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Prospective Memory Functioning After Stroke: A Research Portfolio

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The University of Edinburgh

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TABLE OF CONTENTS

ACKNOWLEDGEMENTS	v
OVERVIEW	vi
ABSTRACT (EMPIRICAL STUDY)	vii
PART I: SYSTEMATIC REVIEW	1-44
CHAPTER 1: SYSTEMATIC REVIEW JOURNAL ARTICLE	2
ABSTRACT	3
INTRODUCTION	4
METHODOLOGY	11
RESULTS	17
DISCUSSION	38
REFERENCES	43
PART II: EMPIRICAL STUDY	51-158
CHAPTER 2: JOURNAL ARTICLE	52
ABSTRACT	53
INTRODUCTION	54
METHODOLOGY	62
RESULTS	68
DISCUSSION	78
REFERENCES	84
CHAPTER 3: EXTENDED METHODOLOGY	95
3.1 DESIGN	95
3.1.1 Ethics	95
3.1.2 Ethical considerations	96

3.2 PARTICIPANTS	97
3.2.1 Stroke patient participants	97
3.2.2 Relative or carer participants	98
3.2.3 Healthy adult participants	98
3.2.4 Determining sample size and power	99
3.3 MEASURES	101
3.3.1 Demographic information	101
3.3.2 Validated questionnaires	101
3.3.3 Standardised neuropsychological tests	103
3.4 PROCEDURE	113
3.4.1 Stroke patient participants	113
3.4.2 Relative or carer participants	114
3.4.3 Healthy adult participants	115
3.4.4 Administration of the measures	116
REFERENCES	117
CHAPTER 4: EXTENDED RESULTS	123
4.1 ANALYTIC STRATEGY	123
4.1.1 Neuropsychological test scores	123
4.2 DISTRIBUTION	124
4.3 DEMOGRAPHIC STATISTICAL ANALYSIS	126
4.3.1 Total sample	126
4.3.2 Stroke patient participants	126
4.3.3 Healthy adult control participants	127
4.4 INFERENTIAL STATISTICAL ANALYSIS	131
4.4.1 Hypothesis 1	131
4.4.2 Hypothesis 2	136
4.4.3 Hypothesis 3	140
4.4.4 Hypothesis 4	148
REFERENCES	155

CHAPTER 5: EXTENDED DISCUSSION	157
5.1 MAIN FINDINGS	157
5.1.1 Hypothesis 1	157
5.1.2 Hypothesis 2	158
5.1.3 Hypothesis 3	161
5.1.4 Hypothesis 4	162
5.2 STRENGTHS AND LIMITATIONS OF STUDY	163
5.3 CLINICAL IMPLICATIONS	165
5.4 DIRECTIONS FOR FUTURE RESEARCH	167
5.5 CONCLUSION	169
REFERENCES	170

APPENDICES

1. Journal of Clinical and Experimental Neuropsychology author guidelines	175
2. Ethical approval: South East Scotland Research Ethics Committee 3	178
3. Management approval: NHS Highland	181
4. Relative and carer participant information sheet	183
5. Relative and carer participant consent form	187
6. Patient participant information sheet	189
7. Patient participant consent form	193
8. Poster	195
9. Healthy adult participant information sheet	196
10. Healthy adult participant consent form	200

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In dedication to my husband, family and friends for their unwavering support and interest in my accomplishments.

OVERVIEW

The following research portfolio is comprised of a systematic review entitled 'Prospective memory functioning after acquired brain injury: A systematic review' (Part I: Chapter 1). Following this review of the wider literature, a major empirical research project was carried out to explore prospective memory functioning after stroke (Part II). This project is reported in the form of a journal article entitled 'Prospective memory functioning after stroke: Objective and subjective assessment' (Chapter 2). Chapter three provides a detailed description of the methods used to conduct the empirical research project. This is followed by an extended report of the results (Chapter 4), and an extended discussion of the main findings (Chapter 5). In the final chapter, consideration is also given to the strengths and limitations of the study, the clinical implications of the findings, and directions for future research.

ABSTRACT: EMPIRICAL STUDY

Background: Prospective memory is the ability to remember to carry out previously planned actions at an appropriate point in the future. Impairments in prospective memory have been found in a range of neurological conditions. While it is assumed that stroke patients will have similar deficits, there is currently a dearth of evidence to support this.

Methods: A between-subjects design was employed to compare 22 community-dwelling stroke patients to 22 healthy adult controls on a standardised objective measure of prospective memory. Subjective reports of everyday memory were measured using a validated questionnaire. Standardised tests were also administered to measure retrospective memory and executive functioning.

Results: Stroke patient's prospective memory performance was significantly poorer than controls. Depression had a significant influence on time-based prospective memory tasks. Executive functioning was shown to be a good predictor of overall prospective memory ability. Stroke patient's insight into their everyday memory abilities was incomplete.

Conclusion: Prospective memory abilities are reduced after stroke. In light of the potential impact of such difficulties on everyday functioning, this aspect of cognitive functioning should be routinely assessed in clinical practice.

PART I
SYSTEMATIC REVIEW

CHAPTER 1: SYSTEMATIC REVIEW

Prospective Memory Functioning after Acquired Brain Injury: A Systematic Review

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Running Head: Prospective Memory in Neurological Populations

*This review has been written in accordance with the Journal of Clinical and
Experimental Neuropsychology author guidelines (Appendix 1)*

Prospective Memory Functioning after Acquired Brain Injury: A Systematic Review

Abstract

Background: Difficulties with prospective memory are commonly reported after acquired brain injury. However, due to a range of methodological limitations in the literature, these difficulties have been poorly characterised.

Objectives: A systematic review was undertaken to examine the evidence regarding prospective memory functioning after acquired brain injury. The relationship between prospective memory and other neuropsychological functions was also evaluated.

Results: Prospective memory is consistently impaired after acquired brain injury. Relationships were found between prospective memory, retrospective memory and executive functioning.

Conclusion: In light of the significance of prospective memory to everyday functioning, there is a need for more robust research.

Introduction

Prospective memory is the ability to remember to carry out previously planned actions at an appropriate point in the future (McDaniel & Einstein, 2007). It is important for the successful completion of a wide range of everyday activities (Graf & Uttl, 2001), such as attending appointments on time, or remembering to post a letter on the way home. Individuals with acquired brain injury commonly report problems with prospective memory (Fish *et al.*, 2010; Hannon *et al.*, 1995) and it has been recognised that difficulties in this aspect of cognition can have a significant impact on independent social and occupational functioning (Raskin & Sohlberg, 2009). However, a number of important methodological limitations in the literature mean that prospective memory impairments in acquired brain injury have been poorly characterised.

Historically, there has been some debate regarding the construct of prospective memory. Ellis (1996) has suggested that the term is misleading as it implies a distinct form of memory. Instead, she proposes that successful prospective remembering can be described as processing that supports the realisation of delayed intentions and their associated actions (Ellis, 1996). In contrast, Graf and Uttl (2001) argue that prospective memory is a distinct form of memory with subdomains analogous to those in retrospective memory. More recently, prospective memory has been conceptualised as a dynamic process where several cognitive processes work together to produce recollection in response to a pre-determined cue (Knight & Titov, 2009). In support of this view, Fish *et al.*, (2010) propose a hierarchical model of prospective memory functioning. At the first level, memory problems (as measured

by tests of recall) will lead to prospective memory problems because individuals will tend to forget the content of their intentions. Where memory is adequate, other forms of capacity limitation (attention, monitoring etc.) will lead to prospective memory failure. Fish *et al.* (2010) suggest that interactions between these levels may also be possible so, for example, encoding of intentions could be interrupted by distraction. A recent study by Carlesimo *et al.* (2010) provides some empirical support for this assumption. These authors found that leading participants with severe closed-head injury to encode task instructions more extensively improved recall of the specific actions to be performed.

Theoretical accounts of prospective memory have primarily come from research on normal ageing. According to Craik's taxonomy of memory (as cited by Einstein & McDaniel, 1990), tasks that are more dependent on self-cueing (such as free recall) are more difficult than those that involve environmental cueing (such as recognition). Einstein and McDaniel (1990) proposed that, in common with retrospective memory tasks, prospective memory tasks are likely to vary in the degree to which they require self-initiated processing. A distinction can be made between tasks where an action must be performed at a specific time (time-based) and tasks where an action is cued by an external event (event-based). Time-based tasks are assumed to be more difficult than event-based tasks as they rely on internal, or self-initiated, cues to reinstate memories (Einstein & McDaniel, 1990). In support of this hypothesis, greater difficulties with time-based tasks have been found in patients with traumatic brain injury (Kinch & McDonald, 2001; Kinsella *et al.*, 1996), Parkinson's disease (Costa *et al.*, 2008; Raskin *et al.*, 2011), Schizophrenia (Wang *et al.*, 2009) and

thalamic stroke (Cheng *et al.*, 2010).

Recently, it has been recognised that event-based prospective memory tasks may also require self-initiated processes. According to McDaniel and Einstein's (2000) multicomponent process model of event-based prospective memory, individuals use multiple approaches to retrieve intentions after a delay. The authors propose that prospective remembering can either be supported by strategic, resource-demanding, monitoring of the environment for the target event, or one can rely on environmental conditions automatically reinstating the intention. Further to this, McDaniel and Einstein (2000) argue that the extent to which prospective remembering is supported by automatic processes, and the likelihood that these processes will be successful, will vary depending on characteristics of the task, target cue, ongoing task and individual.

An alternative model of event-based prospective memory has been suggested by Smith (2003). The preparatory attentional processes and memory processes (PAM) theory argues that event-based prospective memory tasks always involve processes that draw on our limited attentional resources (Smith, 2003). Based on evidence that there is a cost to ongoing tasks when prospective intentions are activated, Smith (2003) proposes that non-automatic preparatory attentional responses occur before the target event. These responses are complimented by retrospective processes that allow discrimination of the target event from other events and recall of the intended action. Smith (2003) suggests that these responses are likely to vary depending on the particular task demands, availability of resources and the importance of the task.

Taken together, the multi-process and PAM models highlight the complexity of the cognitive processes likely to be implicated in prospective memory tasks. This has been demonstrated empirically in the normal aging literature. In a meta-analysis, Henry *et al.* (2004) found that the age-related deficits were greater in event-based prospective memory tasks that imposed a high level of controlled rather than automatic processing. Due to the variety of different task conditions employed between studies, the authors were unable to determine which particular manipulations moderated the deficits. However, they did suggest that the characteristics of event-based tasks are fundamental in determining whether effortful processes are evoked (Henry *et al.*, 2004). In a study of patients with Parkinson's disease, Altgassen *et al.* (2007) found that the performance on an event-based memory task was improved when importance of the prospective task was emphasised over the ongoing task. It was suggested that this may have been due to greater allocation of attention resources during the task or, at the intention formation phase.

As well as different types of prospective memory task, a further distinction has been made between the 'retrospective' component of prospective memory, recalling the action to be performed, and 'prospective' components, recall of the intention to perform some action, (Einstein & McDaniel, 1990; Ellis, 1996). The exact nature of these components is unclear (Smith, 2004). Many researchers in the normal ageing literature have sought to minimise the retrospective demands of prospective memory tasks in order to investigate prospective processes (Ellis & Kvavilashvili, 2000). Separate analysis of these components has been carried out in recent research in

acquired brain injury (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cheng *et al.*, 2010; Henry *et al.*, 2007; Kim *et al.*, 2009) and progressive neurological conditions (Branvin *et al.*, 2000; Kardiasmenos *et al.*, 2008; Katai *et al.*, 2003; Foster *et al.*, 2009). Differential impairments in the prospective component have been observed in Parkinson's disease (Katai *et al.*, 2003) and Multiple Sclerosis (Branvin *et al.* 2000). In both of these studies, patients failed to spontaneously initiate the intended action but were able to recall the task instructions. Kim *et al.* (2009) also found that stroke patient participants were no different than controls in their ability to recall the intended actions, despite having impaired associative memory.

In a study by Kardiasmenos *et al.* (2008), patients with Multiple Sclerosis were impaired on both prospective and retrospective components. Similarly, Carlesimo *et al.* (2010) found that severe-closed head injury patients with impaired prospective memory also recalled significantly fewer intentions than controls in both time- and event-based tasks. They reported that measures of declarative memory had a greater association with the number of intentions performed than the number of intentions recalled. In contrast, the association between executive functioning was similar for retrospective and prospective components. These results suggest that retrospective performance is not clearly related to traditional measures of retrospective or declarative memory. Individuals with impairments in these measures have been shown to recall intentions as well as controls. Therefore, it is possible that more 'executive' memory abilities such as working memory and self-initiated retrieval are implicated. In support of this, Kardiasmenos *et al.* (2008) found the deficit in both components was greater on tasks that depended on more effortful processing than

tasks that were relatively automatic. Foster *et al.* (2009) also found that patients with Parkinson's disease were differentially impaired on an event-based prospective memory task in a high executive control demand condition but not in a low demand condition.

Prospective memory may be most appropriately regarded as an umbrella term that describes underlying functions as well as different types of task (Ellis & Freeman, 2008). According to Dobbs and Reeves (1996), a range of qualitatively different components interact to produce successful prospective memory. These include knowledge of task demands, planning, monitoring, recall of content and output monitoring. In support of this, it has been acknowledged that prospective memory difficulties commonly arise in the context of more general difficulties with memory and executive functioning (Fish *et al.*, 2010) and can occur due to disruption of more than one related cognitive process (Raskin *et al.*, 2009).

Research into prospective memory is still in its infancy (McDaniel & Einstein, 2007) and many fundamental issues are only beginning to receive theoretical and empirical attention (Martin *et al.*, 2003). Individuals with acquired brain injury are likely to be particularly vulnerable to deficits in prospective memory. Therefore, as well as adding to our theoretical understanding, research in this population will lead to improved assessment and rehabilitation. This is particularly important as many patients report problems with prospective memory as their main symptoms (Martin *et al.*, 2003) and deficits in prospective memory may be a better indicator of everyday memory problems than retrospective difficulties (Kinsella *et al.*, 1996). A number of

methodological limitations inherent to the literature have contributed to a lack of clarity regarding the specific characteristics of prospective memory functioning in acquired brain injury. Therefore, the aims of this systematic review are to evaluate the evidence for impairments in prospective memory in acquired brain injury. The evidence for relationships between prospective memory and other cognitive functions will also be reviewed.

Methods

Inclusion and exclusion criteria

Criteria for the inclusion and exclusion of studies in this review were selected using the **PCOS** (population; comparators; outcomes; study design) framework described in the Centre for Reviews and Dissemination guidelines (CRD, 2008).

Population

Studies were included in this review if their primary aim was to measure the prospective memory functioning of participants with an acquired brain injury. This included participants with diagnoses of: *traumatic brain injury; stroke; hypoxic/anoxic brain damage; aneurysm; brain haemorrhage; encephalitis; brain tumour; epilepsy*. Studies were excluded if participants had a diagnosis of: *a progressive neurological illness; mild cognitive impairment*. Studies were confined to those with participants who were 18 years or over. It was anticipated that there would be a paucity of research. Therefore, studies that had a mixed neurological sample were included as long as at least half of the participants had an acquired brain injury.

Comparators

The comparator of interest was prospective memory functioning. Therefore, studies were only included if their aim was to compare the prospective memory functioning of the relevant patient group with a control group.

Outcome measures

Prospective memory functioning was the primary outcome of interest. Studies using standardised neuropsychological tests were sought. However, due to the lack of available standardised measures, laboratory paradigms for assessing prospective memory were accepted if they provided an objective behavioural measure. Studies were excluded if the only measure of prospective memory was subjective. Studies using virtual reality measures of prospective memory were also excluded as these measures are not available clinically and would be difficult to replicate. Secondary outcome measures of interest were objective measures of other cognitive functions. In particular, measures of retrospective memory and executive functioning.

Study design

Randomised controlled trials were sought. However, it was anticipated that these would not be available. Therefore, this review included cohort studies where the outcome of interest was compared in a patient group and a control group. Studies using case-control, case-series or case-report designs were excluded due to the high risk of bias. Previous systematic reviews, literature reviews, unpublished dissertations, book chapters and descriptive studies with no quantifiable outcomes were also excluded. Articles were also excluded if their main aim was to describe the validity or reliability of a measure.

Search strategy and selection of studies

A search was conducted using the OVID electronic databases: Journals @ OVID Full Text (May 27 2011); Medline (1948-May week 3 2011); Cochrane Central Register

of Controlled Trials (Second quarter 2011); Cochrane Database of Systematic Reviews (2005 – May 2011); Embase (1980-week 21 2011). A search was also carried out up until week 21 of 2011 using, the Cumulative Index to Nursing and Allied Health Literature databases (CINAHL Plus Full Text, PsycINFO and Psychology and Behavioural Sciences Collection). The search engine Google Scholar and generic search engine Google were used to search for relevant conference abstracts.

Key words for the searches were identified by reading previously published research. The following were used to identify studies that measured the outcome of interest: *prospective memory; intention memory; memory for future intentions*. These were each combined in turn with the terms: *brain injury; brain damage; head injury; neurological injury; cognitive impairment; brain tumour; epilepsy; aneurysm; stroke*. The terms *brain tumour; brain haemorrhage* and *encephalitis* did not yield any results when combined with prospective memory terms. For searches of OVID databases, the Boolean operator 'AND' was used to search for studies with the outcome and population of interest. The command 'adj' was used to search for key phrases where words had to appear next to each other.

From the search results, titles and abstracts were screened to identify whether the full article was relevant to the review. When it was not clear whether an article was relevant by reading the title and abstract, the whole article was retrieved. Studies were selected based on the exclusion and inclusion criteria reported above (*population, comparators, outcome measures, study design*). Articles were excluded

if the full text was not available in the English language. As a secondary search strategy, the reference lists of articles selected for review were also scanned visually.

Rating methodological quality

Criteria for assessing the methodological quality of papers are outlined in Table 1. These criteria were developed by the author and are based on the Scottish Intercollegiate Guidelines Network methodology checklist for cohort studies (Methodology Checklist 3: Cohort Studies, SIGN, 2011).

Data extraction

Data extracted from each study included: diagnosis and number of participants; measures of prospective memory; measures of retrospective memory; measures of executive functioning; any other measures used; main findings; effect size for prospective memory measures (if reported).

Table 1. Checklist for assessing the methodological quality of studies.

1. Study addresses an appropriate and clearly focussed question	Question(s) appropriate and clearly defined	Well Covered (3)
	Question(s) appropriate and adequately defined	Adequate (2)
	Question(s) inappropriate or poorly defined	Limited (1)
	Question(s) not specified	Not Addressed (0)
2. Control group matched to minimise confounding variables	Two groups comparable in all important variables	Well Covered (3)
	Two groups comparable in most important variables or any differences controlled for	Adequate (2)
	Two groups poorly matched	Limited (1)
	Two groups not matched on any variables	Not Addressed (0)
3. Use of valid and reliable neuropsychological measures	All or majority of measures have evidence for their validity and reliability	Well Covered (3)
	At least 50% of measures have evidence for their validity and reliability	Adequate (2)
	Less than 50% of measures have evidence for their validity and reliability	Limited (1)
	No valid or reliable measures used	Not Addressed (0)
4. Cognitive functions* that may contribute to prospective memory deficits taken into account	Good or excellent assessment of other cognitive functions	Well Covered (3)
	Adequate assessment of other cognitive functions	Adequate (2)
	Limited assessment of other cognitive functions	Limited (1)
	No assessment of other cognitive functions	Not Addressed (0)
5. Measures selected appropriate for assessing relevant cognitive functions	Measures selected provide excellent assessment of relevant functions	Well Covered (3)
	Measures selected provide adequate assessment of relevant functions	Adequate (2)
	Measures selected provide limited assessment of relevant functions	Limited (1)
	Measures selected are inappropriate for assessing relevant functions	Not Addressed (0)
6. Statistics clearly reported and appropriate	Statistics appropriate and clearly reported	Well Covered (3)
	Statistics appropriate, majority clearly reported	Adequate (2)

for analysing primary outcome measures	Statistics appropriate, few clearly reported	Limited (1)
	Selected statistics inappropriate or not clearly reported	Not Addressed (0)
7. Correlation/association between prospective memory and other cognitive functions explored	Good or excellent exploration of the relationship between prospective memory and other cognitive functions	Well Covered (3)
	Adequate exploration of the relationship between prospective memory and other cognitive functions	Adequate (2)
	Limited exploration of the relationship between prospective memory and other cognitive functions	Limited (1)
	Relationship between prospective memory and other cognitive functions not explored	Not addressed (0)
8. Effect sizes reported for prospective memory measures	Effect sizes reported	Yes (1)
	Effect sizes not reported	No (0)

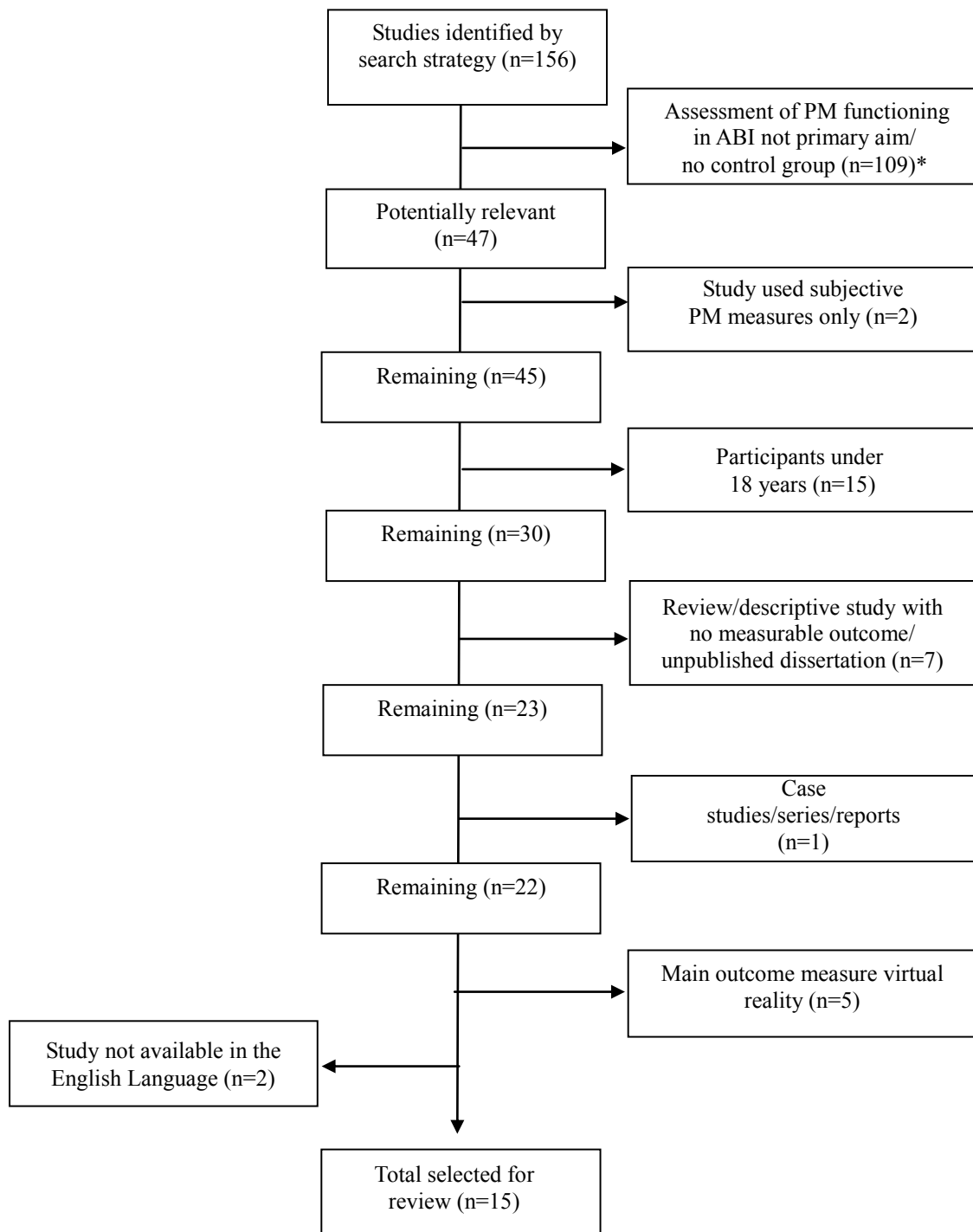
**retrospective memory; executive functioning*

Results

Study Inclusion

The search strategy identified 153 studies. A total of 109 articles were excluded based on the primary exclusion criteria. These were articles that did not describe the assessment of prospective memory functioning in an acquired brain injury population, articles without a control group, or articles where the primary aim was to describe a measure of prospective memory. The remaining articles were excluded based on criteria described in figure 1.

