DO Y

"STOP!"

Think: When I ________________________________, I will need to ____.

MENTAL BLACKBOARD Imagine writing a reminder down on your mental blackboard!

CHECKING You can also remind yourself about the paper throughout the day.

<u>You are now at work/university</u> and going from a meeting/lecture to another. Other people have asked you to do/say something at different meetings/lectures. You still have to remember to give the piece of paper to your friend when you see him in the evening.

What can you do throughout the day?

"STOP!" and CHECK YOUR "MENTAL BLACKBOARD".

Just before you go to each meeting/lecture Stop and Think:

Q. Was there anything I had to remember to do here? What do I <u>still</u> need to remember to do later on today?

A. I still haven't given that piece of paper to John. When I _________ John, I will need to give him the envelope.

Remember the zoo example? See how checking throughout the day would help? Remember the feeding round couldn't start until 2pm and your day started at 9am!

Example 3. Imagine that you are cooking dinner and you've got a pot of rice cooking on the hob and a cake baking in the oven. The phone rings. You rush to answer it. Your housemate is on her way home but running really late. She is due to leave for a holiday and has to get to the airport, but was delayed getting some last minute holiday essentials. She has to catch a train to go to the airport has asked you to check the train times. She also asks if you can put her clothes in her suitcase as she hadn't had time to pack. She will be back home in 15 minutes. What strategies would you use to manage all the things you have to do (and not burn the cake)?

___________________________ and ___________________________________

OR just before you leave the kitchen to answer the phone, say to yourself:

_______ I finish the phone call, I ____.

Then, _____________ & __________________ once you're off the phone.

Did you remember to circle the item describing a piece of luggage?

Appendix L

2A LTP WORKSHEET

The purpose of the next exercise is to get you to think outside the box. This can be useful when you have to demonstrate creativity, imagination to solve problems by looking at them from unexpected perspectives and ability to think fast on your feet; for example when applying for jobs in creative industries such as advertising, marketing and the media**.**

Rate, by ticking a box, how good you would say that you are in thinking outside the box?

Excellent ☐ Good ☐ Average ☐ Poor ☐ Bad ☐

Try and work your way through as many puzzles as you can. You may complete the puzzles in any order you like.

If you get stuck, ask the experimenter for a cue.

Puzzle 1. A man lives on the twelfth floor of an apartment building. Every morning he takes the elevator down to the lobby and leaves the building. In the evening, he gets into the elevator, and, if there is someone else in the elevator -- or if it was raining that day -- he goes back to his floor directly. Otherwise, he goes to the tenth floor and walks up two flights of stairs to his apartment

____

Puzzle 2. A man marries twenty women in his village but isn't charged with polygamy.

____

Puzzle 3. Bruce wins the race, but he gets no trophy.

____

Puzzle 4.
There are a scarf, a carrot and a pile of pebbles together in the middle of a field.

____

Puzzle 5.
A man and his son are driving to watch the football. They have a car accident. The father is killed instantly. His son survives but is in critical condition. He is rushed to the hospital and prepped for surgery. The surgeon enters the operating room, looks at the boy and says, “I can’t operate on this boy. He’s my son.”

____

Puzzle 6. Two men, one big and burly and the other short and thin, enter a bar. They both order identical drinks. The big one gulps his down and leaves; the other sips his slowly, then dies.

____

Puzzle 7. Can you name three consecutive days without using the words Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, or Sunday? (or day names in any other language)

Puzzle 8. A man called to a waiter in a restaurant, "There's a fly in my tea!"
The waiter replied, "I will bring you a fresh cup." After a few moments, the man called out, "This is the same cup of tea!" How did he know?

Puzzle 9.
An Arab sheikh tells his two sons that are to race their camels to a distant city to see who will inherit his fortune. The one whose camel arrives last will win. The brothers, after wandering aimlessly for days, ask a wise man for advice. After hearing the advice they jump on the camels and race as fast as they can to their destination.

Puzzle 10. A man carrying an attaché case full of $20 bills falls on the way to the bank and is never seen again

Puzzle 11.
A farmer has to get a corn, a chicken, and a fox across a river. The farmer is only able to bring one of the above items along with him at a time. The only problem is if he leaves the fox alone with the chicken, the fox will eat the chicken, and if he leaves the chicken along the corn sack, then the chicken will eat the corn sack. How does the farmer get all 3 items across safely?