Figure 1. Flowchart to summarise total number of studies found and reasons for exclusion.



*PM=Prospective Memory; ABI=Acquired Brain Injury

General characteristics of included studies

No randomised controlled studies were identified. All included studies were cohort designs where the primary aim was to investigate prospective memory functioning in an acquired brain injury group. A summary of the articles reviewed is provided in Table 2. The majority of studies assessed both time- and event-based prospective memory. In four studies (Henry *et al.*, 2007; Kliegel *et al.*, 2004; Maujean *et al.*, 2003; Schmitter-Edgecombe & Wright, 2004), only event-based tasks were assessed. Shum *et al.* (1999) included a measure of activity-based prospective memory. A number of studies made a distinction between the retrospective and prospective components of prospective memory tasks in their scoring and analysis (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cheng *et al.*, 2010; Henry *et al.*, 2007; Kim *et al.*, 2009). The majority of studies also measured other cognitive functions thought to be relevant to prospective memory performance. The functions measured varied depending on the specific hypotheses tested. However, the main focus was on retrospective memory and executive functioning.

The sample size for the acquired brain injury groups varied from 7 (Kliegel *et al.*, 2004) to 36 (Groot *et al.*, 2002). Two of the studies compared three groups. Adda *et al.* (2008) compared two patient groups to a control group and Kliegel *et al.* (2004) compared one patient group to a younger adult control group and an older adult control group. Patient participants predominantly had a diagnosis of traumatic brain injury (TBI). Two studies investigated patients after stroke (Cheng *et al.*, 2010; Kim *et al.*, 2009), one investigated patients with a diagnosis of medial temporal sclerosis and associated epilepsy (Adda *et al.*, 2008), and a further two recruited a mixed

sample of participants. Cockburn (1996) included participants with diagnoses of: subarachnoid haemorrhage; head injury and cerebrovascular accident (CVA). The participants in the study by Groot *et al.* (2002) had diagnoses of: TBI (n=22); CVA (n=7); cerebral anoxia (n=3); encephalitis (n=2); Korsakoff's syndrome (n=1) and both cerebral tumour and meningitis (n=1). Recruitment of patients into studies involved purposive sampling, primarily from hospital clinics or community rehabilitation centres.

Controls were well matched on gender and education in most of the studies. All but one (Kliegel *et al.*, 2004) also matched controls on age. A total of ten studies reported exclusion criteria for both patients and controls (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Henry *et al.*, 2007; Kim *et al.*, 2009; Kinch & McDonald, 2001; Kliegel *et al.*, 2004; Maujean *et al.*, 2003; Schmitter-Edgecombe & Wright, 2004; Shum *et al.*, 1999; Tay *et al.*, 2010). However, only four studies (Adda *et al.*, 2008; Kinch & McDonald, 2001; Mathias & Mansfield, 2005; Tay *et al.*, 2010) controlled for the influence of current low mood or anxiety by administering screening measures. Nine studies measured current or premorbid intelligence (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cheng *et al.*, 2010; Groot *et al.*, 2002; Henry *et al.*, 2007; Kliegel *et al.*, 2004; Mathias *et al.*, 2005; Schmitter-Edgecombe & Wright, 2004). In the Cockburn (1996) study an estimate of premorbid intelligence was only available for patient participants.

Only three studies (Kim *et al.*, 2009; Mathias & Mansfield, 2005; Tay *et al.*, 2010) used tests of prospective memory that have strong evidence for their validity and

reliability. Two used a test that was an earlier version of a now standardised assessment (Adda *et al.*, 2008; Groot *et al.*, 2002). The majority of studies employed a range of different experimental procedures (Carlesimo *et al.*, 2010; Cockburn, 1996; Cheng *et al.*, 2010; Henry *et al.*, 2007; Kinch & McDonald, 2001; Kinsella *et al.*, 1996; Kliegel *et al.*, 2004; Maujean *et al.*, 2003; Schmitter-Edgecombe & Wright, 2004; Shum *et al.*, 1999).

Table 2. Summary of studies reviewed

<i>Study</i>	<i>Participants</i>	<i>PM measures</i>	<i>RM measures</i>	<i>Executive Functioning Measures</i>	<i>Other Measures (e.g. Mood, premorbid IQ)</i>	<i>Main Findings</i>	<i>Effect Size reported? (PM)</i>	<i>Quality Rating</i>
Adda et al.(2008)	RMTS(n=26); LMTS(n=22); Controls(n=26)	Adapted version CBPMT(3x TBPM; 3x EBPM).	Memory Questionnaire; RAVLT; RCFT	Stroop Test; Digit Span (WAIS-III); FAS; Hayling& Brixton (competition test); Trails; WMCSST	HADS; Boston Naming Test; Vocabulary, Matrix Reasoning(WAIS-III)	Both patient groups significantly worse than controls on PM testing. LMTS significantly worse than RMTS on time-based tasks. PM performance weakly correlated with all other measures for both groups.	No	21/22
Carlesimo et al. (2010)	Severe closed-head injury(n=18); Controls(n=18)	Experimental procedure (TBPM; EBPM). Manipulated: availability of attentional resources; encoding conditions.	15 word list recall; Short story recall	Phonological word Fluency; MCST	Raven's Coloured Progressive Matrices	Controls more accurate on spontaneous initiation of intentions. Patient's recall of intentions correlated with declarative memory measures. Accuracy in recalling actions significantly associated with an EF measure.	No	17/22
Cockburn (1996)	ABI (n=18); Controls(n=18)	Experimental procedure (TBPM;EBPM). Incorporated in filler tasks (sentence-verification/crossing out lowest number)	RBMT; Prose Recall (WMS) <i>Patients only</i>	WCST; FAS <i>Patients only</i>	NART; WAIS-R <i>Patients only</i>	Significant group difference on TBPM. Relationship between RM and event-based PM for patients. No relationship between TBPM and EF for patients.	No	14/22

Cheng et al.(2010)	Thalamic Stroke(n=18); Controls(n=18)	Experimental procedure with TBPM and EBPM components and RM components. PM tasks embedded in ongoing tasks (number selection and word selection).	Part of experimental procedure	Verbal fluency test (animals); Digit Span Test	MMSE;WAIS-RC	Patients impaired on TBPM but not EBPM. Significant difference in RM performance between groups. However, TBPM impairment could not be explained by RM deficit.	No	16/22
Groot et al.(2002)	Mixed Brain Injury(n=36); Controls(n=28)	Extended version of CBPMT (4x TBPM and 4x EBPM tasks embedded in intellectually demanding filler tasks).	Logical Memory(WMS-R); RCFT; The Recognition Memory Test; Everyday Memory Questionnaire (patient & proxy)	Digit Span; Stroop; MCST; BADS(modified six elements); FAS; Trails; The Cognitive Failures Questionnaire; The Dysexecutive Questionnaire	Raven's Standard Progressive Matrices; SCOLP(Spot-the-Word & Speed of Comprehension Test)	Patient's PM significantly poorer than controls. TBPM more difficult for both groups. Differences in PM performance explained by tests of RM, attention and executive functioning together but not separately.	No	20/22
Henry et al.(2007)	TBI(n=16); Controls(n=15)	Experimental within-subjects procedure. Event-based PM. Task complexity manipulated(4-target word condition and 1-target word condition). Ongoing filler tasks.	AVLT (filler task); retrospective component of PM task	Standard and Alternating Verbal Fluency (phonemic and semantic)	NART	Patients poorer than controls on both EBPM tasks. Complex task more difficult for both groups, no evidence TBI differentially impaired. Failures of RM not major factor in TBI group's performance on PM tasks.	Yes (1-target PM task ES=0.47; 4-target PM task ES=0.42)	15/22

Kim et al.(2009)	Stroke (n=12); Controls(n=12)	Virtual Week board game; Modified version of MI (PM; RM and AM components); RBMT (Remembering a Belonging); PRMQ.	Verbal Paired Associates (WMS-III); CVLT-II	Trails A&B; FAS & Animals; SART; R-SAT	MMSE	Patients poorer than controls on lab measures of PM and AM. Patient deficits on standard measures of RM and executive control. No group difference on more structured clinical measures of EF, RM or PM. No difference in self-rated RM and PM.	No	17/22
Kinch & McDonald (2001)	Severe TBI (n=13); Controls(n=13)	Naturalistic experimental tasks. EBPM, WM demand manipulated ('unfilled' and 'filled' versions). TBPM task embedded in word verification task. Tasks divided into 'timing' and 'content' components.	Logical Memory, Faces(WMS-III)	WCST; COWAT	DASS	Difference between groups not significant for EBPM. Patient's performance significantly poorer than controls on TBPM task. EF associated with PM, particularly TBPM. RM associated with EBPM.	No	19/22
Kinsella et al.(1996)	TBI(n=24); Controls (n=24)	Experimental procedure, 2x PM tasks based on RBMT (1.Request a questionnaire at end of session; 2.Return evaluation form by mail).	AVLT; MFQ	Digit Span	None	Patients more likely to fail on task 1 but not task 2. Patient's self-rated RM failures higher than controls. Performance on task 1 highly correlated with RM for patients and controls.	No	15/22

Kliegel et al.(2004)	TBI: <i>RM in normal limits, impaired EF</i> (n=7) Younger Adult Controls(n=19) Older Adult Controls(n=21)	Complex PM task assessed in 4 phases: intention formation; intention retention; intention re-instantiation; intention execution. Ongoing distractor tasks.	Delayed recall index (WMS-R) -TBI group only	BADS -TBI group only; WCST	MWT-B	Performance of patients and older controls significantly poorer than younger controls on 3 phases of PM task and tests of EF. All 3 groups able to recall their previously planned intention.	No	16/22
Mathias & Mansfield (2005)	TBI(n=25); Controls(n=25)	RBMT(3 EBPM subtests). 2x experimental TBPM tasks (1. Press timer 10 minutes after instructed; 2.Send stamped addressed envelope to experimenter).	RBMT(Story; Pictures;Faces; Route); RAVLT	Digit Span (WAIS-III); Trails A&B; COWAT; WCST	BDI-II;NART	Patient group poorer on measures of short interval EBPM; short interval TBPM and long interval TBPM. Also poorer on tests of verbal declarative memory and some aspects of EF. Other measures of memory and EF not significantly correlated with PM.	Yes (1 st PM task ES=0.79; 2 nd PM task ES=0.86; RBMT ES=0.63)	22/22
Maujean et al. (2003)	Severe TBI(n=14); Controls(n=14)	Experimental dual-task paradigm (ongoing lexical decision task; EBPM task). High and low cognitive demand conditions for ongoing task. Participants asked to respond to cues.	None	TOL; COWAT; LNST(WMS-III)	None	Patients poorer than controls on high demand PM task but not low demand. Significant correlation between WM and PM for both groups (low demand condition). Association with one EF measure and PM for patients.	No	16/22

Schmitter-Edgecombe & Wright (2004)	Severe Closed-Head Injury(n=24); Controls(n=24)	Experimental EBPM task. First presented with baseline WM task. This task then paired with focal-cue (target word) and peripheral-cue (target background) PM tasks.	CVLT(long delay free recall); WMS-R(LMII, VRII)	Digit Span (WAIS-R); SDMT(written & oral); Trails A&B; Alphabet Span Test; COWAT; Stroop;WCST	NAART; Vocabulary, Block Design, Arithmetic, Similarities (WAIS-R)	Patient deficits in EBPM even in context of normal performance on ongoing WM task. No effect of cue manipulation. PM performance in patient group correlated with measures of delayed memory, attention and speed of processing.	No	20/22
Shum et al.(1999)	Severe Long-Term TBI(n=12); Controls(n=12)	Experimental procedure. EBPM and TBPM tasks embedded in general knowledge filler activity. Activity-based PM task at end of session.	None	None	None	Patient's poorer than controls on all 3 PM tasks. TBPM poorer than EBPM for patients and controls. Performance on activity-based PM tasks better than TBPM and EBPM for both groups.	No	09/22
Tay et al.(2010)	Mild TBI(n=31); Controls(n=31)	MIST(Time- and event-based PM; distractor tasks between subtests). Assessed within a month of injury then again at 3 months.	None	None	TOMM;BDI-II	Patient group significantly worse than controls in overall PM performance at acute stage. Deficit still present at 3 months.	No	15/22

Abbreviations: ABI: Acquired Brain Injury; AM: Associative Memory; AVLT: Auditory Verbal Learning Test; BADS: Behavioural Assessment of the Dysexecutive Syndrome; BDI-II: Beck Depression Inventory -2nd Ed; BI: Brain Injury; CBPMT: Cambridge Behaviour Prospective Memory Test; COWAT: The Controlled Oral Word Association Test; CVLT-II: California Verbal Learning Test-2nd Ed; DASS: The Depression, Anxiety, Stress Scales; EBPM: Event-Based Prospective Memory; EF: Executive Functioning; HADS: Hospital Anxiety and Depression Scale; LMTS: Left Medial Temporal Sclerosis; LNST: Letter Number Sequencing Test; MCST: Modified Card Sorting Test; MFQ: Memory Functioning questionnaire; MI: Memory for Intentions; MIST: Memory for Intentions Screening Test; MMSE: Mini Mental State Examination; MWT-B: Mehrfachwahlwortschutztest-B; NAART: North American Adult Reading Test; NART: National Adult Reading Test; PM:Prospective Memory; PRMQ: Prospective and Retrospective Memory Questionnaire; RAVLT: Rey Auditory Verbal Learning Test; RBMT:Rivermead Behavioural Memory Test; RCFT: Rey Complex Figure Test; RM: Retrospective Memory; RMTS: Right Medial Temporal Sclerosis; R-SAT: Revised Strategy Application Test; SART: Sustained Attention to Response Task; SCOLP: The Speed of Comprehension Test; SDMT: STM: Short Term Memory; TBI: Traumatic Brain Injury; TBPM: Time-Based Prospective Memory; TOL: Tower of London Test; TOMM: Test of Memory Malingering; VR: Virtual Reality; WAIS-III: Wechsler Adult Intelligence Test -3rd Ed; WAIS-RC: Wechsler Adult Intelligence Test -Revised Chinese; WM: Working memory; WMCST: Wisconsin Modified Card Sorting Test; WMS-III: Wechsler Memory Scale -3rd Edition; WMS-R: Wechsler Memory Scale-Revised.

Prospective memory functioning after acquired brain injury

In all of the studies reviewed, patients with acquired brain injury had reduced prospective memory functioning when compared to healthy controls. However, in some of these studies (Cheng *et al.*, 2010; Kinch & McDonald, 2001; Kinsella *et al.*, 1996), the deficit was only observed in time-based prospective memory tasks and not in event-based tasks. A further four studies (Henry *et al.*, 2007; Kliegel *et al.*, 2004; Maujean *et al.*, 2003; Schmitter-Edgecombe & Wright, 2004) only measured performance on event-based prospective memory tasks. The remaining studies found impairments in both time- and event-based tasks (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cockburn, 1996; Groot *et al.*, 2002; Kim *et al.*, 2009; Mathias & Mansfield, 2005; Shum *et al.*, 1999; Tay *et al.*, 2010).

Only two studies reported effect sizes for their prospective memory measures (Henry *et al.*, 2007; Mathias & Mansfield, 2005). However, these were moderate to large. A meta-analysis of the TBI literature by Henry *et al.* (2007) found an average moderate to large effect size for the patient deficits in prospective memory. This included the studies by (Carlesimo *et al.*, 2004; Cockburn, 1996; Kinch & McDonald, 2001; Kinsella *et al.*, 1996; Kliegel *et al.*, 2004; Mathias & Mansfield, 2005; Maujean *et al.*, 2003; Scmitter-Edgecombe & Wright, 2004; Shum *et al.*, 1999).

Time- versus event-based tasks

A number of studies with high methodological ratings found that impairments in time-based tasks were greater than those observed for event-based tasks (Adda *et al.*

2008; Groot *et al.* 2002; Kinch & McDonald, 2001; Mathias & Mansfield, 2005). In the above studies, differential performance between time- and event-based tasks was only observed in the acquired brain injury patients. However, in the study by Groot *et al.* (2002), healthy controls also found time-based tasks more difficult. Shum *et al.* (1999) reported that patients with long-term traumatic brain injury were significantly worse than controls on time-event- and activity-based tasks. In common with Groot *et al.*'s (2002) findings, performance on time-based tasks was poorer than event-based tasks for both patients and controls. However, patients were not disproportionately impaired on time-based tasks. Both groups in this study performed at a higher level on activity-based tasks.

Cheng *et al.* (2010) found that thalamic stroke patients had significantly lower scores than controls on the retrospective and prospective components of a time-based task. In contrast, their performance on the prospective component of an event-based task was equal to controls despite reduced performance on the retrospective component. Similarly, Kim *et al.* (2009) found that stroke patient's performance was significantly poorer than controls on a 'time-check' prospective memory task. In this task, participants were required to indicate to the researcher when two specific time periods had lapsed. A significant demand was placed on time-monitoring in this task as time was given by a stopwatch placed face-down on the desk. As well as having fewer correct responses on this task, stroke patients had more 'miss' responses (Kim *et al.* 2009). Patients with mild TBI in Tay *et al.*'s (2010) study had deficits in overall prospective memory (time- and event-based) both at the acute stage and after three

months. However, further analysis demonstrated that patients were only impaired in time-based tasks at the longer interval of 15 minutes. This is in contrast to Cockburn's (1996) findings that individuals in neurological rehabilitation had impairments on time-based tasks even at short intervals (5 minutes).

Prospective memory task conditions

A number of studies manipulated test conditions to further explore the cognitive processes involved in different types of prospective memory task. Schmitter-Edgecombe and Wright (2004), presented participants with a focal (highly associated) or a peripheral (less associated) prospective memory cue in an event-based procedure. Although participants reported that the peripheral task required more effort, the hypothesis that this would increase the need for controlled processing was not supported. Carlesimo *et al.* (2010) explored the impact of manipulating the availability of attentional resources in both time- and event-based tasks. They found that performing a concurrent task significantly reduced patient's accuracy on the time-based task but not on the event-based task.

Maujean *et al.* (2003) manipulated cognitive demand in a dual-task paradigm. Participants carried out event-based tasks concurrently with a low or high demand lexical decision task. Patient's performance was significantly poorer than controls in the high demand condition but not on the low demand condition. Participants in the patient group also performed significantly better on the low demand task than the high. There was no difference between conditions for the control participants.

Maujean *et al.* (2003) concluded that there was a reduction in cognitive resources in the high demand condition.

Henry *et al.* (2007) found that patient's performance was significantly poorer than controls on tests of event-based prospective memory when the tasks were manipulated for complexity. In contrast to Maujean *et al.*'s (2003) findings, patients were poorer than controls even in the low-demand condition. This difference could not be explained by differences in an ongoing task or by increased difficulty with the retrospective component of remembering task instructions. In the Carlesimo *et al.* (2010) study, control participants were significantly more accurate in initiating the prospective intention. Manipulating encoding conditions had no influence on prospective memory for either group. However better encoding conditions at the intention formation stage did improve accuracy of recall for the patient participants. Recall accuracy was not influenced by type of task (time- or event-based) or attentional resources (ongoing task or no ongoing task).

Self-reports of prospective memory

A number of the studies also employed subjective measures of memory. Adda *et al.*, (2008) reported that patients with left MTS scored themselves as having poorer memory than healthy controls. However, they did not differ in their reported use of strategies. In the study by Kim *et al.* (2009) stroke patient's subjective ratings of prospective memory were not significantly different to self-reports by healthy controls. This suggests that patient's insight was incomplete as they were objectively

poorer on measures of memory. Kinsella *et al.* (1996) compared the subjective memory reports of individuals with TBI to their performance on traditional memory tests and two event-based memory tasks. On subjective measures, self-appraisals of memory functioning were more closely related to prospective memory performance than traditional memory test performance. In contrast, Groot *et al.*, (2002) did not find a significant correlation between a subjective measure of memory and objective performance on prospective memory tests.

Summary of prospective memory findings

In all of the studies reviewed, the prospective memory performance of patients was reduced compared to healthy control participants. However, the pattern of difficulties observed was inconsistent. Several studies reported that patient's performance was poorer on both time- and event-based tasks. However, others found differential impairments in time-based prospective memory tasks. The studies with higher methodological quality ratings showed more consistent results. These studies suggest that although prospective memory is reduced after acquired brain injury for both time- and event-based tasks, the deficits are greater for time-based tasks. In the studies that measured both types of prospective memory there were no instances where event-based prospective memory performance was poorer than time-based performance. There is some evidence that increased demands on cognitive resources are associated with greater difficulties in prospective memory.

Relationships between prospective memory and other neuropsychological functions

In five of the reviewed studies, a comprehensive battery of standardised neuropsychological tests was administered (Adda *et al.*, 2008; Groot *et al.*, 2002; Kim *et al.*, 2009; Kinch & McDonald, 2001; Schmitter-Edgecombe & Wright, 2004). Adda *et al.* (2008) reported that prospective memory performance was weakly correlated to all neuropsychological measures for the healthy control participants and right MTS patients. In line with recognised deficits in limbic-hippocampal networks, a strong correlation was found for the left MTS group between a measure of long-term delayed verbal recall and prospective memory. Participants in this study were presented with the prospective memory tasks in a session lasting 105 minutes. Other neuropsychological tests were also administered during this time. Adda *et al.* (2008) suggest that this longer delay placed a stronger emphasis on spontaneous recall rather than strategic monitoring.

Groot *et al.* (2002) found significant relationships between prospective memory performance and a variety of retrospective memory and executive functioning measures together, but not individually. In a mixed neurological group of patients, those who performed more poorly on retrospective memory and executive functioning measures had lower scores on the prospective memory tasks. Similarly, correlational analysis by Schmitter-Edgecombe and Wright (2004) showed that closed-head injury patient's performance on the prospective memory task was associated with measures of attention, speed of processing and verbal and visual memory. Kinch and McDonald (2001) used multiple regression analysis to explore

the relative contributions of retrospective memory and executive functioning to different types of prospective memory task. The authors found that performance on measures of executive functioning accounted for significantly more variance in time-based task scores than retrospective memory performance. In contrast, retrospective memory ability predicted performance on event-based tasks. Kinch and McDonald (2001) also found that poor executive functioning specifically accounted for failures to carry out intentions at the appropriate time in both types of task. Participants with executive impairments were less likely to stop the time-based task at the correct time and to relay a message at the appropriate time (when the researcher returned to the room) in the event-based tasks.

Two of the reviewed studies measured other cognitive functions in the patients with acquired brain injury but not in healthy controls (Carlesimo *et al.*, 2010; Cockburn, 1996). Cockburn (1996) found that there were no significant differences in executive functioning or memory measures according to success or failure on a time-based task. However, patients who failed an event-based task had poorer scores on a prose recall test. Patients who selectively failed the event-based task and not the time-based task had generally poorer retrospective memory and a greater loss of general cognitive ability (Cockburn, 1996). Carlesimo *et al.* (2010) found associations between a test of intelligence and executive functioning and both components (retrospective and prospective) of their prospective memory tasks. However, tests of verbal declarative memory were more strongly associated with the retrospective component than the prospective component. Carlesimo *et al.* (2010) suggest that

poorer encoding of the initial instruction due to executive deficits, and faster forgetting of the information required due to declarative memory deficits combined to produce the observed difficulties on the retrospective component. Kinsella *et al.* (1996) found performance on an event-based task (requesting a questionnaire at the end of the session) was highly correlated with retrospective memory for both patients and controls.

In contrast to the above studies, Mathias and Mansfield (2005) did not find significant correlations between prospective memory and measures of declarative memory and executive functioning. The TBI patients in this study had significant deficits in verbal declarative memory and both time- and event-based prospective memory. However, they were only impaired on one measure of executive functioning battery (verbal fluency). Deficits in prospective memory have been found in the absence of retrospective memory impairment. Kliegel *et al.* (2004) measured a small group of TBI patients with retrospective memory within normal limits and impaired executive functioning. Using a complex prospective memory paradigm, they found that the performance of patients and older controls was significantly worse than that of younger controls on three phases of prospective memory (intention formation; intention re-instantiation and intention execution). All three groups were able to recall their previously planned intention. Similarly, Tay *et al.*'s (2010) analysis of errors on tests of prospective memory showed that mild TBI patients made larger errors in retrieving the intention at the appropriate moment rather than failing to recall a task and carrying it out incorrectly or carrying out the wrong task.

Henry *et al.* (2007) explored the contribution of retrospective deficits to event-based prospective memory by recording whether a TBI group could recall the task instructions at the end of the task. Despite poorer performance on the prospective memory task, patients were equal to controls in their ability to recall the task instructions and their performance on an ongoing short term memory task. As patient's prospective memory was poorer than controls even in a low memory demand condition, Henry *et al.* (2007) suggest that retrospective memory was not a major factor in the observed deficits.

The role of other cognitive functions in prospective remembering may vary depending on the specific task demands. Maujean *et al.* (2003) found a significant correlation between working memory and prospective memory in a low cognitive demand condition but not in a high cognitive demand condition. This was true for both TBI patients and controls. An association was also found between a measure of spontaneous flexibility and performance on the event-based. However this was only present in the high cognitive demand condition. In the study by Kim *et al.* (2009) stroke patients were shown to be impaired on measures of self-initiation and cognitive control and on measures of verbal recall but not recognition. Therefore, the authors suggest that the deficits in prospective memory observed in these patients may occur in situations where the intended action is not well supported by environmental cues. In support of this, Kim *et al.* (2009) found that stroke patients were significantly poorer than controls on a time-based task that placed a high

demand on self-initiated monitoring. However, they were equal to controls on tasks that were designed to mirror routine or habitual tasks.

Summary of relationship with other neuropsychological functions

All reviewed studies explored other neuropsychological functions to some degree. However, there was considerable variation in the functions measured and the quality of assessment employed. Therefore, the relationship between prospective memory and other cognitive functions remains unclear. There is evidence that both retrospective memory and executive functioning are important to successful prospective memory. However, impairments in these abilities do not fully account for prospective memory deficits. An interaction between retrospective and executive processes is likely.

Discussion

Main findings

The results of this systematic review indicate that prospective memory is consistently impaired in individuals with acquired brain injury. The effect sizes for these impairments are moderate to large (Henry *et al.*, 2007). In the majority of studies, deficits were observed in both time- and event-based tasks (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cockburn, 1996; Groot *et al.*, 2002; Kim *et al.*, 2009; Mathias & Mansfield, 2005; Shum *et al.*, 1999; Tay *et al.*, 2010). However, several of the studies with higher methodological quality ratings reported greater deficits in time-based performance than event-based performance (Add *et al.*, 2008; Groot *et al.*, 2002; Kinch & McDonald, 2001; Mathias & Mansfield, 2005). In other studies, a differential impairment was found in time-based tasks (Cheng *et al.*, 2010; Kinch & McDonald, 2001; Kinsella *et al.*, 1996). There were no instances of greater impairments in event-based task performance.

Significant relationships were found between performance on prospective memory tasks and performance on other neuropsychological measures. However, the exact nature of these relationships remains unclear. Deficits in retrospective memory and executive functioning did not fully account for impairments in prospective memory. In light of the framework suggested by Dobbs and Reeves (1996) this is not surprising. Prospective memory is likely to involve a complex interaction between different cognitive processes. . Impairments in prospective memory have been shown to occur in the absence of traditional retrospective memory deficits (Kliegel *et al.*,

2004). The evidence reviewed provides support for the hypothesis that prospective memory tasks involve a greater demand on self-initiated executive functioning processes such as planning and monitoring as well as memory processes such the encoding and retrieval of verbal information. It likely that these 'executive' memory processes are implicated in prospective memory more often than environmentally prompted memory processes. Shallice (1996) suggests that an interaction between processes localised in the prefrontal cortex and those located in the hippocampus is most plausible.

Methodological limitations

A significant number of methodological limitations were observed in the reviewed studies. As all of the studies were cohort-group designs, the findings may not be generalizable to the wider population of individuals with acquired brain injury. Generalisability is further reduced due to the relatively small sample sizes (7-36). There was also significant variation in the methods employed to control for confounding variables. The majority of studies matched brain injured participants to healthy controls by age, gender and education. Psychiatric disorders and substance misuse were commonly reported as exclusion criteria. However, despite early recommendations by Cockburn (1996) regarding the importance of measuring low mood and anxiety, only four studies (Adda *et al.*, 2008; Kinch & McDonald, 2001; Mathias & Mansfield, 2005; Tay *et al.*, 2010) administering screening measures to assess current levels of low mood or anxiety. This is a significant limitation in light of the impact that depression and anxiety can have on cognitive functioning and the

possibility of high levels of comorbid mood disturbances in this population (Kreutzer *et al.*, 2001).

Despite broadly sharing similar aims, a range of different hypotheses were put forward in the literature reviewed regarding the important components of prospective memory. The methodologies employed to test these hypotheses were also heterogeneous. This reduces the meaningfulness of comparisons between studies. The majority of studies did not employ measures of prospective memory with strong evidence for their validity and reliability. As assessments of prospective memory have been developed ahead of a comprehensive theory, there is a consistent lack of demonstrated psychometric properties and representative norms (Shum *et al.* 2002).

Many of the laboratory tasks employed in the reviewed research have a limited number of items or are scored categorically as either 'right' or 'wrong'. This restricted range for scoring may be insensitive to more subtle difficulties with prospective memory. Equally, individuals may present as more impaired than they are due to the restricted opportunity to respond. Ceiling effects have been observed in some of the studies for normal controls. The ecological validity of the experimental paradigms employed in the acquired brain injury studies is low. In a meta-analysis of the normal aging literature, Uttl (2008) highlighted that without valid and reliable tests, conclusions cannot be drawn regarding prospective memory ability, only performance on prospective memory tasks. Similar difficulties are inherent to the acquired brain injury literature.

In light of the assumption that prospective memory involves separable but interacting mnemonic and executive components (Fish *et al.*, 2010), the limited assessment of other neuropsychological functions in many of the studies is problematic. Without an understanding of the pattern of impairments in other cognitive functions, impairments in prospective memory processes cannot be clearly examined. The studies that did assess other cognitive functions did not always use an adequate range of assessments. Crawford *et al.* (2003) has emphasised the importance of using multiple indicators of cognitive function for accurate neuropsychological assessment. Some studies only measured other cognitive functions in the acquired brain injury patients. However, it is likely that any relationship between these cognitive abilities would be relevant to control participants as well as patients with acquired brain injury.

Conclusion

The available evidence suggests that impairments in prospective memory are prevalent after acquired brain injury. This has important implications for clinical practice as there are currently few valid and reliable measures of prospective memory. The inconsistencies in the current literature are largely the result of methodological limitations. Studies with more robust methodology have consistently found that prospective memory abilities are reduced after acquired brain injury for both time- and event-based tasks. These studies have also shown that deficits in time-based performance are greater. The complexity of processes involved in successful

prospective memory is only beginning to be understood. Future research should be more methodologically robust in order to better characterise impairments in prospective memory in acquired brain injury. As well as contributing to theoretical knowledge, this will also improve outcomes for rehabilitation. Strategies to manage deficits in prospective remembering have recently been developed and have been shown to be successful (Raskin & Sohlberg, 2009).

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PART II

EMPIRICAL STUDY

CHAPTER 2: JOURNAL ARTICLE

Prospective Memory Functioning After Stroke: Objective and Subjective Assessment

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Running Head: Prospective Memory Functioning After Stroke

*This article has been written in accordance with the Journal of Clinical and
Experimental Neuropsychology author guidelines (Appendix 1)*

Prospective Memory Functioning after Stroke: Objective and Subjective Assessment

Abstract

Background: Impairments in prospective memory have been found in a range of neurological conditions. While it is assumed that stroke patients will have similar deficits, there is currently a dearth of evidence to support this.

Methods: A between-subjects design was employed to compare 22 community-dwelling stroke patients to 22 healthy adult controls.

Results: Stroke patient's prospective memory performance was poorer than controls. Depression had a significant influence on time-based prospective memory tasks. Executive functioning was shown to be a good predictor of overall prospective memory ability.

Conclusion: Prospective memory should be assessed as part of routine clinical practice.

Introduction

Prospective memory is the ability to carry out previously formed intentions at an appropriate point in the future (McDaniel & Einstein, 2007). A distinction has been made between time-based prospective memory tasks, where the intention is triggered by a specific time, and event-based tasks where the intention is carried out in response to a certain external event (Einstein & McDaniel, 1990). A wide range of everyday activities depend on successful prospective memory, such as taking medication at the appropriate time or remembering to pass on a telephone message. As a result, impairments in this ability can have a significant impact on independent living.

Recent research has shown that prospective memory is impaired in a range of neurological conditions including: traumatic brain injury (Carlesimo *et al.*, 2010; Henry *et al.*, 2007; Kinch & McDonald, 2001; Kliegel *et al.*, 2004); multiple sclerosis (Bravin *et al.*, 2000; Kardiasmenos *et al.*, 2008); Parkinson's disease (Altgassen *et al.*, 2007; Foster *et al.*, 2009; Kliegel *et al.*, 2005; Raskin *et al.*, 2011) and early stage or mild dementia (Duchek *et al.*, 2006; Huppert *et al.*, 2000; Kinsella *et al.*, 2007). Although it has been assumed that stroke patients will have similar deficits, few studies have been carried out to explore prospective memory functioning in this population.

To date, only three known studies have investigated prospective memory after stroke (Brooks *et al.*, 2004; Cheng *et al.*, 2010; Kim *et al.*, 2009). The results of these studies are inconsistent. Thus, Brooks *et al.* (2004), found that stroke patients were impaired on time-, event- and activity-based prospective memory tasks compared to controls. However, the magnitude of this impairment was less for the time-based task than the other tasks. In contrast, the study by Cheng *et al.* (2010) found that thalamic stroke patients were impaired on time-based prospective memory task but not on an event-based task when their scores were compared to healthy controls matched on age and education. As the sample in this study was restricted to thalamic stroke patients, this provides tentative evidence that the pattern of prospective memory impairments may be different for different types of stroke. However, more research is needed to explore this as Cheng *et al.* (2010) investigated a relatively small sample and did not use valid and reliable measures of prospective memory.

Kim *et al.* (2009) compared community-dwelling stroke patients to matched controls on two laboratory-based measures of prospective memory (Virtual Week: Rendell & Craik, 2000; Memory for Intentions task: Cohen *et al.* 2001) and a more structured clinical measure of event-based memory, the 'Remembering a Belonging' subtest from the Rivermead Behavioural Memory Test (RBMT; Wilson *et al.*, 1985). There was no difference between the groups on the RBMT subtest. However, stroke patient participants were impaired on the 'prospective' component of the Memory for Intentions test, another event-based measure. The Virtual Week is a board game task where both time- and event-based tasks are carried out over a number of circuits.

Prospective memory is measured under 'regular' (the same four time- and event-based tasks on all circuits), 'irregular' (a different four time- and event-based tasks on each circuit) and 'time-check' (indicating to the researcher when two specific time periods had lapsed) conditions.

Kim *et al.* (2009) found that stroke patients were significantly poorer than controls on the time-check condition but not in the regular or irregular conditions. Therefore, stroke patients were poorer than controls on some but not all of the time-based tasks in this measure. This can be explained by the significant difference between these tasks. For the 'time-based' tasks in the regular and irregular conditions, participants are required to respond to the relevant square as they move around the board. Therefore, these tasks are better described as event-based tasks. In contrast, the time-check condition involves a significant demand on time-monitoring as time is given by a stopwatch placed face-down on the desk. As well as having less correct responses on this task, stroke patients had more 'miss' responses. Taken together, the results of the Kim *et al.* (2009) study showed that stroke patients were impaired on some laboratory measures of event-based prospective memory and on one measure of time-based prospective memory.

The inconsistencies in previous research can be explained by a range of methodological limitations. In particular, a restricted sample of stroke patients have been studied as Cheng *et al.* (2010) only investigated thalamic stroke patients and the majority of patients in the Kim *et al.* (2009) study had 'frontal' lesions. Further to

this, only one study (Kim *et al.*, 2009) used a measure with strong evidence for validity and reliability. In two of the studies (Brooks *et al.* 2004; Cheng *et al.* 2010) neuropsychological assessment of other cognitive functions was also limited. Despite evidence from the acquired brain injury literature that low mood and anxiety may influence prospective memory (Cockburn, 1996; Kinch & McDonald, 2001), none of the studies controlled for this. Therefore, there is a need to carry out further research.

Successful prospective remembering requires recalling the content of the intention as well as the ability to retrieve the intention and carry it out at the appropriate time (Ellis, 1996; Ellis & Kvavilashvili, 2000). Therefore, it has been acknowledged that prospective memory is likely to be a complex cognitive process involving a retrospective component associated with medial temporal structures and a prospective component associated with frontal brain structures (Adda *et al.*, 2008; Brandimonte, 1996). Knight *et al.* (2005) suggests that the underlying cognitive processes responsible for prospective memory deficits are likely to vary as a consequence of the particular brain structures that have been damaged. Damage to medial temporal or diencephalic memory circuits can cause individuals to forget even simple instructions while damage to prefrontal structures may cause problems with executive functions such as initiation and organisation of recall (Knight *et al.*, 2006).

Despite the heterogeneity of stroke, common impairments have been established. In particular, deficits in memory and executive functioning are widespread

(Intercollegiate Stroke Working Party, 2008). Therefore, it is reasonable to expect that stroke patients may be particularly vulnerable to failures of prospective memory. These could occur due to memory impairments or deficits in executive functioning or due to a combination of both. In light of this, it is theoretically and clinically important to gain a more complete understanding of the complex relationship between prospective memory and other cognitive functions.

It is generally assumed that the retrospective component of prospective memory tasks or remembering 'what' has to be done, relies on the same cognitive system as retrospective or declarative memory (Carlesimo *et al.*, 2010). Deficits in the retrospective component of prospective memory tasks have been found in individuals with multiple sclerosis (Bravin *et al.*, 2000; Kardiasmenos *et al.*, 2008), mild Alzheimer's disease (Martins & Damasceno, 2008), brain injury (Adda *et al.*, 2008; Henry *et al.*, 2004) and stroke (Brooks *et al.*, 2004; Cheng *et al.*, 2010; Kim *et al.*, 2009). Correlations have also been found between tests of retrospective memory and prospective memory performance in a mixed neurological group (Groot *et al.*, 2002). Despite these results, a reliable relationship has not been found between retrospective memory and prospective memory and impaired retrospective memory cannot fully account for prospective memory problems in neurological populations (Kinch & McDonald, 2001).

It is clear that intentions cannot be carried out if their content cannot be recalled. However, there is evidence that impairments in executive functioning may be more

influential to prospective memory performance. Deficits in executive functioning have been found to reduce prospective memory independently of retrospective abilities. In a traumatic brain injury sample, Kliegel *et al.* (2004) explored the prospective memory functioning of individuals with intact retrospective memory and impaired executive functioning. Regardless of retrospective memory abilities, individuals with better executive functioning performed better on prospective tasks. It may also be possible for individuals to fail to recall the content of intentions for reasons unrelated to retrospective memory. Costa *et al.* (2010) found that individuals with amnesic and dysexecutive mild cognitive impairment (MCI) were equally impaired in their ability to recall the specific actions to be performed in a prospective memory task. The authors propose that a pure memory deficit was underlying cause in amnesic group while failure to implement strategic retrieval processes explained poor performance of the dysexecutive group.

An interaction between executive functioning and retrospective memory functioning is likely. Although Carlesimo *et al.*, (2010) found an association between number of intentions recalled and two tests of verbal declarative memory, the authors suggest that memory difficulties alone do not explain results. They proposed that executive deficits may have caused poorer encoding of the task instructions and that this combined with a pure declarative memory deficit to produce poor performance on the retrospective component. In support of this, Kinch & McDonald (2001) suggested that successful performance on prospective memory tasks always relies on an interaction between executive functioning and retrospective memory.

A greater understanding of the particular cognitive functions that mediate prospective memory has come from research into the different types of prospective memory task. It has been proposed that time-based tasks are more difficult due to a greater need for controlled, strategic, attentional processing (Einstein & McDaniel, 1990). However, event-based tasks may also require this kind of processing (Smith, 2003; Smith, 2004). It has also been suggested that characteristics of the individual, the specific task and task conditions will determine whether automatic or strategic processes are involved in event-based prospective memory (McDaniel and Einstein, 2000).

The clinical significance of understanding prospective memory deficits after stroke is supported further by evidence that deficits in prospective memory may be a better indicator of everyday memory problems than traditional tests of declarative or retrospective memory. Kinsella (1996) found that self-reports of everyday memory correlated with a prospective memory measure but not with tests of retrospective memory. The authors suggested that assessing prospective memory may be a better indicator of difficulties in everyday life. Prospective memory failures are also reported more often than retrospective difficulties (Mateer *et al.*, 1987) and may cause more distress for caregivers (Smith *et al.*, 2000). It is important to measure psychological and neuropsychological constructs with multiple measures (Crawford *et al.*, 2006). Self-reports of everyday memory ability are also an important aspect of assessment as self-awareness is often compromised after brain injury (Knight, 2005; Kinsella, 2009) and this has significant implications for rehabilitation.

The aim of the present study was to explore prospective memory functioning in a group of community-dwelling stroke patients using a standardised objective measure of prospective memory. It was hypothesised that stroke participants' performance would be poorer than healthy controls on both time- and event-based tasks. It was also of interest to examine whether individuals would find time-based prospective memory tasks more difficult. A secondary aim was to examine the role of other neuropsychological functions in prospective memory performance. Finally, the relationship between self-ratings of everyday memory and objective performance on memory tests was explored to determine whether stroke survivors have reduced insight into their memory abilities.

The following hypotheses were investigated:

1. *The performance of participants in the stroke group will be significantly poorer than participants in the healthy control group on the objective measure of prospective memory.*
2. *There will be a significant difference in performance between time-based and event-based tasks on the objective measure of prospective memory. Time-based tasks will be more difficult for healthy controls and stroke patient participants.*
3. *There will be a relationship between performance on tests of retrospective memory and executive functioning and performance on the objective measure of prospective memory.*
4. *Stroke patients will have reduced insight into their memory abilities.*

Methods

Research Participants

The sample included 22 community-dwelling stroke patients and 22 adult controls. A total of 20 relatives or carers also participated by providing proxy reports for the stroke group. These reports were unavailable for two of the stroke participants. Stroke patients (9 female; 13 male) were recruited by clinicians already in contact with them as part of routine follow-up or continuing care. Relatives or carers were recruited alongside these participants. Patient diagnoses were: haemorrhagic stroke (6); cerebral infarction (7); stroke unspecified as haemorrhage or infarction (9). Time since stroke ranged from six months to six years. All stroke participants were: 18 years or above; living independently in the community after first stroke; fluent in English and able to read. Exclusion criteria were: significant dysphasia; significant visual or hearing impairments; psychiatric diagnosis or chronic substance misuse; history of brain injury or neurological illness other than stroke; diagnosis of a progressive neurological disorder; more than one stroke; learning disability.

A sample of healthy controls (18 female; 4 male) were recruited from the community by means of a poster and information sheet with the researcher's contact details on it. These were distributed along with participant information sheets in targeted venues such as the hospital, community groups, charity shops and carer and support groups. A number of NHS staff interested in neurological conditions were also recruited. All control participants were healthy adults over the age of 18, fluent in English and able

to read. Exclusion criteria for control participants were: history of neurological illness or brain injury; psychiatric diagnosis or chronic substance misuse; learning disability; diagnosis of a progressive neurological disorder; significant visual or hearing impairments.

Demographic characteristics

The proportion of males and females in each group was significantly different ($\chi^2 = 6.14$, $df = 1$, $p < .05$). The healthy controls were younger ($t(42) = -2.58$, $p < .05$) and had more years in education ($t(42) = 3.26$, $p < .05$) than the stroke group. They also had a higher estimated IQ according to performance on the National Adult Reading Test (NART; $t(42) = 2.80$, $p < .05$).

Measures

Prospective Memory

The Cambridge Prospective Memory Test (CAMPROMPT; Wilson *et al.*, 2005) was used as an objective behavioural measure of prospective memory in this study. The CAMPROMPT is a clinically available, standardised measure of prospective memory. It has been normed for individuals from the age of 16 and over the age of 65. Participants are asked to complete a series of distractor puzzles over a 20 minute period. At the same time, they are asked to complete four event-based and four time-based prospective memory tasks, either during the 20 minute session, or at the end of it. At the beginning of the session, participants are provided with paper and a pencil.

They are then informed that they can use any strategy they like to help them to remember tasks.

Intellectual functioning

A measure of premorbid intellectual functioning is required to interpret scores on the CAMPROMPT. The National Adult Reading Test -Second Edition (NART; Nelson & Willison, 1991) was used to develop the normative data for this test. Therefore, it was used in the current study to provide an estimate of premorbid intellectual functioning for the stroke patient participants and an estimate of current intellectual functioning for the healthy control participants.

Standardised neuropsychological assessments

A range of standardised assessments were administered to measure general cognitive functioning, retrospective memory, executive functioning and visuospatial ability in both groups. The Mini Mental State Examination (MMSE; Folstein *et al.*, 1975) was employed to screen for severe cognitive impairment and provide a general measure of cognitive ability. Word Lists I & II (WLI & WLII) from the Wechsler Memory Scale-Third Edition (WMS-III^{UK}; Wechsler, 1997) were used to measure verbal memory. Visual memory was measured using the Rey Complex Figure Test and Recognition Trial (RCFT; Meyers & Meyers, 1995). This test also provides a measure of visuospatial constructional ability. The Tower Test, Verbal Fluency and Trail-Making tests from the Delis Kaplan Executive Function System (D-KEFS;

Delis *et al.*, 2001) were used to measure a range of executive functions including inhibition, planning, attention and flexibility of thought. Abstract thinking was measured using the Similarities subtest from the Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV^{UK}, Wechsler, 2008). The Digit Span subtest from the WAIS-IV^{UK} was used to measure working memory.

Validated questionnaires

The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983) was used to screen for low mood and anxiety in both groups. This is a brief self-report measure of anxiety and depression. There are 14 items in total, half relating to anxiety and half to depression. As well as good homogeneity and test-retest reliability of the total scale and subscales, the dimensional structure and reliability of the HADS has been found to be stable across medical settings and age groups (Spinoven *et al.*, 1997).

The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith *et al.*, 2000) was administered as a subjective measure of everyday memory. This 16-item, self-report questionnaire provides a measure of prospective and retrospective memory functioning in everyday life. The Total, Prospective and Retrospective scales have good reliability and scores are not influenced by age or gender (Crawford *et al.*, 2003). The proxy-version of the PRMQ has also been demonstrated to have good reliability (Crawford *et al.*, 2006).

Procedure

A cross-sectional, parametric between subjects design was employed to compare a sample of community-dwelling stroke survivors to a sample of healthy controls on an objective measure of prospective memory functioning and a subjective measure of retrospective and prospective memory functioning. The study was approved by South East Scotland Research Ethics Committee.

Stroke patient participants

Potential stroke patient participants who met the inclusion criteria were approached by clinicians already providing them with routine follow-up or care. A detailed participant information sheet was distributed by these clinicians. Those who agreed to proceed with the research were offered an appointment either at home or at the hospital. At the point of recruitment, stroke patient participants were asked if someone who knew them well would be able to complete a brief questionnaire about everyday memory. These relative or carer participants were also provided with a detailed information sheet and written consent form.

Healthy adult control participants

A sample of healthy control participants were recruited by means of a poster placed in targeted community venues with the researcher's contact details on it. A number of control participants were also recruited by means of an email forum for staff interested in neurological conditions. Interested participants contacted the researcher

by telephone or email. If individuals agreed to take part, they were provided with an appointment at home or in the hospital.

Administration of the measures

All potential participants had a minimum of 24 hours to consider their participation in the research. Informed consent was obtained prior to the administration of the measures by means of a written consent form. Participants in the stroke and control groups were asked to complete a standardised questionnaire (HADS) to screen for low mood and anxiety, followed by a questionnaire about their everyday memory (PRMQ). Administration of the standardised neuropsychological measures was consistent with the individual protocols for each test. Tests were administered in the same order for all participants in a quiet room. The order was as follows: (1) MMSE; (2) NART; (3) CAMPROMPT; (4) WLI (WMS-III^{UK}); (5) Rey-Complex Figure Test (copy & immediate recall trials); (6) Tower Test, (7) Verbal Fluency (letter and category) and the (8) Trail-Making test from the DKEFS; (9) Similarities and (10) Digit Span (WAIS-IV^{UK}); (11) WLII (WMS-III^{UK}); (12) Rey-Complex Figure (delayed recall trial). Testing took between 90 and 120 minutes to complete. Two shorter sessions were provided if participants were unable to complete the assessment in one appointment.