Puzzle 12. A man pushes a car up to a hotel and realizes he's bankrupt.

Puzzle 13. What can you put in a wooden box that would make it lighter?
The more of them you put in the lighter it becomes, yet the box stays empty.

Appendix M

2B GMT WORKSHEET
RESEARCHER COPY

The purpose of the next exercise is to introduce strategies that you can use to improve how you use your memory. These can help you plan, organise and do everyday activities that need to be carried out sometime in the future.

In the first exercise, I would like you to think of times when you have forgotten to do something. Try and think why this may have been? What is it that makes you vulnerable to slips? I will give you a few minutes to have a think.

Exercise 1. I would like you to think of times when you may have forgotten to do the following and **try and think why** this might have been. What was the situation? What made you vulnerable to forgetting? (aims to get participants to think of slips) **(2 mins)**

3. Forgetting to buy something that you intended from a supermarket or going to another room to get something but forgetting to get what you intended to get?

   ____
   ____

4. Forgetting an appointment (e.g. doctor, dentist, meeting with tutor etc.) or forgetting to meet a friend (at the right time or right place)?

   ____
   ____

What sort of things did you write down? Prompt with further questions if necessary to get the similar to below (planning, autopilot, mental blackboard). Summarise.

I'm more likely to forget to do something when I:

- don't have time to stop & think (in a hurry)
- are working on 'autopilot' (not planning or thinking what you should be doing)

  OR
- Get distracted or caught up in another task – (Wiped out from your mental blackboard/too many things at once)
- Working on an autopilot (not keeping a check on how you are doing).

Exercise 2. Improving your chances of remembering to do something

4 simple strategies & when to use them:

2. STOP & THINK (grabs your attention)

Most things we have to do in our everyday life are routine or boring activities, ones that we may have done hundreds of times. Most of the time, we just do what we intended, and it works well, sort of like automatic pilot" mode. For example, we don't have to keep thinking "I need to post the letter" constantly in order to successfully post it, but we will need to think about it at some point because we are more likely to make mistakes if we slip into this kind of "automatic pilot" mode - for example, leave the house without the letter. One problem with the 'autopilot' is that it is not very flexible – when something is new or if a situation is changed (e.g. ***your lecture has been rescheduled***) – you're more likely to forget it if you don't stop and think. This can also easily happen if you get distracted and don't take a moment to think what you should be doing (e.g. ***answering exam questions example*** **or** ***browsing the internet***).

Other people are very good at stopping our automatic pilot when they say something to us (e.g. internet browsing, 10mins left in exams). Ideally, we don't want to rely on other people being there to stop the automatic pilot or to wait for chance events to interrupt us – we want to take charge ourselves So, the best way to do this yourself is to say 'STOP!' – then check what you should be doing, whether you are doing it right, and what other things you still have to do.

What can you do to stop this from happening?

- When there is something you have to remember to do later (e.g. send an email) you are more likely to remember to carry it out if you take a moment to stop & think through what you actually have to do and are not distracted by other things while making your plan.
- when you take a break from what you're doing, take a moment to stop & think and to remind yourself of what you still have to do.

2. WHEN X HAPPENS DO Y

When you want to remember things that don't need to be done at a pre-set time, like going to the doctors' at 5pm but rather in response to an event that can take place at any time, such as a phone call, you can make your intention more specific. In doing so, the event (phone call) will work as a 'cue' that can help you to remember to do something. For example; You need to ask John about the price of X". John is likely to phone you later today. Think: "*When* John phones, I must ask him about the price." John might phone at any time, but when he does (the *event*); this will cue you to remembering this goal.

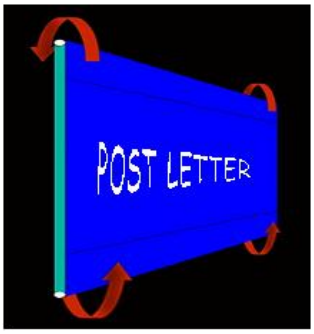
- you're much more likely to remember to do something if you specify exactly what you have to do and when you have to do it. So, rather than thinking 'I must post this letter' think 'when I walk past the postbox on the way to university tomorrow morning, I will need to post the letter'.