Results

A preliminary analysis of the data was carried out to assess the normality of the distribution and homogeneity of variance in two samples: stroke patient participants and healthy adult participants. The data were not significantly skewed or kurtic. Where the variance of scores in the two groups was significantly different, the statistic that does not assume equal variance was reported (Welch's t). Inferential statistical analysis was carried out between and within subjects depending on the particular hypotheses being testing. Neuropsychological test scores were converted into standard T scores. T scores were chosen over percentiles or Z scores as the gradation between them is neither too coarse nor too finely graded (Crawford, 2004)

Group differences in clinical screening measures

Stroke patient participants had significantly higher scores for anxiety ($t(33.12) = 2.65, p < .05$) and depression ($t(24.38) = 4.58, p < .01$) as measured by the HADS. Their scores were also significantly lower on the MMSE ($t(23.2) = 3.4, p < .05$). As the variance of scores in the two groups was significantly different for these measures, the statistic that does not assume equal variance was reported (Welch's t).

Group differences in neuropsychological measures

Group differences in the standardised neuropsychological measures were explored using t -tests for independent samples. Stroke patient participants had reduced

retrospective memory abilities when compared to the healthy control group. There was a significant difference between the two groups on all measures of verbal memory (WLI total recall: $t(36) = 5.38, p < .01$; WLII delayed recall: $t(42) = 4.51, p < .01$; WLII recognition: $t(24) = 6.05, p < .01$) and two of the visual memory measures (RCFT immediate recall: $t(42) = 2.95, p < .01$; RCFT delayed recall: $t(42) = 2.91, p < .01$). The difference between the scores on the RCFT recognition trial was not significant ($t(42) = 1.89, p = .06$).

Significant group differences were also found on measures of executive functioning. Patient participants' performance was poorer than healthy controls on the Tower Test ($t(42) = 2.21, p < .05$), Letter ($t(42) = 3.61, p < .01$) and Category Fluency ($t(42) = 3.33, p < .01$), Similarities ($t(42) = 5.36, p < .01$) and Trails 3 ($t(41) = 3.01, p < .01$). The patient participants' scores were also significantly lower on a measure of visuospatial ability (RCFT copy trial: $t(23) = 5.83, p < .01$). The difference between the groups was not significant on measures of working memory (Digit Span Forwards: $t(42) = .75, p = .45$; Digit Span Backwards: $t(37) = 1.60, p = .11$) or cognitive flexibility (Trails 4: $t(41) = 1.69, p = .09$).

The performance of participants in the stroke group will be significantly poorer than participants in the healthy control group on the objective measure of prospective memory.

After adjusting for the influence of age, years in education, estimated FSIQ, anxiety and depression, the performance of the stroke patient participants was significantly

poorer on the objective measure of prospective memory ($F(1,36) = 5.00, p < .05$). Unadjusted and adjusted means can be seen in Table 2.1. The effect size for this result was large ($\eta_p^2 = .12$). A significant relationship was found between depression ($F(1,36) = 4.91, p < .05$) and performance on the CAMPRMPT, with depression accounting for 12 per cent of the variance in total scores. Again, the effect size for this result was large ($\eta_p^2 = .12$).

Table 2.1 Unadjusted and Adjusted mean CAMPRMPT *T* scores for healthy control and stroke groups.

	CAMPRMPT	
	Unadjusted Mean (SD)	Adjusted Mean (SE)
Healthy Controls	54.09 (4.99)	50.54 (2.18)
Stroke Patients	39.22 (10.56)	42.61 (2.11)

There will be a significant difference in performance between time-based and event-based tasks on the objective measure of prospective memory. Time-based tasks will be more difficult.

A repeated measures ANCOVA was carried out with experimental group (stroke patient participants or healthy controls) as the between-subjects factors and type of prospective memory task (time- or event-based) as the within-subjects factor. Age, years in education, anxiety and depression were entered as covariates. The interaction between type of prospective memory task and group was not significant ($F(1,37) = .10, p = .75$) indicating that the change between time and event-based

scores was not significantly different in the two experimental groups. There was also a significant main effect of group ($F(1,37) = 7.01, p < .05$). However, a significant interaction was found between the depression covariate and type of prospective memory ($F(1,37) = 5.52, p < .02$).

The main effect for type of prospective memory task was not significant ($F(1,37) = 3.70, p = .06$). However, where an interaction is present between a covariate and the within-subjects factor, further analysis must be carried out as any change in the within-subjects effect is an artefact of the calculations performed by SPSS (Van Breukelen & Van Dijk, 2007). This can be corrected by centring the means of covariates prior to the ANCOVA by subtracting the group mean from each subject's individual mean. The ANCOVA was re-run with depression as the only significant covariate. After centring the means for this covariate, the interaction between group and type of prospective memory task was non-significant ($F(1,40) = .00, p = .99$) and there were significant main effects of type of prospective memory task ($F(1,40) = 6.12, p < .05$) and group ($F(1,40) = 18.98, p < .01$). This indicated that time-based tasks were more difficult for both groups. However, healthy control participants performed at a higher level than stroke participants on both types of prospective memory task.

To further explore the impact of depression on type of task, one-way ANCOVAs were carried out. Separate ANCOVAs were run for time-based performance and event-based performance with depression as a covariate. Depression was found to

make a significant unique contribution to time-based performance ($F(1,43) = 5.02$, $p < .05$) but not to event-based performance ($F(1,43) = .25$, $p = .61$). The effect size for the contribution of depression to time-based performance was large ($\eta_p^2 = .11$).

There will be a relationship between prospective memory and measures of executive functioning and retrospective memory.

Pearson's correlations were carried out to explore the relationship between performance on the neuropsychological measures and performance on the CAMPRMPT. As performance on these measures should contribute to prospective memory scores in both stroke patients and healthy controls, the groups were combined for this analysis. There was an association between higher performance on these measures and higher CAMPRMPT scores.

As shown in Table 2.2, significant positive correlations were found between performance on the CAMPRMPT and all measures of verbal memory (WLI total recall: $r = .45$, $n = 44$, $p < .01$; WLI delayed recall: $r = .41$, $n = 44$, $p < .01$; WLI recognition: $r = .60$, $n = 44$, $p < .01$), a measure of visuospatial ability (RCFT copy trial: $r = .55$, $n = 44$, $p < .01$) and a measure of visual recognition memory (RCFT recognition trial: $r = .42$, $n = 44$, $p < .01$). Significant positive correlations were also found between performance on the CAMPRMPT and some measures of executive functioning (Letter fluency: $r = .35$, $n = 44$, $p < .05$; Trails 3: $r = .45$, $n = 44$, $p < .01$; Digit span backwards: $r = .40$, $n = 44$, $p < .01$; Similarities: $r = .47$, $n = 44$, $p < .01$).

Table 2.2 Correlations between performance on neuropsychological measures and total CAMPROMPT scores for all participants.

	CAMPROMPT		
	Pearson Correlation	Sig. (2-tailed)	<i>N</i>
WLI			
Total Recall	0.45	0.002	44
WLII			
Delayed Recall	0.41	0.005	44
Recognition	0.60	0.0005	42
RCFT			
Copy	0.55	0.0005	44
Immediate Recall	0.22	0.161	44
Delayed Recall	0.25	0.096	44
Recognition Trial	0.42	0.004	44
DKEFS			
Tower Test	0.14	0.368	44
Letter Fluency	0.35	0.022	44
Category Fluency	0.25	0.107	44
Trails 3	0.45	0.002	43
Trails 4	0.22	0.154	43

WAIS-IV			
DSF	0.29	0.057	44
DSB	0.40	0.007	44
Similarities	0.47	0.001	44

Hierarchical multiple regression analyses were carried out to explore the relative contribution of retrospective memory and executive functioning to performance on three separate dependent variables: CAMPROMPT total score, total time-based score and total event-based score. The experimental groups were combined for this analysis and two composite scores were formed, one to combine retrospective memory measures and another to combine executive functioning measures. Visuospatial functioning was retained as a separate independent variable. In light of the relationship between depression and performance on the objective measure of prospective memory, hierarchical multiple regression was selected to control for effect of this covariate. Depression was entered in the first step, followed by the three neuropsychological variables (retrospective memory composite score; executive functioning composite score; visuospatial functioning).

CAMPROMPT Total score

The regression model containing depression and all of the neuropsychological variables explained 49.1 per cent of the variance in the CAMPROMPT *T* score ($F(4,42) = 9.17, p < .01$). Retrospective memory and visuospatial ability were shown to

be poor predictors of CAMPRMPT score. However, depression (Beta= -1.57, SE= .52, $p < .01$) and executive functioning (Beta= .06, SE= .03, $p < .05$) both made a significant unique contribution to explaining the variance in total CAMPRMPT scores.

Time-based score

Retrospective memory, executive functioning and visuospatial ability were shown to be poor predictors of total time-based scores. The regression model containing depression and all of the neuropsychological variables explained 45.2 per cent of the variance in the time-based scores ($F(4,38) = 7.83$, $p < .01$). Depression (Beta= -.37, SE= .26, $p < .05$) made the strongest unique contribution to explaining performance.

Event-based score

In the event-based analysis, anxiety and depression were both entered in the first model. This explained 17.1 per cent of the variance in event-based scores ($F(2,40) = 4.12$, $p < .05$), neither depression nor anxiety made a significant unique contribution. In the second model; retrospective memory, executive functioning and visuospatial ability were also shown to be poor predictors of event-based score. This model explained 28 per cent of the variance in the event-based scores ($F(5,37) = 2.88$, $p < .05$).

Stroke participants will have reduced insight into their memory abilities.

For the purposes of this analysis, insight into memory functioning was assessed in three different ways. Firstly, stroke participants' PRMQ self-ratings were compared to control participants' PRMQ self-ratings. Stroke participants' self-ratings were then compared to proxy-ratings by relatives or carers. Finally, the relationship between PRMQ self-reports and objective measures of prospective and retrospective memory were explored. All scores from the PRMQ were converted into standard *T* scores with increasing scores indicating more favourable ratings.

Comparison of PRMQ self-reports

Adjusting for the influence of anxiety and depression with ANCOVA, healthy controls and stroke patients did not differ in their self-ratings of everyday prospective and retrospective memory ($F(1,39)= 1.99, p= .16$). This indicates that, despite poorer performance on objective measures of prospective and retrospective memory, stroke patient participants did not rate their everyday memory abilities any differently to healthy controls.

Comparison of PRMQ self-reports and PRMQ proxy-reports

A repeated measures ANOVA was used to examine the difference between patient self-reports and proxy reports. There was no difference between the groups ($F(1,19) = .35, p= .55$). There was also a significant correlation between self-report ratings and proxy ratings ($r= .72, p< .01$).

Comparison of PRMQ self-reports and objective measures of prospective and retrospective memory

There was a medium positive correlation between stroke patient's total PRMQ score and their performance on the CAMPROMPT ($r = .44$, $n=22$, $p < .05$). This indicates that increasingly positive appraisals of everyday memory were associated with increasing scores on the CAMPROMPT. A significant negative correlation was also found between PRMQ self-reports and depression ($r = -.64$, $n=22$, $p < .01$) and anxiety ($r = -.63$, $n=22$, $p < .1$) indicating that as anxiety and depression increase, appraisals of everyday memory become increasingly negative.

Discussion

Main findings

The aim of the present study was to explore prospective memory functioning in community-dwelling stroke survivors. It was predicted that the performance of stroke patient participants would be significantly poorer than healthy adult controls on a standardised objective measure of prospective memory. This hypothesis was supported. The results are consistent with findings from previous stroke studies (Brooks *et al.*, 2004; Cheng *et al.*, 2010; Kim *et al.*, 2009). Time-based tasks were more difficult than event-based tasks for both groups. This supports the findings by Groot *et al.* (2002). However, a significant main effect of group was found indicating that stroke patient's performance was poorer than controls on both types of prospective memory task.

The finding that time-based tasks were more difficult for both stroke patients and healthy adult controls was expected based on the theoretical argument that time-based tasks involve more effortful, controlled processing than event-based tasks which are better supported by environmental cues. There has been significant theoretical (McDaniel & Einstein, 2000; Smith, 2003) and empirical interest in defining the processes involved in event-based performance (Henry *et al.*, 2007; Kliegel *et al.*, 2004; Maujean *et al.*, 2003; Schmitter-Edgecombe & Wright, 2004). However, the empirical exploration of time-based task conditions has not been equal

as there is a general consensus in the literature that time-based tasks are more difficult.

There is evidence that more salient cues can improve prospective memory performance. Cockburn (1996) found visually distinctive cues produced a higher success rate. This is relevant to the current study as one of the time-based tasks in the CAMPROMPT involves a large clock placed in front of the participant while the other two involve monitoring a timer that counts down. The experimental time-based tasks in the literature have been more challenging. Typically, participants have to turn their heads to monitor a clock behind them. The CAMPROMPT tasks also have strong visual cues. For example, several items to be passed to the researcher are placed on the desk in front of the participants for the duration of the test. The role of visual memory in these tasks is supported by correlational analysis. Positive relationships were observed between visual memory measures and CAMPROMPT performance.

The tasks in the CAMPROMPT are designed to be analogous to everyday activities and may be better supported by environmental cues than the tasks typically employed to test time-based performance. However, significant reductions were found in the present study indicating that time-based tasks are vulnerable to stroke even in less demanding conditions. The influence of depression on these tasks suggests that even moderate levels of depression can have significant consequences for prospective remembering

Relationships were found between prospective memory performance and a range of retrospective memory and executive functioning measures in the current study. However, multiple regression analyses revealed level of depression and executive functioning abilities as the only significant predictors of performance. Increasing levels of depression were associated with poorer CAMPROMPT performance, while increased executive abilities were associated with higher prospective memory performance. Regression analysis of time- and event-based performance separately showed that level of depression was a good predictor of time-based performance. Although measures of low mood and anxiety and neuropsychological functioning contributed to event-based performance, none of these measures made a unique contribution. These results provide support for the role of executive functions in time-based tasks.

The results regarding insight are mixed. However, there is some evidence that stroke patient's insight into their memory abilities is not complete. Despite evidence that they performed at a significantly lower level on objective tests of prospective and retrospective memory, stroke patient participants did not rate their everyday memory ability any differently to controls. This is in contrast to the finding that individuals with brain injury often report prospective memory as one of their most significant areas of impairment (Hannon *et al.* 1995). Although total PRMQ self-ratings had a positive correlation with CAMPROMPT scores, analyses of the prospective and retrospective subscales indicates that there was no relationship between self-ratings

of prospective memory and objective prospective memory performance. Equally, retrospective PRMQ ratings were not associated with objective retrospective memory ability. The positive relationship between total PRMQ self-ratings and CAMPROMPT scores appears to be explained by the association between retrospective memory scale ratings and CAMPROMPT performance.

Clinical implications

The results of the current study support the assumption that prospective memory deficits are widespread after stroke. As prospective memory is a multi-component process, there are likely to be a variety of potential pathways to these deficits. Therefore, evaluation of prospective memory abilities should be carried out as part of a comprehensive neuropsychological assessment. Unfortunately, this is currently rare in routine clinical practice as assessment of memory abilities has traditionally focussed on retrospective memory or memory for past events. In common with previous studies, the present results indicate that measures of retrospective memory are not good predictors of prospective memory functioning. This has implications for clinical practice as unrecognised difficulties with prospective memory may restrict individuals' ability to engage in or adhere to rehabilitation strategies. In contrast to retrospective memory, executive functioning was shown to be a good predictor of prospective memory performance. Therefore, it is particularly important to assess prospective memory where executive deficits are present as these individuals are likely to require support to carry out delayed intentions.

Due to the high level of comorbid mood disturbances in stroke survivors, the finding that depression impacts on time-based prospective memory functioning is significant. Individuals who are depressed will likely have further difficulties with time-based tasks than those who are not depressed. As prospective memory is crucial for completing a wide range of everyday activities, it is also possible that individuals with greater deficits in this aspect of cognitive functioning will be more vulnerable to anxiety and depression. Mood disturbances and prospective memory difficulties may reinforce each other as part of a vicious circle. Therefore, clinicians should routinely screen for low mood and anxiety at the assessment stage and continue to monitor for mood disturbances during rehabilitation. Clinicians who are working with depression after stroke should also be aware of its impact on prospective memory abilities.

The finding that the stroke patients in the present study had reduced insight into their memory functioning also has implications for assessment and treatment. Without a comprehensive assessment, individuals may be unable to report failures of prospective memory. They may also have difficulty differentiating between memory for future intentions and memory for past events, attributing everyday failures of prospective memory to poor short-term memory or poor memory for past events. Similarly, individuals with everyday experience of good prospective memory may attribute this to having a good memory for past events. The finding that there was a positive relationship between positive self-ratings of retrospective memory and better performance on the objective measure of prospective memory provides some support for this.

Conclusion

Prospective memory difficulties are prevalent after stroke and should be routinely assessed in clinical practice. Individuals with poor executive functioning and comorbid mood disturbances are likely to be particularly vulnerable to difficulties with this aspect of cognitive functioning. Therefore, clinicians should screen for these difficulties at the assessment stage and continue to monitor individuals throughout rehabilitation.

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CHAPTER 3: EXTENDED METHODOLOGY

3.1 Design

A cross-sectional, parametric between subjects design was employed to compare a sample of community-dwelling stroke survivors to a sample of healthy controls on an objective measure of prospective memory functioning and a subjective measure of retrospective and prospective memory functioning. Within subjects analysis was carried out to explore performance on different types of prospective memory task. To explore the relationship between prospective memory and other cognitive functions, the two samples were also compared on objective measures of retrospective memory, executive functioning and visuospatial functioning. To control for possible confounds, participants were screened for low mood, anxiety and IQ. The independent variable is the presence of stroke and the dependent variables are objective and subjective indices of prospective memory.

3.1.1 Ethics

The study was reviewed by academic staff at the University of Edinburgh. Favourable ethical approval was granted by NHS Lothian Research Ethics Committee (Appendix 2). Management approval was obtained from NHS Highland to carry out the research (Appendix 3) and NHS Highland Research and Development Department acted as the sponsor for this study.

3.1.2 Ethical Considerations

Potential ethical issues regarding capacity to consent were not applicable as all participants included in the study were living independently in the community and able to provide informed consent. It was acknowledged that participation in this study could uncover previously undiagnosed clinical problems. To address this, consent was obtained prior to assessment for the researcher to inform participants if any clinical issues were identified. Consent was also obtained to contact participants' General Practitioner if necessary. It was also possible that participants would disclose psychological distress during the study. In this case, further assessment would have been provided.

As the study potentially involved vulnerable adults, a further ethical concern was method of recruitment. Participants in the stroke group were recruited by clinicians already in contact with them as part of routine follow-up or care. All participants were 18 years or above and there was no upper age limit. Before consenting to take part in the study, participants were able to discuss any concerns with the researcher. They were also given the contact details of an independent person from Chest, Heart & Stroke Scotland. It was emphasised that participation in the research was voluntary and individuals could withdraw at any time. It was also made clear that declining to participate in the study would have no effect on current or future treatment. Following their participation in the study, all individuals had the option to request brief written feedback of their results.

Participation involved undergoing a battery of neuropsychological assessments for a period of 90 minutes up to a maximum of two hours. Therefore, all participants were offered a short break during testing. If participants could not complete the assessment in one session due to fatigue, they were provided with a second appointment. A key ethical consideration was whether to exclude stroke participants with a diagnosis of dysphasia. It was decided that individuals would only be excluded if, based on the clinical judgement of the referring clinician and the researcher, their receptive or expressive language abilities were significantly impaired to the level that they would be unable to engage in the neuropsychological assessments.

3.2 Participants

A purposive sample was sought for two independent groups: stroke patient participants and healthy adults. For each stroke patient participant, a carer or relative was also recruited to complete a proxy version of the Prospective and Retrospective Memory Questionnaire (PRMQ; Smith *et al.*, 2000).

3.2.1 Stroke patient participants

Participants in the stroke group were a sample of individuals living independently in the community following first their first stroke at least six months previously. Participants were: 18 years or above; living in the community post first stroke; fluent in English and able to read. Exclusion criteria were: significant dysphasia; significant visual or hearing impairments; psychiatric diagnosis or chronic substance misuse; history of brain injury or neurological illness other than stroke; diagnosis of a

progressive neurological disorder; more than one stroke; learning disability.

3.2.2 Relative or carer participants

For each participant in the stroke group, a relative, friend or carer participant was also recruited. They were asked to complete a proxy version of a brief, 16 item questionnaire about everyday memory mistakes (PRMQ; Smith *et al.*, 2000). These participants were recruited at the same time as the stroke patient participants. Recruiting clinicians asked patients whether someone who knew them well would be able to fill in a brief questionnaire. Prior to completing this questionnaire, relative or carer participants were provided with an information sheet (Appendix 4) and consent form (Appendix 5). They either completed this by coming along to the session with the stroke patient participant or, if this was not convenient, the relevant documents were sent to them in the post. In this case, they were provided with a pre-paid envelope.

3.2.3 Healthy adult participants

A sample of healthy adult controls were recruited. An attempt was made to match them for age to stroke participants. Control participants were recruited from the community by means of a poster with the researcher's telephone number on it. These were distributed in target venues such as the hospital, community groups, charity shops and carer and support groups. Following the distribution of the poster on an email forum for those with a special interest in neurological disorders, a number of NHS Highland staff were also recruited. All control participants were healthy adults

over the age of 18, fluent in English and able to read. Exclusion criteria for control participants were: history of neurological illness or brain injury; psychiatric diagnosis or chronic substance misuse; learning disability; diagnosis of a progressive neurological disorder; significant visual or hearing impairments.

3.2.4 Determining sample size and power

The sample size for the present study was calculated by examining the effect sizes from similar studies. Only three known studies have measured prospective memory functioning in a stroke group compared to healthy controls (Brooks *et al.*, 2004; Cheng *et al.*, 2010; Kim *et al.*, 2009). In all of these studies, a significant difference in prospective memory functioning was found between the clinical group and the control group. As the stroke sample in Cheng *et al.*'s (2010) study was restricted to thalamic stroke patients and Brooks *et al.* (2004) employed a virtual reality measure, the study by Kim *et al.* (2009) was considered to be closest to the proposed study. Using valid and reliable measures of prospective memory, these authors found significant impairments in 12 community-dwelling stroke survivors compared to 12 controls matched for age and education. In common with the proposed study, the groups were also compared on standardised measures of executive functioning and immediate memory.

Three different measures of prospective memory were employed by Kim *et al.* (2009), the Virtual Week (Rendell & Craik, 2000), a modified version of the Memory for Intentions task developed by Cohen *et al.* (2001) and the Remembering a Belonging subtest from the Rivermead Behavioural Memory Test (RBMT, Wilson *et*

al., 1985). The Virtual Week was selected as the main outcome as it provides the broadest measure of prospective memory. A range of scores are available for this test. Therefore, a decision was made regarding which outcome was closest to a measure of overall prospective memory performance.

Performance on the Virtual Week is measured under 'regular' (the same four time- and event-based tasks on all circuits), 'irregular' (a different four time- and event-based tasks on each circuit) and 'time-check' (indicating to the researcher when two specific time periods have elapsed) conditions. Responses are also further categorised as, 'correct', 'wrong', 'late' or 'miss'. The closest outcome to an index of overall prospective memory ability was considered to be the proportion of correct responses (collapsed over all conditions). Kim *et al.* (2009) reported a large effect size ($\eta_p^2 = .30$) for the difference between the groups on this measure.

A study by Groot *et al.* (2002) was also examined to estimate the required sample size. The main outcome measure in this study (The Cambridge Behaviour Prospective Memory Test; CBPMT; Kime *et al.*, 1996) is an earlier version of the principal measure in the proposed study. Groot *et al.* (2002) found that the prospective memory performance of a mixed neurological group was significantly poorer than healthy controls. As the sample sizes are unequal in this study, the effect size was calculated using a formula for unequal-*n* designs (Rosnow *et al.*, 2000). The difference between the means on the CBPMT was very large ($d = 1.7$). This indicates that the overlap between the CBPMT scores between the two distributions was less

than 30 per cent (Becker, 2000).

In light of the effect sizes in the studies by Kim *et al.* (2009) and Groot *et al.* (2002), it was predicated that the difference between healthy controls and stroke survivors in the proposed study would be marked. Therefore, it was considered appropriate to estimate a large effect size. G*power, a general power analysis program (Erdfelder *et al.*, 1996) was used to calculate the minimum number of participants required to detect a large effect size when using 1-tailed independent *t*-tests. A large effect size (.80) and a significance criterion of .05, at power of .80, would predict that to detect a large difference between two groups a sample size of 21 is required in each group. A total of 22 individuals in both groups participated in the present study, meeting the conditions to detect a large effect.

3.3 Measures

3.3.1 Demographic Information

Demographic information regarding gender, age and level of education was collected from the both the stroke patient and control participants. Information regarding time since stroke and type of stroke was collected from stroke participants' medical records. Consent for this was obtained prior to participation.

3.3.2 Validated Questionnaires

All participants in the study were asked to complete a brief questionnaire regarding their own memory or, in the case of the relative or carer participants, the memory of

their relative, friend or partner. The patient and control participants were also asked to complete a brief screening measure for low mood and anxiety. Each of these will be described in turn.

3.3.2.1 The Prospective and Retrospective Memory Questionnaire (PRMQ; Smith et al., 2000).

This self-report questionnaire provides a subjective measure of prospective and retrospective memory failures in everyday life. The questionnaire consists of 16 items, eight relating to prospective memory and eight relating to retrospective memory. Items are further divided into eight categories (prospective memory/retrospective memory x short-term/long-term x self-cued/environmentally cued). Individuals rate how often they experience particular types of memory mistake on a five-point scale (very often; quite often; sometimes; never; rarely). This results in a minimum score of 16 and a maximum score of 80. The Total, Prospective and Retrospective scales have good reliability (Cronbach's alpha .89, .84 and .80 respectively) and scores are not influenced by age or gender (Crawford *et al.*, 2003). The proxy-version of the PRMQ has also been demonstrated to have good reliability with Cronbach's alpha of .92 for the Total scale, .87 for the Prospective scale and .83 for Retrospective scale (Crawford *et al.*, 2006). Equal assessment of both types of memory in this questionnaire allows for a broader measure of everyday memory and provides information about the relative frequency of prospective and retrospective complaints (Smith *et al.*, 2000).

3.3.2.2 *The Hospital Anxiety and Depression Scale (HADS; Zigmond & Snaith, 1983).*

The Hospital Anxiety and Depression Scale is a brief self-report measure of anxiety and depression. There are 14 items in total, half relating to anxiety and half to depression. For both subscales, raw scores of between 8 and 10 identify mild cases, 11–15 moderate cases, and 16 or above, severe cases. As well as good homogeneity and test-retest reliability of the total scale and subscales, the dimensional structure and reliability of the HADS has been found to be stable across medical settings and age groups (Spinhoven *et al.*, 1997). In a review of 747 papers that had used the HADS, Bjelland *et al.* (2002) found that Cronbach's alpha for HADS-Anxiety varied from .68 to .93 (mean .83) and for HADS-Depression from .67 to .90 (mean .82). They also noted sensitivity and specificity for both HADS-Anxiety and HADS-Depression of approximately .80. Crawford *et al.* (2001) provided normative data for the HADS and found that demographic variables have only a modest influence on test scores. There is evidence that the HADS has the same properties whether it is used with the general population, in general practice or with psychiatric patients (Bjelland *et al.* 2002) making it an appropriate screening instrument for the current study.

3.3.3 *Standardised Neuropsychological Tests*

A standardised neuropsychological test was administered to gain an objective measure of prospective memory functioning. Further neuropsychological tests were administered to both groups to measure: general cognitive functioning; premorbid

intellectual functioning; retrospective memory; executive functioning and visuospatial ability. The following measures were used:

1. The Mini Mental State Examination.
2. The National Adult Reading Test.
3. The Cambridge Prospective Memory Test.
4. Word Lists I & II: Wechsler Memory Scale - Third Edition.
5. Rey-Oesterrieth Complex Figure Test.
6. Tower Test, Verbal Fluency and Trails: Delis-Kaplan Executive Function System.
7. Similarities and Digit Span: Wechsler Adult Intelligence Scale – Fourth Edition.

Each test will be described and discussed in turn.

3.3.3.1 The Mini Mental State Examination (MMSE; Folstein et al., 1975).

The Mini Mental State Examination is a brief, standardised assessment of mental state that requires only 5-10 minutes to administer. It provides an assessment of orientation, memory and attention, as well as the ability to name, follow written and verbal commands, write a sentence and copy a complex pentagon (Folstein *et al.*, 1975). This measure was employed in the present study to screen for severe cognitive impairment. The MMSE has also been used as a brief measure of general cognitive functioning in previous stroke studies (Cheng *et al.*, 2010; Kim *et al.*, 2009). A comprehensive review of the MMSE by Tombaugh *et al.* (1997) found satisfactory reliability and construct validity. However, measures of criterion validity showed

high levels of sensitivity for moderate to severe cognitive impairment and lower levels for milder cognitive impairment. Content analysis by the authors also revealed that the MMSE is highly verbal and not all items are equally sensitive to cognitive impairment.

A further difficulty with the MMSE is that scores are strongly influenced by age and education (Lezak *et al.*, 2004). There is also some evidence that different cognitive functions are associated with total MMSE scores at different ages, with individual differences in reasoning ability having the strongest relationship in younger adults and differences in memory ability taking precedence in individuals over the age of 70 (Soubelet & Salthouse, in press). Despite these limitations, the MMSE was deemed appropriate for the present study as it was primarily used to screen for severe cognitive impairment. A comprehensive assessment of cognitive functioning is provided by the wider test battery. The brevity of the MMSE also means that it did not significantly add to the burden of testing for participants

3.3.3.2 The National Adult Reading Test -Second Edition (NART; Nelson & Willison, 1991).

The NART is a measure of premorbid intellectual functioning. Individuals are asked to read aloud 50 irregular words that increase in difficulty. To minimise the possibility of reading by phoneme decoding or 'sounding out', rather than word recognition, the words do not follow normal rules of pronunciation. Therefore, correct pronunciation relies on prior knowledge of the word. In the original study by

Nelson & O'Connell (1978) performance on the NART was shown to be resistant to cortical atrophy. The NART has been shown to have high construct validity as a measure of general intelligence (Crawford *et al.*, 1989), high interrater reliability and high test-retest reliability (Crawford *et al.*, 1992). Estimated premorbid IQ as measured by the NART has also been shown to have a higher correlation with Wechsler Adult Intelligence Scale (WAIS/WAIS-R) scores than those estimated by demographic variables (Crawford *et al.*, 2001).

Evidence for the use of the NART in brain injured populations is mixed. Crawford *et al.* (1988) found there was no significant difference in NART performance between normal controls and individuals with dementia or closed head injury. Watt & O'Carroll (1999) investigated the utility of a range of premorbid measures in a closed head injury population and found the same result. However, a recent study by Morris *et al.* (2005) found that performance on the NART was affected by brain injury severity with greater severity associated with poorer performance. In light of this, it is possible that some stroke patient's premorbid IQ may be underestimated by the NART. However, other measures of premorbid intelligence such as the Wechsler Test of Adult Reading (WTAR) may also be influenced by brain injury (Morris *et al.*, 2005). A measure of premorbid intellectual functioning is required to interpret scores on the Cambridge Prospective Memory Test (CAMPRMPT; Wilson *et al.*, 2005) and, as the NART was used to develop the normative data for this test, it was deemed to be the most appropriate measure of premorbid functioning.

3.3.3.3 *The Cambridge Prospective Memory Test (CAMPROMPT; Wilson et al., 2005).*

The CAMPROMPT is a clinically available, standardised objective measure of prospective memory. Participants are asked to complete a series of distractor puzzles over a 20 minute period. At the same time, they are asked to complete four event-based and four time-based prospective memory tasks, either during the 20 minute session, or at the end of it. At the beginning of the session, participants are provided with paper and a pencil. They are then informed that they can use any strategy they like to help them to remember tasks.

The CAMPROMPT has been normed for adults from the age of 16 and over the age of 65. Norms were collected in the original study for a mixed neurological clinical group including individuals with diagnoses of, traumatic brain injury (TBI), progressive and non-progressive neurological disorders and cerebrovascular accident (CVA). Correlations were found for the clinical group between performance on the CAMPROMPT and performance on a range of other neuropsychological measures. The scoring system for the CAMPROMPT is highly reliable (interrater reliability of .99). A small practice effect was found on test-retest reliability. However, two parallel forms are available. Wilson *et al.* (2005) found no significant difference on performance between these forms. Therefore, either version can be used if re-test is required at a later date.

3.3.3.4 *Word Lists I & II: Wechsler Memory Scale-Third Edition (WMS-III^{UK}; Wechsler, 1997).*

Word Lists is an optional subtest from the WMS-III^{UK}. It provides a quick to administer measure of immediate and delayed verbal memory. The examiner reads aloud a list of 12 semantically unrelated words and instructs the examinee to recall them in any order. This list is read aloud in the same order over four trials. Following the presentation of a one-trial interference list of 12 words, a short-delay recall trial is administered where examinees are asked to recall the original list. Subjects are instructed that there will be a delayed recall trial approximately 30 minutes later. After this delayed trial, a recognition task is administered where examinees are asked to correctly identify the 12 target words from a list containing an equal number of unrelated new words.

Lezak *et al.* (2004) suggest that every memory assessment should include immediate recall, delayed recall after a period of interference and a test of recognition. Word Lists fulfils this requirement. The average reliability of the optional subtests in the WMS-III ranges from .74 to .93 with a median of .81 and an inter-rater reliability of .90 (Wechsler, 1997). Test re-test showed an average stability between .62 and .82 with a median of .71 (Wechsler, 1997). A potential limitation of this measure is that normative data is only available from 16-80 years. Therefore, scores for individuals over the age of 70 should be interpreted with caution (Wechsler, 1997). Due to the normative sample's low performance in the 55-65 age bracket (average delayed recall of only 3.5 words), a recall of only one word on the delayed trial is scored in

the low-average range (Lezak *et al.*, 2004).

3.3.3.5 Rey Complex Figure Test and Recognition Trial (RCFT; Meyers & Meyers, 1995).

This test provides a measure of visuospatial constructional ability and visual memory. Subjects are presented with a complex figure and asked to copy it. Without prior warning, they are then asked to draw the figure from memory immediately after a short-delay and later after a long-delay. A copy score allows a measure of visuospatial constructional ability. A recognition trial is also presented. Provided that the long-delay trial is presented within an hour, the length of delay does not affect subject's performance and, in normal subjects, there is very little difference between the immediate and delayed recall trials (Spreeen & Strauss, 1998). The reliability and validity of the RCFT has been described by Meyers and Meyers (1995). Inter-rater reliability coefficients ranged from .93 to .99 for total raw scores with a median of .94 indicating excellent inter-rater reliability. Due to ceiling effects in the copy, recognition true positive and recognition true negatives trials, test-retest reliability was only reported for scores with sufficient range and distribution of scores. Pearson correlations were .75 for the immediate trial, .88 for the delayed trail and .87 for the recognition trial. There was 100% agreement for the other scores based on t-tests. The RCFT also has good construct validity and correlates with other tests. The Convergent and discriminant validity shows it is a measure of visuospatial constructional ability and visuospatial memory

3.3.3.6 Tower Test, Verbal Fluency & Trail-Making Test: Delis Kaplan Executive Function System (D-KEFS; Delis *et al.*, 2001).

The D-KEFS is a set of nine stand-alone measures that provide a comprehensive assessment of key executive functions. Two general types of component process are isolated and measured by the tests, fundamental cognitive skills on which the higher-level executive functions depend and multiple higher-level cognitive functions that contribute to successful performance on a particular test (Swanson, 2005). It was not desirable to use all of the D-KEFS measures in the current study as this would have significantly increased the burden of testing for participants. Therefore, a range of tests were selected to contribute to a broad measure of executive functioning. As all of the subtests used in the study are modifications of earlier experimental tests there is a large body of evidence for their validity (Delis *et al.*, 2001). The D-KEFS tests have also been normed for participants from 8 to 89 years (Lezak *et al.*, 2004).

Multi-process theories of executive functioning, of which Shallice's supervisory attentional system (SAS) is the longest established, propose that the frontal lobe executive system consists of a number of different components that work together to accomplish everyday tasks (Burgess & Alderman, 2004). As deficits in these components can occur in isolation, Burgess *et al.* (1998) recommend that assessment of executive functioning should at least include: a general measure of inhibitory abilities; measures of executive memory abilities (i.e., working memory and delayed word list recall) and a measure of multitasking ability. Burgess & Alderman (2004) suggest that these tests should then be supplemented with measures of other

executive abilities such as rule attainment and following, planning, abstract reasoning and initiation. Subtests from the D-KEFS were selected with this in mind.

3.3.3.6.1 Tower Test

The D-KEFS Tower Test requires participants to move disks of varying sizes across three pegs to build a target tower in the fewest number of moves. They are also asked to observe two rules. This test was selected for the present study as it measures a broad range of executive abilities including, spatial planning, rule learning, inhibition of impulsive and perseverative responding, and the ability to establish and maintain instructional set. Key fundamental cognitive abilities also assessed by this task include visual attention and visual-spatial skills (Swanson, 2005). The primary measure is total achievement score. This test has moderate internal consistency and test retest reliability (Delis *et al.*, 2001).

3.3.3.6.2 The Trail-Making Test – Conditions 3 & 4

The Trail-Making Test has five conditions, all of which require the participant to connect target circles in a visual array by drawing a line through them. The primary executive measure in this test is the Number-Letter Switching condition (condition 4). In this condition, participants are presented with an array of numbers and letters. They are instructed to connect letters and numbers in an alternating fashion so that the letters are connected alphabetically and the numbers are in numerical order (1, A, 2, B etc.). This test was used in the present study as a measure of attention and flexibility of thinking. It can also be used as a test of planning (Lezak *et al.*, 2004).

The primary measure for this task is completion time. Condition 3 was also administered to control for difficulties with letter-sequencing. In this condition participants are required to connect target letters alphabetically, ignoring distractor numbers.

3.3.3.6.3 Verbal Fluency - Letter and Category Conditions

Verbal fluency tasks require individuals to generate as many words as possible within a given time-limit (60 seconds). In the letter fluency condition, participants are asked to generate lists of words beginning with a particular letter. There are three trials in this condition (F, A, S). Category fluency requires participants to first list as many animals as possible within the 60 second time-limit and then list as many boy's names as possible in 60 seconds. Letter Fluency has been shown to have moderate to high internal consistency. Category fluency has lower internal consistency. Delis *et al.* (2001) report that the test re-test reliability for both conditions is good to high.

3.3.3.7 Similarities & Digit Span: Wechsler Adult Intelligence Scale-Fourth Edition (WAIS-IV^{UK}, Wechsler, 2008).

The WAIS-IV^{UK} is a comprehensive test battery with excellent psychometric properties. A large standardisation sample of 2200 individuals means that normative data is available for individuals up to the age of 90. The similarities and digit span subtests provide measures of abstract thinking and working memory respectively. They were selected for the current study to add to the executive functioning measures from the DKEFS. The reliability of the WAIS-IV^{UK} subtests are reported by Wechsler

et al. (2008). Across the age ranges, the average split-half reliability of the similarities subtest is good (.87) as is test-retest stability (.87). The average split-half reliability of the digit span subtest is excellent (.93) with a test-retest stability of .87. The reliability and validity of the WAIS-IV^{UK} has been demonstrated in a wide range of clinical populations including a brain injured sample (Wechsler *et al.*, 2008).

3.4 Procedure

Favourable ethical and management approval was obtained from NHS Lothian Research Ethics Committee and NHS Highland respectively (see appendices).

3.4.1 Stroke patient participants

Participants in the stroke group were approached in the first instance by clinicians from NHS Highland and Chest, Heart & Stroke Scotland who were already providing routine follow-up or care. Potential participants who met the inclusion criteria were provided with a participant information sheet (Appendix 6) by these clinicians. If individuals were interested in finding out more about the research, or agreed in principal to take part, verbal consent was obtained for their telephone contact details to be passed to the researcher. All potential participants were given a minimum of 24 hours to read the relevant documentation and consider their participation in the study. The researcher then contacted them by telephone to discuss the research and answer any questions or concerns. If they agreed to take part, they were offered an appointment either at home or at the hospital.

At this appointment, participants were asked to read and sign the consent form (Appendix 7) before completing the assessments. In all cases, written consent was only obtained after the participant had time to consider their participation in the research and ask any questions. All participants were given time to read the information sheet and consent form in advance of completing the assessments. All points on the consent form were discussed individually by the researcher. It was emphasised that participation was voluntary and that consent could be withdrawn at any time without giving any reason. Demographic information regarding, age; years in formal education; type of stroke and time since stroke was either collected during the assessment appointment or by reviewing participants' medical records at a later date.

3.4.2 Relative or carer participants

At the point of recruitment, stroke patients were asked if someone who knew them well would be able to complete a brief questionnaire. These relative or carer participants were provided with an information sheet (Appendix 4) and consent form (Appendix 5) by the initial clinician. If this was not possible, the relevant documents and the questionnaire were posted to them with a pre-paid envelope. Participants either returned the questionnaire by post or gave it to the patient participant to return to the researcher in person. All completed questionnaires were accompanied by a signed consent form. In common with the stroke participants, potential relative and carer participants had a minimum of 24 hours to consider their participation and they were invited to contact the researcher if they required any further information.

3.4.3 Healthy adult participants

Control participants were recruited from the community by means of a poster with the researcher's telephone number on it (Appendix 8). This poster was accompanied by a healthy participant information sheet (Appendix 9) and was placed in targeted venues including community groups and the Chest, Heart & Stroke Scotland charity shop. Interested participants telephoned the researcher. They were then provided with further information about the study and given the opportunity to ask questions and discuss any concerns. The majority of control participants were recruited by means of an email forum for NHS Highland staff interested in neurological conditions. The poster advertisement was distributed on this email forum along with a copy of the healthy participant information sheet. Interested individuals contacted the researcher by email or telephone. Potential participants were provided with further information about the research and given the opportunity to ask questions. All potential control participants had a minimum of 24 hours to consider their participation in the research. If they agreed to take part, they were provided with an appointment at home or in the hospital. At this appointment, participants were asked to read and sign a consent form (Appendix 10) before completing the assessments. Demographic information regarding age and years in formal education was also gathered. In common with the stroke participants, all control participants were given time to read the information sheet and consent form in advance of completing the assessments. At the point of obtaining written consent, all points on the consent form were discussed individually by the researcher. It was emphasised that participation was voluntary and that consent could be withdrawn at any time without giving any reason.

3.4.4 Administration of the measures

Participants in the stroke and control groups were asked to complete a standardised questionnaire (HADS) to screen for low mood and anxiety. This was followed by a questionnaire about their memory (PRMQ) which consists of 16 questions. A battery of cognitive tests were then administered to assess: general cognitive functioning; premorbid intelligence; prospective memory; retrospective memory; executive functioning; visuospatial ability and speed of processing. Administration was consistent with the individual protocols for each test. Tests were administered in the same order for all participants in a quiet room. The order was as follows: MMSE; NART; CAMPROMPT; Word Lists I (WMS-III^{UK}); Rey-Complex Figure Test (copy & immediate recall trials); Tower Test, Verbal Fluency- letter and category and Trails (DKEFS); Similarities and Digit Span (WAIS-IV^{UK}); Word Lists II (WMS-III^{UK}); Rey-Complex Figure (delayed recall trial). Participants were not advised about their performance on the tests. However, they were given the opportunity to request brief written feedback of their results.

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CHAPTER 4: EXTENDED RESULTS

4.1 Analytic strategy

A preliminary analysis of the data was carried out to assess the normality of the distribution and homogeneity of variance in two samples: stroke patient participants and healthy adult participants. A descriptive statistical analysis was then carried out for participants in both groups. Inferential statistical analysis was carried out between or within groups depending on the individual hypotheses being tested.

4.1.1 Neuropsychological test scores

Raw scores were converted into standard scores (*T* scores) for all neuropsychological measures with the exception of three subtest scores where this was not possible: the copy trial from the Rey Complex Figure Test (RCFT) and total time- and event-based task scores from the Cambridge Prospective Memory Test (CAMPROMPT). There are significant ceiling effects for the copy trial of the RCFT in that 70.7 per cent of the normative sample achieved a raw score of 35 (out of a maximum of 36) or more (Meyers & Meyers, 1995). As a result, scores on this trial are classified on an ordinal scale according to the percentile range that they fall within (≤ 1 ; 2-5; 6-10; 11-16; > 16). In keeping with the other continuous variables in the present study, it was deemed preferable to analyse raw scores for this subtest as this would provide a greater range of scores for comparison. In the case of the CAMPROMPT, scores for three time- and three event-based prospective memory tasks are combined to provide a total score. For the purposes of this analysis, raw scores were recorded separately

for each type of task and summed to produce a total time- and total event-based score.

The neuropsychological measures employed in the present study have different scoring scales. To allow for comparisons between these measures, all standard scores were transformed into a common metric as recommended by Crawford (2004). *T* scores were chosen over percentiles or *Z* scores as the graduation between them is neither too coarse nor too finely graded (Crawford, 2004). The following formula was used to convert standard scores into *T* scores:

$$X_{new} = \frac{S_{new}}{S_{old}} (X_{old} - \bar{X}_{old}) + \bar{X}_{new}$$

where X_{new} = the transformed score, X_{old} = the original score, S_{old} = the standard deviation of the original scale, S_{new} = the standard deviation of a *T* score (10), \bar{X}_{old} = the mean of the original scale and \bar{X}_{new} = the mean of the *T* score (50).

4.2 Distribution

Parametric tests are more robust than non-parametric tests (Clark-Carter, 2004). However, a number of assumptions must be met before parametric tests can be used. Measurement must be at least interval level, scores should follow a normal distribution and the variance of the samples should not be significantly different (Clark-Carter, 2004; Dancey & Reidy, 2002). Normality was assessed using the Kolmogorov-Smirnov test. Data are said to be significantly skewed or kurtic if the *Z*

scores are greater than 2.58. Twelve variables were found to have significant levels of skew and kurtosis.

As the presence of skew and kurtosis may not be enough to bias analysis, it was necessary to further analyse the degree of skew and kurtosis. Separate analysis of the two groups showed that the skew and kurtosis in the stroke group's data was not significant for any of the variables. However, there was significant skew and kurtosis in the Hospital Anxiety and Depression Scale (HADS) depression scores and Word Lists II recognition trail scores for the control group. Following further exploration of this data with box plots, an extreme outlier was identified in the HADS depression scores. There were also two significant outliers in the Word Lists II recognition trial scores. These outliers were removed from the data and tests of skew and kurtosis were re-run. As the skew and kurtosis was no longer significant, these outliers were not reinstated. This was deemed appropriate as outliers can have a significant impact on regression analysis (Dancey & Reidy, 2002) and it is preferable that the results of statistical analysis reflect most of the data rather than being highly influenced by one or two errant points (Stevens, 2002).

Homogeneity of variance was assessed using Levene's test. If Levene's test is significant ($p > .05$), this indicates that the assumption of equal variances has been violated. Parametric tests are sufficiently robust that violation of this assumption is not considered to be too problematic, particularly if the data follow a normal distribution and the sample sizes are equal (Clark-Carter, 2004). The violation can be

corrected by reporting the test statistic that does not assume equal variances (Welch's *t*-test). Unless otherwise stated, all data met the assumption of homogeneity of variance. An alpha level of $p < .05$ was used for all analysis.

4.3 Demographic statistical analysis

4.3.1 Total sample

Approximately 192 individuals were invited to take part in this study. A total of 44 agreed to participate: 22 healthy adult controls and 22 stroke patients.

4.3.2 Stroke patient participants

All stroke patient participants were living independently in the community after experiencing one stroke. At the time of their participation in the research, a minimum of six months had passed since their stroke. Of the 35 individuals invited to take part in the study, 26 agreed to participate. This represents an overall response rate of 74 per cent. A total of seven individuals did not wish to take part after finding out more information about the study and two were unable to take part due to other commitments. Of the individuals who agreed to take part, two were withdrawn from the study prior to the assessment phase. One did not meet eligibility criteria due to the presence of significant dysphasia and the other had experienced a stroke within the last 6 months. A third participant withdrew their consent after completing half of the assessment. A final participant was withdrawn from the study after being admitted to hospital prior to their appointment. Therefore, a total of 22 participants

completed the assessments. Diagnoses for this group were: haemorrhagic stroke (6); cerebral infarction (7); stroke unspecified as haemorrhage or infarction (9). The time since stroke ranged from 6 months to 6 years. Further demographic information can be seen in Table 4.1.