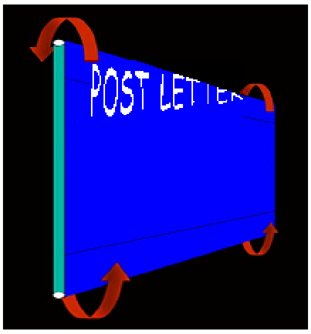
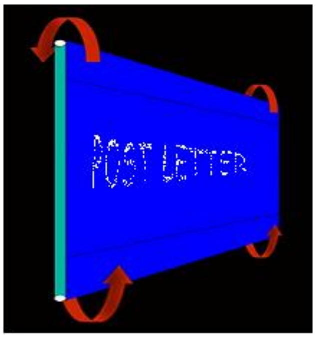
Because you have created a link between the cue (post box) and action (post letter), this should be more likely **to pop into your mind** when you pass the post box.

3. USE YOUR MENTAL BLACKBOARD

The way in which our brain stores our plans and intentions is a sort of “mental blackboard”, (refer to picture) like the old fashioned kind which rolls around to provide more space to write on. (***Anyone write things on their hand example? -> = ‘diary in head’***) When we have something to remember to do, it gets stored for a short amount of time on this blackboard. Sometimes the information on one side gets pushed aside/rolled over, and although we can’t see it anymore, the information is often still there, we just need to roll the board over in order to find it. Also, there is only a limited amount of space on the blackboard - if too much information is stored there it becomes full, and some of it can get rubbed out; For example, when you get distracted by other things. If you leave the board unchecked for a long time, information can fade. What can you do to prevent this from happening? You could keep checking the blackboard, but this may only work for a short amount of time. You could make the information more memorable by associating it with something else (***strategy 2***), creating a mental picture of it or simply stop for a moment to check what’s on it (***strategy 1***). All of these things can help move the information into longer-term memory.

- things to do can be written on the ‘mental blackboard’
- check your mental blackboard regularly – particularly during natural breaks in tasks; what do I still have on my to do list? Have I got off track or am I still doing what I supposed to do?
- But remember, there’s limited amount of space on it! - And checking it unnecessarily can interfere with other things you are doing!



Next, I would like you to work through a few examples so that you get a chance to practice these strategies. You will find this most useful if you can relate it to your everyday life at home, work or at the university - whether it is getting bigger tasks done like getting all information you need for a project or small everyday things such as remembering to take something with you when you leave the house.

I would also like to give you an additional task to do. When you come across a word that describes an item of luggage, I would like you to circle it. Try and use the techniques you’ve used to help you remember to do this.

Remember, you are best to concentrate on the task on hand when there is nothing extra to remember to do and that breaks between tasks are a good way to remind yourself of the things you still have to remember to do.

Example 1. You have just started a job in a large zoo. It is 9am on your first day and the head keeper is explaining your duties to you. One of your daily tasks will be to feed the animals. You will have to do this as quickly as you can, but you can't start the feeding round until 2pm. You have responsibility for feeding the lions, giraffes, chimpanzees, camels, gazelles, emus, wolves and the meerkats. You have a truck in which you transport the various different meals for each of the animals. The head keeper explains that each type of animal has a different food, and each of the meals is in a different labelled container in the truck. However, the head keeper also explains that all of the animals with hooves need to have a bale of hay as well. The hay is kept in storage sheds behind each of the enclosures.

Work though example 1 with the participant

STOP & THINK Q. - What do I need to remember to do?

A. – Get a bale of hay in addition to food each time I get to an animal with hooves.

Q. - Which animals have hooves?

A. - ______________, ______________ & _______________

WHEN X HAPPENS DO Y

Think: When I go past the _________/ _________ /

________, I will need to give a bale of hay as well.

MENTAL IMAGINE! Picture yourself doing this OR

BLACKBOARD imagine your mental blackboard reads “GET HAY”.

AFTER EACH (view this as a break) animal on your delivery round, ___________ & ______________ to remind yourself what you still have to remember to do.

Example 2. Imagine you meet your friend <u>in the morning</u> and she gives you a piece of paper with a phone number written on it for you to give to your other friend. You will be meeting your other friend <u>later on that evening</u>. You have a busy day ahead of you at work/university.

WHEN X HAPPENS DO Y

"STOP!" Think: When I ________________________________, I will need to ____.

MENTAL BLACKBOARD Imagine writing a reminder down on your mental blackboard!

CHECKING Stop & Think for a moment to remind yourself about the paper throughout the day.