4.3.3 Healthy adult participants

As healthy control participants were recruited by advertisement in a range of community venues, it is not possible to precisely calculate how many potential participants were approached. However, information is available regarding the response rate from an advert placed on an NHS staff email forum with approximately 150 members. A total of 18 potential participants contacted the researcher as a result of this advert. Of these, 13 agreed to take part in the study. This represents a response rate of 12 per cent. Only 4 healthy control participants approached the researcher in response to adverts placed in community groups. The remaining 4 controls were acquaintances of the researcher. In summary, a minimum of 158 participants were approached. Of these, 22 agreed to take part representing an overall response rate of 14 per cent. Demographic information for this group can be seen in Table 4.1.

Table 4.1 Differences in mean demographic and clinical characteristics between healthy adult control participants and stroke patient participants.

	Healthy Controls (22)	Stroke Patients (22)	Summary Statistics		
	Mean (SD)	Mean (SD)	<i>t</i>	<i>df</i>	<i>p</i>
Age (years)	53.77 (13.67)	65.00 (15.12)	2.58	42.00	0.013
Education (years)	15.27 (2.37)	12.86 (2.51)	3.26	42.00	0.002
Estimated FSIQ	118.54 (5.43)	113.54 (6.34)	2.80	42.00	0.008
Anxiety (HADS)	3.22 (2.09)	5.63 (3.71)	2.65*	33.12	0.012
Depression (HADS)	1.04 (0.92)	4.40 (3.30)	4.58*	24.38	0.0005
MMSE	29.68 (0.47)	28.13 (2.07)	3.40*	23.20	0.002
	N (%)	N (%)	<i>x</i> ²	<i>df</i>	<i>p</i>
Gender			6.14	1	0.013
Female	18 (82)	9 (41)			
Male	4 (18)	13 (59)			

Abbreviations: HADS: Hospital Anxiety and Depression Scale; FSIQ: Full Scale IQ; MMSE: Mini Mental State Examination; SD: Standard Deviation.

**Assumption of equal variance violated: Welch's t-test reported*

As detailed in Table 4.1, there was a significant difference between the groups on all of the demographic and clinical variables. The healthy control group were younger,

had more years in education, and a higher estimated IQ according to their performance on the National Adult Reading Test (NART). The proportion of males and females in each group was also significantly different. As would be expected when comparing a clinical population to healthy controls, the stroke group's scores were statistically significantly higher for anxiety and depression as measured by the HADS. There was also a significant difference between the groups on a measure of general cognitive functioning. Stroke patient participants had significantly lower scores on the Mini Mental State Examination (MMSE).

Group differences in the standardised neuropsychological measures were explored using *t*-tests for independent samples. The results of these comparisons can be seen in Table 4.2.

Table 4.2 Difference between the two experimental groups on all standardised neuropsychological measures.

	Healthy Controls (22)	Stroke Patients (22)	Summary Statistics		
	Mean (SD)	Mean (SD)	<i>t</i>	<i>df</i>	<i>p</i>
WLI					
Total Recall	58.54 (8.38)	40.68 (13.13)	5.38*	36	0.0005
WLII					
Delayed Recall	60.63 (8.50)	47.18 (11.10)	4.51*	42	0.0005
Recognition	60.25 (3.02)	44.59 (11.72)	6.05	24	0.0005

RCFT					
Copy	34.59 (1.59)	24.50 (7.96)	5.83*	23	0.0005
Immediate Recall	55.54 (13.33)	42.32 (16.31)	2.95	42	0.005
Delayed Recall	53.55 (13.82)	40.23 (16.40)	2.91	42	0.006
Recognition	54.23 (11.19)	48.09 (10.31)	1.89	42	0.066
DKEFS					
Tower Test	56.32 (8.62)	50.36 (9.21)	2.21	42	0.032
Letter Fluency	61.32 (15.11)	45.68 (13.53)	3.61	42	0.001
Category Fluency	56.96 (13.99)	44.55 (10.45)	3.33	42	0.002
Trails 3	48.18 (6.81)	39.95 (10.77)	3.01	41	0.004
Trails 4	47.23 (7.89)	42.19 (11.33)	1.69	41	0.097
WAIS-IV					
DSF	48.82 (7.42)	47.00 (8.59)	0.75	42	0.456
DSB	51.05 (6.21)	47.27 (9.12)	1.60	37	0.116
Similarities	55.41 (6.46)	44.86 (6.59)	5.36	42	0.0005

Note: Values reported are T scores with the exception of Rey Complex Figure Test (RCFT) copy trial where the raw score is reported. All t values are 2 tailed. Abbreviations: DKEFS: Delis-Kaplan Executive Function System; DSB: Digit Span Backwards; DSF: Digit Span Forwards; SD: Standard Deviation; WLI: Word Lists I; WLII: Word Lists II; WAIS-IV: Wechsler Adult Intelligence Scale - 4th Edition.

**Assumption of equal variance violated: Welch's t reported.*

As shown in Table 4.2, stroke patient participants had reduced retrospective memory abilities when compared to the healthy control group. There was a significant difference between the two groups on all measures of verbal memory (WLI total recall; WLII delayed recall; WLII recognition) and two measures of visual memory (RCFT immediate recall trial; RCFT delayed recall trial). The difference between scores on the RCFT recognition trial was not significant ($t(42) = 1.89, p = .06$).

Significant group differences were also found on measures of executive functioning. Patient participants' performance was poorer than healthy control participants on the Tower Test Letter and Category Fluency tests, the Trail Making Test - condition 3 (Trails 3) and Similarities. The patient participants' scores were also significantly lower on a measure of visuospatial ability (RCFT copy trial). The difference between the experimental groups was not significant on measures of working memory (Digit Span Forwards and Backwards) or cognitive flexibility (Trails 4).

4.4 Inferential statistical analysis

4.4.1 Hypothesis 1: The performance of participants in the stroke group will be significantly poorer than participants in the healthy control group on the objective measure of prospective memory.

Prospective memory was objectively assessed using the CAMPROMPT. As there is an effect of age and IQ on this measure (Wilson *et al.*, 2005), total scores are

calculated based on four different age bands (16-35; 35-50; 51-65; 66+) and three different IQ bands (below 90; 90-110; Above 110). By looking up an individual's total raw score within their age group and ability band, prospective memory performance can be classified as: impaired; borderline; poor; average; above average; very good. For the purposes of this analysis, total CAMPROMPT raw scores were converted into *T* scores using the mean and standard deviation of the original normative sample.

Data were available to calculate three different *T* scores. One based on comparison with the total normative sample, one based on comparison with the relevant age-group and another with the relevant IQ band. The groups in the present study were significantly different in both age ($t(48) = 2.58, p < .05$ 2 tailed) and estimated FSIQ ($t(42) = 2.80, p < .01$ 2 tailed). Therefore, it was considered appropriate to use the *T* scores based on comparison with the total sample for analysis as this takes all age and ability levels into account. The mean and standard deviations for the normative sample were supplied by the lead statistician involved in the development of the CAMPROMPT (P. Watson, personal communication, 20th July 2011).

The means and standard deviations of the *T* scores of the healthy control and stroke patient participant's performance on the CAMPROMPT can be seen in Table 4.3.

Table 4.3 Means and Standard Deviations of the *T* scores of the healthy control and stroke participants' performance on the CAMPRMPT.

	Healthy Controls (22)	Stroke Patients (22)	Summary Statistics		
	Mean (SD)	Mean (SD)	<i>F</i>	<i>df</i>	<i>p</i>
CAMPROMPT	54.00 (4.89)	39.22 (10.56)	35.40*	1	0.0005
CAMPROMPT (IQ)	51.22 (5.91)	36.00 (12.00)	28.47*	1	0.0005
CAMPROMPT (AGE)	56.31 (5.04)	42.72 (10.24)	31.17*	1	0.0005

Note: For information, means are also reported for CAMPRMPT T scores calculated by relevant IQ band and by relevant age band. Abbreviations: CAMPRMPT: Cambridge Prospective Memory Test; SD: Standard Deviation.

**Assumption of equal variance violated: Welch's t reported.*

As shown in Table 4.3, the performance of stroke participants was significantly poorer than control participants on the CAMPRMPT ($F(1,42) = 35.4, p < .01$). The effect size for this result was very large ($\eta_p^2 = .45$). As the two groups were significantly different on all demographic and clinical screening variables, it was important to examine whether any of these variables were significantly correlated with performance on the CAMPRMPT.

Pearson's correlations were carried out for age, years in education, IQ, anxiety and depression scores, MMSE scores and the CAMPRMPT total score. All

demographic variables were significantly correlated with total score performance on the CAMPRMPT. Medium correlations were found between, age ($r = -.38$, $n=44$, $p < .05$ 2 tailed), years in education ($r = .39$, $n=44$, $p < .01$ 2 tailed), predicted IQ ($r = .31$, $n=44$, $p < .05$ 2 tailed) and CAMPRMPT scores. The direction of these correlations indicates that there was an association between more years in education and higher IQ and higher CAMPRMPT scores. In contrast, greater age and higher levels of anxiety ($r = -.32$, $n=44$, $p < .05$ 2 tailed) and depression ($r = -.59$, $n=44$, $p < .01$ 2 tailed) were associated with lower CAMPRMPT scores. There was a positive correlation between MMSE scores and CAMPRMPT total score ($r = .64$, $n=44$, $p < .01$ 2 tailed), with higher MMSE scores associated with higher CAMPRMPT scores.

To control for the influence of these variables, a one-way analysis of covariance was carried out (ANCOVA). For the purposes of this analysis, ANCOVA was used as a statistical matching procedure. Therefore, all demographic and clinical screening variables that significantly correlated with the dependent variable were included as covariates. MMSE score was not controlled for as this would be controlling for cognitive impairment. The data met the assumptions of normality, homogeneity of variances and homogeneity of regression slopes. Unadjusted and adjusted mean T scores can be seen in Table 4.4.

Table 4.4 Unadjusted and Adjusted mean CAMPROMPT *T* scores for healthy control and stroke groups.

	CAMPROMPT	
	Unadjusted Mean (SD)	Adjusted Mean (SE)
Healthy Controls	54.09 (4.99)	50.54 (2.18)
Stroke Patients	39.22 (10.56)	42.61 (2.11)

After adjusting for the influence of age, years in education, estimated IQ, HADS anxiety and depression, there was still a significant difference between the healthy control and stroke participants' performance on the CAMPROMPT ($F(1,36) = 5.00$, $p < .05$). The effect size for this result was large ($\eta_p^2 = .12$). The covariate depression was significantly related to CAMPROMPT score ($F(1,36) = 4.91$, $p < .05$). The effect size for this result was also large ($\eta_p^2 = .12$) and indicates that 12 per cent of the variance in CAMPROMPT scores can be accounted for by depression.

4.4.1.1 Summary

The stroke patient participants' performance on the objective measure of prospective memory was significantly poorer than the healthy control participant's performance. A significant relationship was found between depression scores and performance on the objective measure of prospective memory.

4.4.2 Hypothesis 2: There will be a significant difference in performance between time-based and event-based tasks on the objective measure of prospective memory. Time-based tasks will be more difficult for healthy controls and stroke patient participants.

The means and standard deviations for the total time- and event-based CAMPROMPT scores can be seen in table 4.5.

Table 4.5 Means and standard deviations for total performance on time- and event-based CAMPROMPT tasks for the stroke patient participants and the healthy control participants.

	Healthy Controls (21) Mean (SD)	Stroke Group (22) Mean (SD)
Time-Based PM	14.42 (3.68)	7.90 (4.78)
Event-Based PM	15.66 (2.30)	11.09 (3.81)

Note: Values reported are raw scores for time-based prospective memory (total performance on three tasks) and total event-based prospective memory (total performance on three tasks). Abbreviations: PM: Prospective Memory; SD: Standard Deviation.

A repeated measures ANOVA was carried out with experimental group (stroke patient participants or healthy controls) as the between-subjects factors and type of

prospective memory task (time- or event-based) as the within-subjects factor. The data met the assumptions of normality, homogeneity of variances, homogeneity of regression slopes and homogeneity of intercorrelations. The interaction between type of prospective memory task and group was not significant ($F(1,42) = 1.81, p = .18$). This indicates that the change between time and event-based scores was not significantly different in the two experimental groups. There was a significant main effect for type of prospective memory task ($F(1,42) = 8.65, p = .05$). Therefore, there was a significant difference in average performance between time- and event-based tasks independent of patient or control status. Analysis of profile plots indicated that time-based tasks were more difficult for both groups. A significant main effect was also found for group ($F(1,42) = 42.47, p < .01$) indicating that healthy control participants performed at a higher level than stroke participants on both types of prospective memory task.

As the two groups differed in age, years in education, IQ and scores on clinical screening measures, Pearson's correlations were carried out to explore whether there was an association between these demographic and clinical variables and performance on the prospective memory tasks. Correlations were carried out separately for time- and event-based tasks. Pearson's correlations showed a significant correlation between time-based performance and age ($r = .38, n = 44, p < .01$ 2 tailed); years in education ($r = .38, n = 44, p < .01$ 2 tailed); estimated FSIQ ($r = .34, n = 44, p < .05$) and depression scores ($r = -.56, n = 44, p < .01$). For event-based tasks, there was a significant correlation with age ($r = -.36, n = 44, p < .05$), years in

education ($r = .31$, $n = 44$, $p < .05$), anxiety ($r = -.32$, $n = 44$, $p < .05$) and depression ($r = -.39$, $n = 44$, $p < .01$).

To control for the influence of these variables, a mixed repeated measures ANCOVA was carried out with experimental group as the between subjects factor and type of prospective memory task as the within-subjects factor. Age, years in education, anxiety and depression were entered as covariates. The data met the assumptions of normality, homogeneity of variances, homogeneity of regression slopes and homogeneity of intercorrelations. The interaction between type of prospective memory task and group was not significant ($F(1,37) = .10$, $p = .75$) indicating that there was a change in time- and event-based scores for both groups. There was also a significant main effect of group ($F(1,37) = 7.01$, $p < .05$). However, a significant interaction was found between the depression covariate and type of prospective memory ($F(1,37) = 5.52$, $p < .02$).

Where an interaction is present between a covariate and the within-subjects factor, further analysis must be carried out as any change in the within-subjects effect is an artefact of the calculations performed by SPSS (Van Breukelen & Van Dijk, 2007). As described by these authors, the main effect for type of prospective memory task was no longer significant ($F(1,37) = 3.70$, $p = .06$). Van Breukelen and Van Dijk (2007) highlight that this change in the within-subjects effect should not be interpreted as the within-subject effect is 'the intercept of the regression of change on group and covariates, and so it reflects the change for a person with value zero on all

predictors' (p.904). Therefore, it is necessary to centre covariates prior to the ANCOVA by subtracting the group mean from each subject's individual mean. Centred covariates have a mean of zero. The ANCOVA was re-run with depression as the only significant covariate. After centring the means, the interaction between group and type of prospective memory task was non-significant ($F(1,40) = .00, p = .99$) and there were significant main effects of type of prospective memory task ($F(1,40) = 6.12, p < .05$) and group ($F(1,40) = 18.98, p < .01$).

One-way ANCOVAs were carried out to explore the relationship between depression and type of prospective memory task. Separate ANCOVAs were run for time-based performance and event-based performance with depression as a covariate. Depression was found to make a significant unique contribution to time-based performance ($F(1,43) = 5.02, p < .05$). The effect size for this result was large ($\eta_p^2 = .11$). However, depression did not make a significant contribution to event-based performance ($F(1,43) = .25, p = .61$).

4.4.2.1 Summary

There was a significant difference in average performance between time- and event-based tasks for both experimental groups. Time-based task performance was poorer than event-based task performance. The stroke participants' performance was significantly poorer than control participants' performance on both time- and event-based tasks. A significant relationship was found between depression scores and time-based performance.

4.4.3 Hypothesis 3: There will be a relationship between performance on tests of retrospective memory and executive functioning and performance on the objective measure of prospective memory.

Pearson's correlations were carried out to explore the relationship between performance on the neuropsychological measures and performance on the objective measure of prospective memory. As these abilities should contribute to prospective memory performance in stroke patient participants and healthy control participants, the experimental groups were combined for this analysis (n=44). The results of the correlations can be seen in Table 4.6.

Table 4.6 Correlations between performance on neuropsychological measures and total CAMPROMPT scores for all participants.

	CAMPROMPT		
	Pearson Correlation	Sig. (2-tailed)	N
WLI			
Total Recall	0.45	0.002	44
WLII			
Delayed Recall	0.41	0.005	44
Recognition	0.60	0.0005	42
RCFT			

Copy	0.55	0.0005	44
Immediate Recall	0.22	0.161	44
Delayed Recall	0.25	0.096	44
Recognition Trial	0.42	0.004	44
DKEFS			
Tower Test	0.14	0.368	44
Letter Fluency	0.35	0.022	44
Category Fluency	0.25	0.107	44
Trails 3	0.45	0.002	43
Trails 4	0.22	0.154	43
WAIS-IV			
DSF	0.29	0.057	44
DSB	0.40	0.007	44
Similarities	0.47	0.001	44

Abbreviations: DKEFS: Delis-Kaplan Executive Function System; DSB: Digit Span Backwards; DSF: Digit Span Forwards; SD: Standard Deviation; WLI: Word Lists I; WLII: Word Lists II; WAIS-IV: Wechsler Adult Intelligence Scale - 4th Edition.

As shown in Table 4.6, there was a significant positive relationship between performance on the CAMPROMPT and performance on all measures of verbal memory (WLI total recall; WLII delayed recall; WLII recognition), a measure of

visuospatial ability (RCFT copy trial) and a measure of visual recognition memory (RCFT recognition trial). Significant positive correlations were also found between performance on the CAMPRMPT and some measures of executive functioning (Letter fluency; Trails 3; Digit span backwards; Similarities). These results indicate that higher scores on these measures are associated with higher CAMPRMPT scores.

Multiple regression was carried out to explore these relationships further. Multiple regression analyses allow for comparisons between, the total relationship of the independent variable (IV) with the dependent variable (DV), the unique relationship of the IV with the DV and the correlations of the IVs with each other. An important assumption of multiple regression is that the IVs are not highly correlated with each other. When IVs are highly correlated (correlations of .7 or above) assessment of their importance to the regression is more ambiguous (Tabachnick & Fidell, 1989).

As shown in Table 4.9, significant relationships were found with nine of the neuropsychological variables and the CAMPRMPT *T* score. A number of these variables were also significantly related to each other with bivariate correlations of .7 and above. In this case it is recommended that variables are removed or a composite score is formed to include highly correlated variables (Pallant, 2005). Therefore, two composite scores were formed; one to combine retrospective memory measures and another to combine executive functioning measures. Visuospatial functioning was retained as a separate variable.

In light of the relationship between depression and performance on the objective measure of prospective memory, Hierarchical multiple regression was selected to control for effect of this covariate. Depression was entered in the first step, followed by the three neuropsychological variables (retrospective memory composite score; executive functioning composite score; visuospatial functioning). All data met the assumptions of normality, linearity and homoscedasticity. There were no significant outliers. Exploration of collinearity diagnostics indicated that multicollinearity was not present. The result of the regression analysis can be seen in Table 4.7.

Table 4.7 Hierarchical multiple regression model of depression, retrospective memory, executive functioning and visuospatial functioning on CAMPRMPT scores for all participants.

	Summary Statistics			
	B	SE B	β	<i>p</i>
Model 1.				
Constant	52.77	1.88		0.0005
Depression	-2.22	0.46	-0.59	0.0005
Model 2.				
Constant	21.69	10.84		0.053
Depression	-1.57	0.52	-0.42	0.004

RM Composite	-0.02	0.03	-0.12	0.522
EF Composite	0.06	0.03	0.28	0.045
Visuospatial Ability	0.44	0.27	0.30	0.110

Abbreviations: EF: Executive Functioning; RM: Retrospective Memory; SE: Standard Error

The first model explained 35.6 per cent (R^2) of the variance in CAMPROMPT scores ($F(1,42) = 22.63, p < .01$). The association between the variables was moderate (Multiple $R = .59$). As shown in Table 4.7, depression made a significant unique contribution (Beta = -2.22, SE = .46, $p < .01$). In the second model; retrospective memory composite score and visuospatial ability were shown to be poor predictors of CAMPROMPT score. The association between the variables was moderately strong (Multiple $R = .70$). This model explains 49.1 per cent of the variance in the CAMPROMPT T score ($F(4,42) = 9.17, p < .01$). Depression (Beta = -1.57, SE = .52, $p < .01$) made the strongest unique contribution to explaining performance on the CAMPROMPT. However, executive functioning also made a significant unique contribution (Beta = .06, SE = .03, $p < .05$).

Further hierarchical multiple regression analyses were carried out to explore predictors of time- and event-based performance. There was a significant correlation between time-based prospective memory performance and depression scores ($r = -.56, n = 44, p < .01$). Event-based performance was significantly correlated with

anxiety ($r = -.32$, $n=44$, $p < .05$) and depression ($r = -.39$, $n=44$, $p < .01$). The results of these analyses can be seen in Table 4.8 and Table 4.9.

Table 4.8 Hierarchical multiple regression model of depression, retrospective memory, executive functioning and visuospatial functioning on total time-based CAMPRMPT scores for all participants.

	Summary Statistics			
	B	SE B	β	<i>p</i>
Model 1.				
Constant	13.98	0.92		0.0005
Depression	-1.02	0.23	-0.56	0.0005
Model 2.				
Constant	-0.99	5.41		0.855
Depression	-0.67	0.26	-0.37	0.014
RM Composite	-0.00	0.017	-0.02	0.914
EF Composite	0.02	0.01	0.23	0.113
Visuospatial Ability	0.19	0.13	0.27	0.170

Abbreviations: EF: Executive Functioning; RM: Retrospective Memory; SE: Standard Error

In the time-based analysis, depression was entered in the first model. This was

followed by a second model including all of the neuropsychological variables. The first model explained 32.4 per cent of the variance in CAMPRMPT scores ($F(1,42) = 19.61, p < .01$). The association between the variables was moderate (Multiple $R = .56$). As shown in Table 4.8, depression made a significant contribution (Beta = $-.56, SE = .23, p < .01$). In the second model; retrospective memory, executive functioning and visuospatial ability were shown to be poor predictors of time-based score. The association between the variables was moderately strong (Multiple $R = .67$). This model explained 45.2 per cent of the variance in the time-based scores ($F(4,38) = 7.83, p < .01$). Depression (Beta = $-.37, SE = .26, p < .05$) made the strongest unique contribution to explaining performance.

The results of the hierarchical regression models for event-based CAMPRMPT scores can be seen in Table 4.9

Table 4.9 Hierarchical multiple regression models of anxiety, depression, retrospective memory, executive functioning and visuospatial functioning on total event-based CAMPRMPT scores for all participants.

	Summary Statistics			
	B	SE B	β	<i>p</i>
Model 1.				
Constant	15.26	0.94		0.0005
Anxiety	-0.18	0.20	-0.15	0.387
Depression	-0.40	0.22	-0.30	0.084

Model 2.				
Constant	6.97	4.62		0.140
Anxiety	-0.20	0.20	-0.17	0.313
Depression	-0.27	0.24	-0.21	0.267
RM Composite	-0.01	0.01	-0.27	0.262
EF Composite	0.02	0.01	0.33	0.051
Visuospatial Ability	0.12	0.11	0.25	0.272

Abbreviations: EF: Executive Functioning; RM: Retrospective Memory; SE: Standard Error

In the event-based analysis, anxiety and depression were entered in the first model. This explained 17.1 per cent of the variance in event-based scores ($F(2,40) = 4.12$, $p < .05$). The association between the variables was moderate (Multiple $R = .41$). As shown in Table 4.9, neither depression nor anxiety made a significant unique contribution. In the second model; retrospective memory, executive functioning and visuospatial ability were also shown to be poor predictors of event-based score. The association between the variables was moderately strong (Multiple $R = .53$). This model explains 28 per cent of the variance in the event-based scores ($F(5,37) = 2.88$, $p < .05$).

4.4.4 Hypothesis 4: Stroke patients will have reduced insight into their memory abilities.

Everyday memory was assessed by the Prospective and Retrospective Memory Questionnaire (PRMQ). This 16 item self-report questionnaire includes eight questions that refer to prospective memory failures and eight that refer to retrospective memory failures. Responses (never; rarely; sometimes; quite often; very often) are scored from 1-5 with increasing number indicating increasingly negative appraisal of everyday memory abilities. The minimum score is 16 and the maximum score is 80. Two subscales are available, one for the total of prospective failures and one for total retrospective failures. Total scores and subscale scores were converted into *T* scores. A proxy version of this questionnaire is also available to gather ratings of everyday memory from relatives or carers.

For the purposes of this analysis, insight into memory functioning was assessed in three different ways. Firstly, stroke participants' self-ratings were compared to control participants' self-ratings. Stroke participants' self-ratings were then compared to proxy-ratings by relatives or carers. Finally, the relationship between PRMQ self-reports and objective measures of prospective and retrospective memory were explored.

4.4.4.1 Comparison of self-report ratings

A one-way ANOVA was carried out to compare self-reports on the PRMQ. The means and standard deviations of the *T* scores of the healthy control group and stroke group's self-ratings on the PRMQ can be seen in Table 4.10.

Table 4.10 Means and Standard Deviations of the *T* scores of the healthy control and stroke participants' self-ratings on the PRMQ.

	Healthy Controls (22)	Stroke Patients (22)	Summary Statistics		
	Mean (SD)	Mean (SD)	<i>F</i>	<i>df</i>	<i>p</i>
PRMQ Self Report	55.13 (9.00)	47.04 (19.04)	3.19	1	0.081

As shown in Table 4.10, there was no difference between the stroke patient participants' everyday memory ratings and healthy controls' ratings. As the groups differed significantly on all demographic and clinical screening measures it was important to see if any of these measures correlated with PRMQ *T* scores. Pearson's correlations identified a significant correlation between anxiety ($r = -.59$, $n=44$, $p < .01$) and depression ($r = -.64$, $n=44$, $p < .01$) scores and PRMQ *T* scores. To control for the influence of these variables, a one-way between-groups ANCOVA was carried out. Data met the assumptions of normality, linearity, homogeneity of variances and homogeneity of regression slopes. Unadjusted and adjusted mean PRMQ *T* scores

can be seen in Table 4.11.

Table 4.11 Unadjusted and Adjusted mean PRMQ *T* scores for healthy control and stroke groups.

	PRMQ	
	Unadjusted Mean (SD)	Adjusted Mean (SE)
Healthy Controls (21)	55.61 (8.93)	55.61 (1.82)
Stroke Group (22)	47.27 (18.57)	47.27 (2.77)

After adjusting for the influence of anxiety and depression with ANCOVA, healthy controls and stroke patients did not differ in their self-ratings of everyday prospective and retrospective memory ($F(1,43) = 1.71, p = .19$). This indicates that, despite poorer performance on objective measures of prospective and retrospective memory, stroke patient participants did not rate their everyday memory abilities any differently to healthy controls. A significant relationship was found between anxiety ($F(1,43) = 6.83, p < .05$) and depression ($F(1,43) = 13.04, p < .01$) scores and PRMQ self-ratings. The effect sizes for these results were large with the covariate of depression accounting for 25 per cent ($\eta_p^2 = .25$) of the variance in PRMQ scores and the anxiety covariate accounting for 14 per cent ($\eta_p^2 = .14$).

4.4.4.1.2 Summary

Healthy controls and stroke patients do not differ in their self-ratings of everyday prospective and retrospective memory.

4.4.4.2 Comparison of stroke group's self-report ratings with relative or carer proxy ratings.

Proxy ratings were only gathered for participants in the stroke group. This analysis was carried out with 20 people as proxy ratings were not available for two of the participants. Means and standard deviations for the self-report and proxy ratings can be seen in Table 4.12.

Table 4.13 Mean and standard deviations for the stroke participants' self-report PRMQ *T* scores and the proxy PRMQ *T* scores.

PRMQ Self-Report	PRMQ Proxy	Summary Statistics		
Mean (SD)	Mean (SD)	<i>F</i>	<i>df</i>	<i>p</i>
49.15 (17.75)	47.50 (14.39)	0.35	1	0.557

A repeated measures ANOVA was used to examine the difference between patient self-reports and proxy reports. There was no difference between the groups ($F(1,19)$

= .35, $p = .55$). There was also a significant correlation between self-report ratings and proxy ratings ($r = .72, p < .01$).

4.4.4.3 Relationship between stroke patient participants' self-report ratings on the PRMQ and performance on the objective measures of prospective and retrospective memory.

Pearson's correlations were carried out to explore the relationship between PRMQ self-ratings (total score; retrospective subscale; prospective subscale), CAMPRMPT T scores and retrospective memory composite scores. These correlations can be seen in Table 4.13.

Table 4.13 Correlations between PRMQ self-ratings and performance on the objective measures of prospective and retrospective memory for the stroke patient participants.

	CAMPRMPT T score			RM Composite Score		
	Pearson Correlation	Sig. (2-tailed)	N	Pearson Correlation	Sig. (2-tailed)	N
PRMQ Total	0.44	0.039	22	0.08	0.704	22
PRMQ RM	0.45	0.032	22	0.05	0.793	22
RRMQ PM	0.39	0.068	22	0.10	0.629	22

As shown in Table 4.13, there was a medium positive correlation between total PRMQ score and performance on the CAMPROMPT ($r = .44$, $n = 22$, $p < .05$). This indicates that increasingly positive appraisals of everyday memory were associated with increasing scores on the CAMPROMPT. Analysis of the prospective and retrospective subscale scores showed that there was a significant correlation between the retrospective memory subscale of the PRMQ and performance on the CAMPROMPT ($r = .45$, $n = 22$, $p < .05$). This indicates that positive ratings of retrospective memory ability are associated with higher CAMPROMPT scores. However, the correlation between the prospective subscale ratings and performance on the CAMPROMPT was not significant ($r = .39$, $n = 22$, $p = .68$). There was no significant correlation between total ($r = .11$, $n = 22$, $p = .62$) or retrospective ($r = .07$, $n = 22$, $p = .74$) PRMQ self-ratings and performance on the objective measures of retrospective memory.

A significant negative correlation was also found between PRMQ self-reports and depression ($r = -.64$, $n = 22$, $p < .01$) and anxiety ($r = -.63$, $n = 22$, $p < .1$) indicating that as anxiety and depression increase, appraisals of everyday memory become increasingly negative.

4.4.4.1.2 Summary – Hypothesis 4

The results indicate that the stroke patient's insight into their memory abilities is not complete. Despite evidence that they performed at a significantly lower level on objective tests of prospective and retrospective memory, stroke patient participants

did not rate their everyday memory ability any differently to controls. Although total PRMQ self-ratings had a positive correlation with CAMPROMPT scores, analyses of the prospective and retrospective subscales indicates that there was no relationship between self-ratings of prospective memory and objective prospective memory performance. Equally, retrospective PRMQ ratings were not associated with objective retrospective memory ability. The positive relationship between total PRMQ self-ratings and CAMPROMPT scores appears to be explained by the association between retrospective memory scale ratings and CAMPROMPT performance.

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CHAPTER 5: EXTENDED DISCUSSION

5.1 Discussion of main findings

The aim of this study was to explore prospective memory functioning after stroke. It was hypothesised that stroke patient's performance would be significantly poorer than healthy controls on a standardised, objective measure of prospective memory. It was also of interest to determine whether time-based prospective memory tasks are more difficult than event-based tasks. Secondary aims were to explore the relationship between prospective memory and other cognitive functions and to evaluate whether stroke patients have insight into their everyday memory abilities.

5.1.1 Hypothesis 1: The performance of the participants in the stroke group will be significantly poorer than the healthy control participants on the objective measure of prospective memory.

After controlling for significant group differences in age, years in education, estimated IQ and levels of anxiety and depression, the performance of stroke patient participants was significantly poorer than healthy controls on the objective measure of prospective memory. This result supports the experimental hypothesis and is consistent with findings from previous stroke studies (Brooks *et al.*, 2004; Cheng *et al.*, 2010; Kim *et al.*, 2009). An inverse relationship was found between levels of depression and overall prospective memory performance, with depression accounting for a significant proportion of the variance in total scores. The present study is the

first to control for mood disturbance in a stroke population. However, similar results have been reported in traumatic brain injury (Hannon *et al.*, 1999; Kinch & McDonald, 2001) and depressed adults (Rude *et al.*, 1999).

5.1.2 Hypothesis 2: There will be a difference in performance between time-based and event-based tasks on the objective measure of prospective memory. Time-based tasks will be more difficult for all participants.

It has been proposed that time-based prospective memory tasks are more difficult than event-based tasks due to their reliance on internal, self-initiated processing (Einstein & McDaniel, 1990). In light of this, it was hypothesised that time-based tasks would be more difficult for both experimental groups. The results support this hypothesis. Performance on time-based tasks was poorer than on event-based tasks for stroke patient participants and healthy controls. This supports the previous findings by Groot *et al.* (2002) and Shum *et al.* (1999) that both healthy control participants and patients with acquired brain injury had greater difficulties with time-based tasks.

Differential impairments in time-based prospective memory task have been observed in thalamic stroke (Cheng *et al.* 2010) and TBI (Kinch & McDonald, 2001; Kinsella *et al.*, 1996). However, the majority of previous studies in acquired brain injury have reported patient impairments in both types of task (Adda *et al.*, 2008; Carlesimo *et al.*, 2010; Cockburn, 1996; Groot *et al.*, 2002; Kim *et al.*, 2009; Mathias &

Mansfield, 2005; Shum *et al.*, 1999; Tay *et al.*, 2010). The results of the present study support these findings. Although the performance of both experimental groups was reduced on time-based tasks, the stroke patient participants were significantly poorer than controls on both types of task.

A significant interaction was observed in the present study between type of prospective memory task and depression. Further analysis revealed that levels of depression made a significant contribution to performance on time-based prospective memory tasks but not to event-based tasks. Previous studies have rarely controlled for the influence of depression and reported results are mixed. In common with the present study, Hannon *et al.* (1999) and Kinch & McDonald (2001) observed that depression significantly impacted on time-based performance for patients with TBI. Rude *et al.* (1999) found similar results in depressed adults.

In contrast, Mathias and Mansfield (2005) and Tay *et al.* (2010) concluded that increased levels of depression following TBI made a limited contribution to prospective memory. This inconsistency may be explained by the different levels of depression observed in these studies. The majority of TBI patients and controls in the study by Mathias and Mansfield (2005) were classified as having mild levels of depression. As the level of depression was similar in both experimental groups, the contribution of depression was not considered as a covariate in their analysis. Tay *et al.* (2010) reported that there was no correlation between higher depression in the patient group and overall prospective memory scores. However, information

regarding the level of mood disturbance was not reported in this study. It is possible that in both of these studies, the level of depression was not significant enough to impact on prospective memory.

It is assumed that time-based tasks place a significant demand on self-initiated processes including the monitoring and checking of time (Einstein & McDaniel, 1996). The influence of depression on time-based performance has been attributed to deficits in this monitoring of time. Rude *et al.* (1999) found that depressed individuals monitored the passage of time less frequently than non-depressed individuals. Further support for this hypothesis comes from Cheng *et al.*'s (2010) findings that thalamic stroke patients had deficits in time-based tasks but not event-based tasks. These authors highlight that the thalamus has been implicated in time-perception.

Shum *et al.* (1999) explored time-monitoring behaviour and found it to be similar between healthy controls and patients with TBI. Therefore, it can be assumed that patients with acquired brain injury would typically engage in the same time-monitoring behaviours as healthy controls. However, as these behaviours are vulnerable to comorbid low mood this can lead to greater impairments in time-based tasks. This is particularly significant to the present study as although all of the time-based CAMPROPT tasks involve time-monitoring, time is given by relatively salient cues in the form of a stopwatch and a large wall clock that are placed in front of participants. This suggests that deficits in time-monitoring can occur even in low

demand conditions.

In the present study, anxiety did not make a unique contribution to time- or event-based prospective memory. However, correlational analysis revealed a negative association between levels of anxiety and performance on event-based tasks. Evidence from the acquired brain injury literature suggests that time- and event-based tasks are differentially vulnerable to depressed mood and anxiety. Depression has been shown to have a greater influence on time-based tasks, while anxiety has an influence on event-based tasks (Cockburn, 1996; Kinch & McDonald, 2001). The results of the present study support this. However, it is possible that the levels of anxiety in this study were not high enough to make a significant unique contribution to performance on event-based tasks.

5.1.3 Hypothesis 3: There will be a significant relationship between measures of executive functioning and retrospective memory and performance on the objective prospective memory measure.

Significant correlations were found between a range of neuropsychological measures and performance on the CAMPROMPT. This supports previous correlational findings in TBI by Groot *et al.* (2002) and Schmitter-Edgdecombe and Wright (2004). Despite these relationships, multiple regression analyses showed that level of depression and executive functioning abilities were the only significant predictors of performance. Increasing depression led to poorer CAMPROMPT performance while

increased executive skills related to better prospective memory skills. Regression analysis of time- and event-based performance separately showed that level of depression was a good predictor of time-based performance. Although measures of low mood and anxiety and neuropsychological functioning were correlated with event-based performance, none of these measures predicted performance. Kinch and McDonald (2001) also used multiple regression analysis in a TBI group. In support of the findings in the present study, these authors found that performance on measures of executive functioning accounted for significantly more variance in time-based task scores than retrospective memory performance. However, in contrast, to the present result, Kinch and McDonald (2001) reported that retrospective memory ability predicted performance on event-based tasks. This discrepancy may be due to differences in the populations studied. Participants in the study by Kinch and McDonald (2001) were predominantly inpatients who had suffered severe head injuries. Therefore these participants may have had greater impairments in retrospective memory than the stroke patients in the present study.

5.1.4 Hypothesis 4: Stroke patients will have reduced insight into their everyday prospective and retrospective memory ability.

The results of the present study suggest that stroke patient participants' insight into their everyday memory may be incomplete. Despite significantly poorer performance on objective tests of prospective and retrospective memory, patients did not rate their memory any differently to controls on a subjective measure of prospective and retrospective memory. Patient's self-ratings were also equal to proxy ratings by

relatives and carers. There was also a moderate correlation between these ratings. These results are unexpected and are in contrast to the findings by Roche *et al.* (2007) that TBI patients consistently underestimated their level of impairment compared to carers. It is possible that the relatives and carers in the current study were not aware of any everyday memory deficits in the stroke patients. However, further research would be needed to determine the underlying reasons for this result.

Congruent findings between the current study and that of Kinsella *et al.* (1996) were found in that self-ratings of everyday memory were associated with performance on objective measures of prospective memory but not with measures of retrospective memory. This suggests that stroke patients who rated their everyday memory more favourably performed at a higher level on objective measures of prospective memory. Further analysis revealed that ratings on the retrospective but not the prospective subscale of the PRMQ were correlated with total CAMPROMPT scores. The influence of depression and anxiety on PRMQ self-report ratings was also considered. Depression and anxiety scores were negatively correlated with PRMQ total scores and both subscale scores. Therefore, there was a relationship between increased levels of anxiety and depression and more negative appraisal of prospective and retrospective memory abilities.

5.2 Strengths and limitations

This study is the first to assess prospective memory performance in stroke patients using a standardised, clinically available measure. The CAMPROMPT was designed

to be an ecologically valid measure of prospective memory abilities. The naturalistic properties of the CAMPROMPT allow participants to take notes. In the normative study by Wilson *et al.* (2005), increased note-taking was associated with higher performance. This was not explored in the present study. However, it may have been important in explaining variations in prospective memory performance. It is likely that stroke patients with impairments in prospective memory would vary in terms of their ability to use strategies.

Controlling for confounding factors is a significant strength of this study. This was particularly significant in the case of low mood. A comprehensive assessment of other neuropsychological functions was also carried out. However, as is common in research using purposive clinical samples, difficulties were experienced with recruitment. Therefore the experimental groups were poorly matched on age, gender, years in education and IQ. This led to the use of a significant number of covariates in the analysis. The use of multiple covariates can be problematic as a point of diminishing returns is reached in adjustment of the dependent variable (Tabachnick & Fidell, 1989). However, the use of covariates is appropriate when they are correlated with the dependent variable and not with each other as was the case in the present study. The use of multiple regression is also questioned with smaller sample sizes. A minimum rule of thumb is to have at least five cases per independent variable. As the analysis was carried out with all participants (n=44) and five independent variables, this condition was met.

5.3 Clinical implications

The results of the current study support the assumption that prospective memory deficits are widespread after stroke. As prospective memory is a multi-component process, there are likely to be a variety of potential pathways to these deficits. Therefore, evaluation of prospective memory abilities should be carried out as part of a comprehensive neuropsychological assessment. Unfortunately, this is currently rare in routine clinical practice as assessment of memory abilities has traditionally focussed on retrospective memory or memory for past events. In common with previous studies, the present results indicate that measures of retrospective memory are not good predictors of prospective memory functioning. This has implications for clinical practice as unrecognised difficulties with prospective memory may restrict individuals' ability to engage in or adhere to rehabilitation strategies. In contrast to retrospective memory, executive functioning was shown to be a good predictor of prospective memory performance. Therefore, it is particularly important to assess prospective memory where executive deficits are present as these individuals are likely to require support to carry out delayed intentions.

Due to the high level of comorbid mood disturbances in stroke survivors, the finding that depression impacts on time-based prospective memory functioning is significant. Approximately 33 per cent of stroke survivors experience depression with the risk of occurrence being similar for early, medium and late stages after stroke (Hackett *et al.*, 2005). For the majority of people mood disturbances will resolve spontaneously

after a few months (Hackett *et al.*, 2005). However, disturbance of mood is associated with severity of cognitive impairment and may exacerbate other impairments and limit functional recovery (ISWP, 2008). Individuals who are depressed will likely have further difficulties with time-based tasks than those who are not depressed. As prospective memory is crucial for completing a wide range of everyday activities, it is also possible that individuals with greater deficits in this aspect of cognitive functioning will be more vulnerable to anxiety and depression. Mood disturbances and prospective memory difficulties may reinforce each other as part of a vicious circle. Therefore, clinicians should routinely screen for low mood and anxiety at the assessment stage and continue to monitor for mood disturbances during rehabilitation. Clinicians who are working with depression after stroke should also be aware of its impact on prospective memory abilities.

It is possible that a sampling bias may have occurred in the current study as the majority of stroke patients were referred by clinical psychology. As a result, they may have had more comorbid mood disturbance. However, the participants were likely to be largely representative as there were no psychiatric diagnoses and the level of depression was moderate. Mean scores for depression were below the suggested clinical cut-off (<8) and the maximum score for both anxiety and depression was in the moderate range.

The finding that the stroke patients in the present study had reduced insight into their memory functioning also has implications for assessment and treatment. Without a

comprehensive assessment, individuals may be unable to report failures of prospective memory. They may also have difficulty differentiating between memory for future intentions and memory for past events, attributing everyday failures of prospective memory to poor short-term memory or poor memory for past events. Similarly, individuals with everyday experience of good prospective memory may attribute this to having a good memory for past events. The finding that there was a positive relationship between positive self-ratings of retrospective memory and better performance on the objective measure of prospective memory provides some support for this.

Lack of awareness has been associated with poorer outcomes in rehabilitation (Knight *et al.*, 2005) This may be particularly problematic for prospective memory functioning in everyday life as patients are unlikely to adopt compensatory strategies to aid their prospective memory if they anticipate that they will be able to remember as accurately as they did before their brain injury (Knight *et al.*, 2005). Links have also been reported between self-reported cognitive complaints and post-injury emotional distress and fatigue (Tay *et al.* 2010).

5.4 Directions for future research

The current evidence suggests that all stroke patients will have some reduction in prospective memory performance. However more robust research with larger samples will be needed to confirm this. It would also be of interest to explore whether the pattern of prospective memory difficulties observed varies depending on

type of stroke and severity of stroke. Stroke patients in the present study were poorer on both types of prospective memory task. However, there is some evidence that the pattern of impairment may differ depending on the type of stroke. Cheng *et al.* (2010) reported that stroke patients with thalamic lesions were impaired on time-based tasks, but not on event-based tasks. However, the results of this study should be interpreted with caution due to methodological limitations. The authors did not use valid and reliable measures. Therefore, further research with larger samples is needed.

Despite early recommendations from Cockburn (1996), few studies of prospective memory in acquired brain injury control for the influence of disturbances in mood. The significant influence of mood on prospective memory observed in the present study highlights the relevance of this. There is currently tentative evidence that time-based tasks are more vulnerable to depression and that event-based tasks are influenced by levels of anxiety. It would also be of interest to specifically explore the interaction between time-based prospective memory and depression by comparing depressed and non-depressed patients with acquired brain injury.

A recent meta-analysis of the normal ageing literature by Utzl (2008) reported a vast range of methodological difficulties. These problems have been transferred to the acquired brain injury research. While interesting relationships have been identified by the increased research in neurological conditions there is now a need for more robust research with larger samples. Comparison between studies is currently

difficult due to the range of laboratory paradigms employed. Therefore there is a need for more research with valid and reliable measures.

5.5 Conclusion

The current study supports previous findings that prospective memory ability is reduced after stroke. Impairments in this aspect of cognition are not unique to stroke and have been consistently found in a range of neurological conditions. Despite this, prospective memory is not routinely assessed in clinical practice. This is particularly problematic as traditional measures of retrospective memory are not good predictors of prospective memory performance. A wide range of everyday tasks crucial to independent living require adequate prospective memory. Therefore, the consequences of unrecognised difficulties with prospective remembering may be severe. Individuals with poor executive functioning and comorbid mood disturbances are likely to be particularly vulnerable to difficulties with this aspect of cognitive functioning. Therefore, clinicians should screen for these difficulties at the assessment stage and continue to monitor individuals throughout rehabilitation.

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APPENDICES

1. Journal of Clinical and Experimental Neuropsychology author guidelines
2. Ethical approval: South East Scotland Research Ethics Committee 3
3. Management approval: NHS Highland
4. Relative and carer participant information sheet
5. Relative and carer participant consent form
6. Patient participant information sheet
7. Patient participant consent form
8. Poster
9. Healthy adult participant information sheet
10. Healthy adult participant consent form

Instructions for Authors



SUBMISSION OF MANUSCRIPTS:

All parts of the manuscript should be typewritten, double-spaced, with margins of at least one inch on all sides. Number manuscript pages consecutively throughout the paper. Authors should also supply a shortened version of the title suitable for the running head, not exceeding 50 character spaces. Although there is no word limit for papers submitted to the journal, each article should be summarized in an abstract of not more than 100 words. Avoid abbreviations, diagrams, and reference to the text in the abstract.

References

Reference citations within the text. Use authors' last names, with the year of publication, e.g., "(Brown, 1982; Jones & Smith, 1987; White, Johnson, & Thomas, 1990)". On first citation of references with **three to five** authors, give all names in full, thereafter use [first author] "et al.". In the references, the first **six** authors should be listed in full. If more than one article by the same author(s) in the same year is cited, the letters a, b, c, etc., should follow the year. If a paper is in preparation, submitted, or under review, the reference should include the authors, the title, and the year of the draft (the paper should also be cited throughout the paper using the year of the draft). Manuscripts that are "in press" should also include the publisher or journal, and should substitute "in press" for the date.

Reference list. A full list of references quoted in the text should be given at the end of the paper in alphabetical order of authors' surnames (or chronologically for a group of references by the same authors), commencing as a new page, typed double spaced. Titles of journals and books should be given in full, e.g.:

Books:

Rayner, E., Joyce, A., Rose, J., Twyman, M., & Clulow, C. (2008). *Human development: An introduction to the psychodynamics of growth, maturity and ageing* (4th ed.). Hove, UK: Routledge.

Chapter in edited book:

Craik, F. I. M., Naveh-Benjamin, M., & Anderson, N. D. (1998). Encoding processes: Similarities and differences. In M. A. Conway, S. E. Gathercole, & C. Cornoldi (Eds.), *Theories of memory* (Vol. 2, pp. 61–86). Hove, UK: Psychology Press.

Journal article:

Adlington, R. L., Laws, K. R., & Gale, T. M. (2009). The Hatfield Image Test (HIT): A new picture test and norms for experimental and clinical use. *Journal of Clinical and Experimental Neuropsychology*, *31*, 731-753. doi:10.1080/13803390802488103

Tables

These should be kept to the minimum. Each table should be typed double spaced on a separate page, giving the heading, e.g., "Table 2", in Arabic numerals, followed by the legend, followed by the table. Make sure that appropriate units are given. Instructions for placing the table should be given in parentheses in the text, e.g., "(Table 2 about here)".

Figures

Figures should only be used when essential and the same data should not be presented both as a figure and in a table. Where possible, related diagrams should be grouped together to form a single figure. Each figure should be on a separate page, not integrated with the text. The figure captions should be typed in a separate section, headed, e.g., "Figure 2", in Arabic numerals. Instructions for placing the figure should be given in parentheses in the text, e.g., "(Figure 2 about here)".