<u>You are now at work/university</u> and going from a meeting/lecture to another. Other people have asked you to do/say something at different meetings/lectures. You still have to remember to give the piece of paper to your friend when you see him in the evening.

What can you do throughout the day?

"STOP!" and CHECK YOUR "MENTAL BLACKBOARD".

Just before you go to each meeting/lecture Stop and Think:

Q. Was there anything I had to remember to do here? What do I <u>still</u> need to remember to do later on today?

A. I still haven't given that piece of paper to John. When I _________ John, I will need to give him the envelope.

Remember the zoo example? See how checking throughout the day would help? Remember the feeding round couldn't start until 2pm and your day started at 9am!

Example 3. Imagine that you are cooking dinner and you've got a pot of rice cooking on the hob and a cake baking in the oven. The phone rings. You rush to answer it. Your housemate is on her way home but running really late. She is due to leave for a holiday and has to get to the airport, but was delayed getting some last minute holiday essentials. She has to catch a train to go to the airport has asked you to check the train times. She also asks if you can put her clothes in her suitcase as she hadn't had time to pack. She will be back home in 15 minutes. What strategies would you use to manage all the things you have to do (and not burn the cake)?

___________________________ & ___________________________________

OR just before you leave the kitchen to answer the phone, say to yourself:

_______ I finish the phone call, I _______________________________________.

Then, _____________ & __________________ once you're off the phone to remind yourself of what you had to do.

Did you remember to circle the item describing a piece of luggage? (easily forgotten when doing other things → relate back to strategies)

Appendix N

2B LTP WORKSHEET

The purpose of the next exercise is to get you to think outside the box. This can be useful when you have to demonstrate creativity, imagination to solve problems by looking at them from unexpected perspectives and ability to think fast on your feet; for example when applying for jobs in creative industries such as advertising, marketing and the media**.**

Try and work your way through as many puzzles as you can. You may complete the puzzles in any order you like.

If you get stuck, ask the experimenter for a cue.

Puzzle 1. A man lives on the twelfth floor of an apartment building. Every morning he takes the elevator down to the lobby and leaves the building. In the evening, he gets into the elevator, and, if there is someone else in the elevator -- or if it was raining that day -- he goes back to his floor directly. Otherwise, he goes to the tenth floor and walks up two flights of stairs to his apartment

____

Puzzle 2. A man marries twenty women in his village but isn't charged with polygamy.

____

Puzzle 3. Bruce wins the race, but he gets no trophy.

____

Puzzle 4.
There are a scarf, a carrot and a pile of pebbles together in the middle of a field.

____

Puzzle 5.
A man and his son are driving to watch the football. They have a car accident. The father is killed instantly. His son survives but is in critical condition. He is rushed to the hospital and prepped for surgery. The surgeon enters the operating room, looks at the boy and says, “I can’t operate on this boy. He’s my son.”

____

Puzzle 6. Two men, one big and burly and the other short and thin, enter a bar. They both order identical drinks. The big one gulps his down and leaves; the other sips his slowly, then dies.

____

Puzzle 7. Can you name three consecutive days without using the words Monday, Tuesday, Wednesday, Thursday, Friday, Saturday, or Sunday? (or day names in any other language)

____

Puzzle 8. A man called to a waiter in a restaurant, "There's a fly in my tea!"
The waiter replied, "I will bring you a fresh cup." After a few moments, the man called out, "This is the same cup of tea!" How did he know?

____

Puzzle 9.
An Arab sheikh tells his two sons that are to race their camels to a distant city to see who will inherit his fortune. The one whose camel arrives last will win. The brothers, after wandering aimlessly for days, ask a wise man for advice. After hearing the advice they jump on the camels and race as fast as they can to their destination.

____

Puzzle 10. A man carrying an attaché case full of $20 bills falls on the way to the bank and is never seen again

____

Puzzle 11.
A farmer has to get a corn, a chicken, and a fox across a river. The farmer is only able to bring one of the above items along with him at a time. The only problem is if he leaves the fox alone with the chicken, the fox will eat the chicken, and if he leaves the chicken along the corn sack, then the chicken will eat the corn sack. How does the farmer get all 3 items across safely?

____

Puzzle 12. A man pushes a car up to a hotel and realizes he's bankrupt.

____

Puzzle 13. What can you put in a wooden box that would make it lighter?
The more of them you put in the lighter it becomes, yet the box stays empty.

____