Statistics Results of statistical tests should be given in the following form:

"... results showed an effect of group, $F(2, 21) = 13.74$, $MSE = 451.98$, $p < .001$, but there was no effect of repeated trials, $F(5, 105) = 1.44$, $MSE = 17.70$, and no interaction, $F(10, 105) = 1.34$, $MSE = 17.70$."

Other tests should be reported in a similar manner to the above example of an *F*-ratio. For a fuller explanation of statistical presentation, see the *APA Publication Manual* (6th ed.).

Abbreviations. Abbreviations that are specific to a particular manuscript or to a very specific area of research should be avoided, and authors will be asked to spell out in full any such abbreviations throughout the text. Standard abbreviations such as RT for reaction time, SOA for stimulus onset asynchrony or other standard abbreviations that will be readily understood by readers of the journal are acceptable. Experimental conditions should be named in full, except in tables and figures.

Appendix 2: Ethical Approval

Lothian NHS Board

South East Scotland Research
Ethics Committee 2
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Dear Ms Barr

Study Title: Prospective memory functioning after stroke: Objective and subjective assessment
REC reference number: 11/S1102/2

Thank you for your letter of 03 February 2011, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information was considered in correspondence by a sub-committee of the REC. A list of the sub-committee members is attached.

Confirmation of ethical opinion

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form, protocol and supporting documentation as revised, subject to the conditions specified below.

Ethical review of research sites

The favourable opinion applies to all NHS sites taking part in the study, subject to management permission being obtained from the NHS/HSC R&D office prior to the start of the study (see "Conditions of the favourable opinion" below).

Conditions of the favourable opinion

The favourable opinion is subject to the following conditions being met prior to the start of the study.

Management permission or approval must be obtained from each host organisation prior to the start of the study at the site concerned.



Headquarters
Waverley Gate, 2-4 Waterloo Place, Edinburgh EH1 3EG

Chair Dr Charles J Winstanley
Chief Executive Professor James J Barbour O.B.E.
Lothian NHS Board is the common name of Lothian Health Board

For NHS research sites only, management permission for research ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission for research is available in the Integrated Research Application System or at <http://www.rdforum.nhs.uk>.
Where the only involvement of the NHS organisation is as a Participant Identification Centre (PIC), management permission for research is not required but the R&D office should be notified of the study and agree to the organisation's involvement. Guidance on procedures for PICs is available in IRAS. Further advice should be sought from the R&D office where necessary.

Sponsors are not required to notify the Committee of approvals from host organisations.

It is the responsibility of the sponsor to ensure that all the conditions are complied with before the start of the study or its initiation at a particular site (as applicable).

Approved documents

The final list of documents reviewed and approved by the Committee is as follows:

<i>Document</i>	<i>Version</i>	<i>Date</i>
REC application	1	14 January 2010
Participant Consent Form: Patient	2	02 March 2007
Questionnaire: The Prospective and Retrospective Memory Questionnaire	Validated	
Letter from Sponsor		12 January 2011
Supervisors CV		
Travel Claim Form		
GP/Consultant Information Sheets	1	13 January 2011
Participant Information Sheet: Patient	2	02 March 2011
Participant Consent Form: Relative and Carer	1	02 March 2011
Participant Consent Form: Healthy Adult	2	02 March 2011
Questionnaire Pack		
Investigator CV		
Response to Request for Further Information		03 February 2011
Participant Information Sheet: Healthy Adult	2	02 March 2011
Questionnaire: HADS	Validated	
Advertisement		
Protocol	1	13 January 2011
Participant Information Sheet: Relative and Carer	1	02 March 2011

Statement of compliance

The Committee is constituted in accordance with the Governance Arrangements for Research Ethics Committees (July 2001) and complies fully with the Standard Operating Procedures for Research Ethics Committees in the UK.

After ethical review

Now that you have completed the application process please visit the National Research Ethics Service website > After Review

You are invited to give your view of the service that you have received from the National Research Ethics Service and the application procedure. If you wish to make your views known please use the feedback form available on the website.

The attached document "*After ethical review – guidance for researchers*" gives detailed guidance on reporting requirements for studies with a favourable opinion, including:

- Notifying substantial amendments
- Adding new sites and investigators
- Progress and safety reports
- Notifying the end of the study

The NRES website also provides guidance on these topics, which is updated in the light of changes in reporting requirements or procedures.

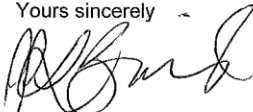
We would also like to inform you that we consult regularly with stakeholders to improve our service. If you would like to join our Reference Group please email referencegroup@nres.npsa.nhs.uk.

11/S1102/2

Please quote this number on all correspondence

With the Committee's best wishes for the success of this project

Yours sincerely



Mr Thomas Russell
Chair

Email: lyndsay.baird@nhslothian.scot.nhs.uk

Enclosures:

List of names and professions of members who were present at the meeting and those who submitted written comments

Appendix 3: Management Approval

Mr Angus Watson
Research & Development Director
NHS Highland Research & Development Office
Room S101
Centre for Health Science
Old Perth Road
Inverness
IV2 3JH

Tel: 01463 255822
Fax: 01463 255838
E-mail: angus.watson@nhs.net



24 March 2011

NHS Highland R&D ID: 731

Mrs Arlene Barr
Trainee Clinical Psychologist
NHS Highland
Department of Psychological Services
Drumossie Unit
New Craigs Hospital
Inverness
IV3 8NP

Dear Mrs Barr,

Management Approval for Non-Commercial Research

I am pleased to tell you that you now have Management Approval for the research project entitled: '**Prospective Memory Functioning After Stroke: Objective and Subjective Assessment**'. I acknowledge that:

- The project is sponsored by NHS Highland.
- The project does not require external funding.
- Research Ethics approval for the project has been obtained from the South East Scotland 2 Research Ethics Committee, (Reference Number: 11/S1102/2).
- The project is Site-Specific Assessment exempt.

The following conditions apply:

- The responsibility for monitoring and auditing this project lies with NHS Highland.



Headquarters:
NHS Highland, Assynt House, Beechwood Park, Inverness, IV2 3HG

Chairman: Mr Garry Coutts
Chief Executive: Elaine Mead
Highland NHS Board is the common name of Highland Health Board

- This study will be subject to ongoing monitoring for Research Governance purposes and may be audited to ensure compliance with the Research Governance Framework for Health and Community Care in Scotland (2006, 2nd Edition), however prior written notice of audit will be given.
- All amendments (minor or substantial) to the protocol or to the REC application should be copied to the NHS Highland Research and Development Office together with a copy of the corresponding approval letter.
- The paperwork concerning all incidents, adverse events and serious adverse events, thought to be attributable to participant's involvement in this project should be copied to the NHS Highland R&D Office.

Please report the information detailed above, or any other changes in resources used, or staff involved in the project, to the NHS Highland Research and Development Manager, Frances Hines (01463 255822, frances.hines@nhs.net).

Yours sincerely,



Mr Angus Watson
NHS Highland Research and Development Director

cc Frances Hines, R&D Manager, NHS Highland Research & Development Office, Room S101, The Centre for Health Science, Old Perth Road, Inverness, IV2 3JH
Kenneth Laidlaw, Senior Lecturer in Clinical Psychology, Room 2.13, University of Edinburgh Medical School, Teviot Place, Edinburgh, EH8 9AG

Appendix 4: Relative and Carer Participant Information Sheet



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP

Tel: 01463 253 697



Date 2nd March 2011

Relative and Carer Participant Information Sheet – Version 1

Study Title: Prospective memory functioning after stroke: Objective and Subjective assessment

You are being invited to take part in a research study. It is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Talk to others about the study if you wish before you decide to take part and please ask if you would like more information. *Thank you for your time.*

Why are we doing this research?

The aim of this research project is to explore prospective memory functioning in people who have had a stroke. Prospective memory is our memory for carrying out previously planned actions in the future. For example, remembering to take medication at the correct time, or remembering to pick up some milk on the way home from work. This kind of memory is used for many everyday tasks and it is important for living independently. As a result, difficulties with prospective memory can have a significant impact on people's home, work and social lives.

We hope to learn more about prospective memory functioning after stroke. We will look at the relationship between how we view our memory and how we actually perform on memory tests. We will also look at how other mental processes might be related to prospective memory. In the long term, understanding more about how stroke affects prospective memory may lead to better rehabilitation for stroke survivors.

Why have I been chosen?

We would like you to take part because you are a relative, close friend or carer of someone who has had a stroke.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do wish to take part, you will be asked to sign a consent form. You are free to change your mind at any point during the study and you can withdraw at any time without giving a reason. If you do change your mind and withdraw from the study, any treatment you are receiving now or in the future will not be affected.

What is involved?

You will be asked to complete a questionnaire about the memory of your relative or the person you are caring for who has had a stroke. We would like you to complete this because you know the person well. This questionnaire has 16 questions. You will be able to complete the questionnaire at a time and place of your convenience. If you choose to attend an appointment at the hospital, you will be able to claim reasonable travel expenses in line with NHS Highland policy.

Is there any harm in participating in this research?

The questionnaires used in this study will not cause you any harm. However, if you were to have any concerns, the named researcher (Arlene Barr) would discuss these with you.

How is this research useful?

There are no direct benefits or disadvantages to you in taking part. However, we hope that the study will help us to learn more about how prospective memory is affected by stroke. In the long term, understanding more about this may contribute to improving rehabilitation for those who have experienced stroke.

Will my taking part in this research study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. Only members of the research team will have access to this information. Any information about you will have your name and address removed so that you cannot be recognised from it.

With your permission we will inform your General Practitioner (GP) of your participation in this study. In the unlikely event that participation uncovers a problem, we will seek your permission to inform your GP.

What if there is a problem?

If you have a concern about any aspect of this study you should ask to speak to the named researcher, Arlene Barr, who will do her best to answer your questions. If you would like to speak to an independent person about this study, you may also contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you wish to complain formally, you can do this through the hospital's complaints procedure. Details can be obtained from the hospital. In the unlikely event that you are harmed during the research and this is due to someone's negligence then you have grounds for legal action for compensation against the organisation named on the consent form. Should this occur, you may have to pay your legal costs. The normal National Health Service complaints mechanism will still be available to you.

What will happen to the results of this research study?

The results of this study will be written up as a report for NHS Highland and for the University of Edinburgh. The results may also be published in scientific journals and if so, will be published one to two years after the end of the study in September 2011. It will not be possible to identify participants in any of these reports.

Who is organising the research?

This study is part of the researcher's Doctorate in Clinical Psychology qualification. This qualification is being completed through the National Health Service (NHS) Highland, National Education for Scotland (NES) and the University of Edinburgh.

Who has reviewed the study?

All research is looked at by an independent group of people called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity. This research has been reviewed by an NHS ethics committee.

Who do I contact for further information?

If you would like any more information about the study, please contact Arlene Barr (Trainee Clinical psychologist) on 01463 253 697. Alternatively, if you would like to speak to an independent person about this study, please contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you would like a written summary of the main research findings please contact Arlene Barr on 01463 253 697. This can be provided for all participants at the end of the study in September 2011.

Thank you for considering taking part in this study

Appendix 5: Relative or Carer Consent Form



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP



Tel: 01463 253697

Date 2nd March 2011

RELATIVE/CARER CONSENT FORM – Version 1

Title of study: Prospective memory functioning after stroke: Objective and subjective assessment

Centre Name:

Name of researcher: Arlene Barr

Participant Identification Number:

Please INITIAL

1. I confirm that I have read and understand the information sheet concerning the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason
3. I agree to take part in the above research study.
4. I understand that relevant sections of my medical notes and data collected during the study may be looked at by the study researcher and individuals from the Sponsor, regulatory authorities or from the NHS organisation, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.
5. I agree to my General Practitioner (GP) being informed of my participation in this research.
6. In the unlikely event that there is an underlying clinical problem identified during the course of this research, the researcher will inform me of this. I give consent to the researcher providing me with this feedback.
7. In the unlikely event that there is an underlying clinical problem identified, I give consent to the researcher contacting my GP to inform them of this.

Name of participant

Signature

Date

Name of researcher

Signature

Date

Following completion of this consent form, one copy will be given to the participant and one will be kept in their medical records.

Appendix 6: Patient Participant Information Sheet



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP

Tel: 01463 253 697



Date 2nd March 2011

Patient Participant Information Sheet – Version 2

Study Title: Prospective memory functioning after stroke: Objective and Subjective assessment

You are being invited to take part in a research study. It is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Talk to others about the study if you wish before you decide to take part and please ask if you would like more information. *Thank you for your time.*

Why are we doing this research?

The aim of this research project is to explore prospective memory functioning in people who have had a stroke. Prospective memory is our memory for carrying out previously planned actions in the future. For example, remembering to take medication at the correct time, or remembering to pick up some milk on the way home from work. This kind of memory is used for many everyday tasks and it is important for living independently. As a result, difficulties with prospective memory can have a significant impact on people's home, work and social lives.

We hope to learn more about prospective memory functioning after stroke. We will look at the relationship between how we view our memory and how we actually perform on memory tests. We will also look at how other mental processes might be related to prospective memory. In the long term, understanding more about how stroke affects prospective memory may lead to better rehabilitation for stroke survivors.

Why have I been chosen?

We would like you to take part because you are 18 years or older and have had a stroke.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do wish to take part, you will be asked to sign a consent form. You are free to change your mind at any point during the study and you can withdraw at any time without giving a reason. If you do change your mind and withdraw from the study, any treatment you are receiving now or in the future will not be affected.

What is involved?

You will be seen once by Arlene Barr, Trainee Clinical Psychologist. First, you will be asked a couple of brief questions about your general health and whether you have any problems with seeing or hearing. Then you will be asked to complete a questionnaire about your memory. This questionnaire has 16 questions. Someone who knows you well will also be asked to complete this questionnaire. You will be asked to complete a brief questionnaire about how you have been feeling over the past week. This questionnaire has 14 questions.

Following this, you will be asked to complete a series of puzzles that will test your memory, language and concentration skills. These will require various responses such as saying different words, drawing diagrams or answering questions. In total, this will last around two hours and can be done either at home or at the hospital, wherever is convenient for you. If you do choose to attend the hospital, you will be able to claim reasonable travel expenses in line with NHS Highland policy. You will be offered the opportunity to have a break during testing. If necessary, a second appointment will be offered to complete testing if you feel you are unable to complete the tasks in one appointment due to fatigue.

Is there any harm in participating in this research?

The tasks and questionnaires used in this study will not cause you any harm. However, if you were to have any concerns, the named researcher (Arlene Barr) would discuss these with you.

How is this research useful?

There are no direct benefits or disadvantages to you in taking part. However, we hope that the study will help us to learn more about how prospective memory is affected by stroke. In the long term, understanding more about this may contribute to improving rehabilitation for those who have experienced stroke.

Will my taking part in this research study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. Only members of the research team and the staff already involved in your treatment will have access to this information. Any information about you which leaves the hospital will have your name and address removed so that you cannot be recognised from it.

With your permission we will inform your General Practitioner of your participation in this study. In the unlikely event that participation in the research highlights an underlying clinical problem you will be informed about this through feedback from the assessment. You will then be advised to contact your GP and we will seek your permission to inform them.

What if there is a problem?

If you have a concern about any aspect of this study you should ask to speak to the named researcher, Arlene Barr, who will do her best to answer your questions. If you would like to speak to an independent person about this study, you may also contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you wish to complain formally, you can do this through the hospital's complaints procedure. Details can be obtained from the hospital. In the unlikely event that you are harmed during the research and this is due to someone's negligence then you have grounds for legal action for compensation against the organisation named on the consent form. Should this occur, you may have to pay your legal costs. The normal National Health Service complaints mechanism will still be available to you.

What will happen to the results of this research study?

The results of this study will be written up as a report for NHS Highland and for the University of Edinburgh. The results may also be published in scientific journals and if so, will be published one to two years after the end of the study in September 2011. It will not be possible to identify participants in any of these reports.

If you wish to receive a summary of your own results, please indicate this on the consent form. This summary will be sent to your home address at the end of the study.

Who is organising the research?

This study is part of the researcher's Doctorate in Clinical Psychology qualification. This qualification is being completed through the National Health Service (NHS) Highland, National Education for Scotland (NES) and the University of Edinburgh.

Who has reviewed the study?

All research is looked at by an independent group of people called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity. This research has been reviewed by an NHS ethics committee.

Who do I contact for further information?

If you would like any more information about the study, please contact Arlene Barr (Trainee Clinical psychologist) on 01463 253 697. Alternatively, if you would like to speak to an independent person about this study, please contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you would like a written summary of the main research findings please contact Arlene Barr on 01463 253 697. This can be provided for all participants at the end of the study in September 2011.

Thank you for considering taking part in this study

Appendix 7: Patient Participant Consent Form



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP



Tel: 01463 253697

Date 2nd March 2011

PATIENT CONSENT FORM – Version 2

Title of study: Prospective memory functioning after stroke: Objective and subjective assessment

Centre Name:

Name of researcher: Arlene Barr

Participant Identification Number:

**Please
INITIAL**

- | | |
|---|----------------------|
| 1. I confirm that I have read and understand the information sheet concerning the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily. | <input type="text"/> |
| 2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason, and without my medical care, educational or legal rights being affected. | <input type="text"/> |
| 3. I agree to take part in the above research study. | <input type="text"/> |
| 4. I understand that relevant sections of my medical notes and data collected during the study may be looked at by the study researcher and individuals from the Sponsor, regulatory authorities or from the NHS organisation, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records. | <input type="text"/> |
| 5. I agree to my General Practitioner (GP) being informed of my participation in this research. | <input type="text"/> |
| 6. In the unlikely event that there is an underlying clinical problem identified during the course of this research, the researcher will inform me of this. I give consent to the researcher providing me with this feedback. | <input type="text"/> |
| 7. In the unlikely event that there is an underlying clinical problem identified, I give consent to the researcher contacting my GP to inform them of this. | <input type="text"/> |

Name of participant

Signature

Date

Name of researcher

Signature

Date

Following completion of this consent form, one copy will be given to the participant and one will be kept in their medical records.

Would you like the opportunity to take part in a major research project about memory?

We are looking to recruit healthy volunteers aged **18 years or over** to take part in a research study. You can take part at a time and place of your convenience. It will take no longer than 90 minutes.

You will be asked to complete a series of puzzles that will test your memory, language and concentration skills. These will require various responses such as saying different words, drawing diagrams or answering questions.

We are hoping to find out more about memory functioning in people who have had a stroke. We will look at the relationship between how we view our memory and how we actually perform on memory tests. In the long term, understanding more about how memory is affected by stroke may lead to better rehabilitation for stroke survivors.

If you are interested in taking part, please take a participant information sheet and consent form and contact the researcher Arlene Barr at **Drumossie Unit, New Craigs Hospital Inverness** on **01463 253 697**

Thank you for taking the time to read this

Appendix 9: Healthy Adult Participant Information Sheet



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP

Tel: 01463 253 697



Date 2nd March 2011

Healthy Adult Participant Information Sheet – Version 2

Study Title: Prospective memory functioning after stroke: Objective and Subjective assessment

You are being invited to take part in a research study. It is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully. Talk to others about the study if you wish before you decide to take part and please ask if you would like more information. *Thank you for your time.*

Why are we doing this research?

The aim of this research project is to explore prospective memory functioning in people who have had a stroke. Prospective memory is our memory for carrying out previously planned actions in the future. For example, remembering to take medication at the correct time, or remembering to pick up some milk on the way home from work. This kind of memory is used for many everyday tasks and it is important for living independently. As a result, difficulties with prospective memory can have a significant impact on people's home, work and social lives.

We hope to learn more about prospective memory functioning after stroke. We will look at the relationship between how we view our memory and how we actually perform on memory tests. We will also look at how other mental processes might be related to prospective memory. In the long term, understanding more about how stroke affects prospective memory may lead to better rehabilitation for stroke survivors.

Why have I been chosen?

We would like you to be in the control group, you have been chosen because you are 18 years or over.

Do I have to take part?

It is up to you to decide whether or not to take part. If you do wish to take part, you will be asked to sign a consent form. You are free to change your mind at any point during the study and you can withdraw at any time without giving a reason.

What is involved?

You will be seen once by Arlene Barr, Trainee Clinical Psychologist. First, you will be asked a couple of brief questions about your general health and whether you have any problems with seeing or hearing. Then you will be asked to complete a questionnaire about your memory. This questionnaire has 16 questions. You will then be asked to fill out a brief questionnaire about how you have been feeling in the past week. This questionnaire has 14 questions.

Following this, you will be asked to complete a series of puzzles that will test your memory, language and concentration skills. These will require various responses such as saying different words, drawing diagrams or answering questions. In total, this will last around two hours and can be done either at home or at the hospital, wherever is convenient for you. If you choose to come to the hospital, you will be able to claim reasonable travel expenses in line with NHS Highland policy. You will be offered a break during testing.

Is there any harm in participating in this research?

The tasks and questionnaires used in this study will not cause you any harm. However, if you were to have any concerns, the named researcher (Arlene Barr) would discuss these with you.

How is this research useful?

There are no direct benefits or disadvantages to you in taking part. However, we hope that the study will help us to learn more about how prospective memory is affected by stroke. In

the long term, understanding more about this may contribute to improving rehabilitation for those who have experienced stroke.

Will my taking part in this research study be kept confidential?

All information that is collected about you during the course of the research will be kept strictly confidential. Only members of the research team will have access to this information. Any information about you will have your name and address removed so that you cannot be recognised from it.

With your permission we will inform your General Practitioner of your participation in this study. In the unlikely event that participation uncovers a problem, we will also seek your permission to inform your GP.

What if there is a problem?

If you have a concern about any aspect of this study you should ask to speak to the named researcher, Arlene Barr, who will do her best to answer your questions. If you would like to speak to an independent person about this study, you may also contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you wish to complain formally, you can do this through the hospital's complaints procedure. Details can be obtained from the hospital. In the unlikely event that you are harmed during the research and this is due to someone's negligence then you have grounds for legal action for compensation against the organisation named on the consent form. Should this occur, you may have to pay your legal costs. The normal National Health Service complaints mechanism will still be available to you.

What will happen to the results of this research study?

The results of this study will be written up as a report for NHS Highland and for the University of Edinburgh. The results may also be published in scientific journals and if so, will be published one to two years after the end of the study in September 2011. It will not be possible to identify participants in any of these reports.

If you wish to receive a summary of your own results, please indicate this on the consent form. This summary will be sent to your home address at the end of the study.

Who is organising the research?

This study is part of the researcher's Doctorate in Clinical Psychology qualification. This qualification is being completed through the National Health Service (NHS) Highland, National Education for Scotland (NES) and the University of Edinburgh.

Who has reviewed the study?

All research is looked at by an independent group of people called a Research Ethics Committee to protect your safety, rights, wellbeing and dignity. This research has been reviewed by an NHS ethics committee.

Who do I contact for further information?

If you would like any more information about the study, please contact Arlene Barr (Trainee Clinical psychologist) on 01463 253 697. Alternatively, if you would like to speak to an independent person about this study, please contact Margaret Somerville, Director of Advice and Support for Chest, Heart & Stroke Scotland on 01463 713 433.

If you would like a written summary of the main research findings please contact Arlene Barr on 01463 253 697. This can be provided for all participants at the end of the study in September 2011.

Thank you for considering taking part in this study

Appendix 10: Healthy Adult Participant Consent Form



Department of Psychological Services

Drumossie Unit
New Craigs Hospital
6-16 Leachkin Road
Inverness
IV3 8NP



Tel: 01463 253697

Date 2nd March 2011

CONTROL PARTICIPANT CONSENT FORM – Version 2

Title of study: Prospective memory functioning after stroke: Objective and subjective assessment

Centre Name:

Name of researcher: Arlene Barr

Participant Identification Number:

Please INITIAL

1. I confirm that I have read and understand the information sheet concerning the above study. I have had the opportunity to consider the information, ask questions and have had these answered satisfactorily.
2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason
3. I agree to take part in the above research study.
4. I understand that relevant sections of my medical notes and data collected during the study may be looked at by the study researcher and individuals from the Sponsor, regulatory authorities or from the NHS organisation, where it is relevant to my taking part in this research. I give permission for these individuals to have access to my records.
5. I agree to my General Practitioner (GP) being informed of my participation in this research.
6. In the unlikely event that there is an underlying clinical problem identified during the course of this research, the researcher will inform me of this. I give consent to the researcher providing me with this feedback.
7. In the unlikely event that there is an underlying clinical problem identified, I give consent to the researcher contacting my GP to inform them of this.

Name of participant

Signature

Date

Name of researcher

Signature

Date

Following completion of this consent form, one copy will be given to the participant and one will be kept in their medical records.