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Development of Novel Computerised Tools to Assess Memory and Planning in People with Brain Injury

AND

Clinical Research Portfolio

VOLUME I

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VOLUME I: Table of Contents

Chapter 1: Systematic Review

A Systematic Review of the Validity of Computerised Measures of Executive Function Based on Real World Environments

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Prepared in accordance with guidelines for submission to *Journal of International Neuropsychological Society (Appendix 1.1)*

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Abstract

Background: Current neuropsychological assessment measures often do not capture the nuances of day-to-day tasks that present a challenge to people who experience executive functioning difficulties after acquired brain injury. Computerised assessment tools using virtual environments may provide greater ecological validity than traditional executive function measures and ensure increased methodological control over real-world observation. This review systematically examines the ability of computerised measures simulating real world environments to predict executive function difficulties in tasks of everyday living.

Methods: Electronic database searches of published studies ranging from 1980-2014 were performed. Additional hand searches of reference lists and selected journals were completed. Studies that fulfilled the inclusion criteria were reviewed using a methodological quality rating checklist derived from Cook and Campbell's (1979) list of threats to experimental validity.

Results: Only three of the nine studies included in this review gained a methodological rating greater than or equal to 12 points out of 20. Threats to validity included limited sample sizes, analyses that were exploratory in nature and the omission of a real-world task with which to compare performance on computerised measures. Despite this, overall evidence suggests that computerised measures of executive function that are based on everyday tasks are sensitive to cognitive impairments that impact on everyday functioning.

Conclusions: There is a dearth of methodologically robust research examining the ecological validity of computerised measures of executive function. Results tentatively suggest that computerised assessment may be a promising method of accurately predicting day-to-day

difficulties in people with brain injury. Findings have potential theoretical and practical implications in neuropsychological assessment and rehabilitation settings.

Introduction

Executive functioning is an umbrella term that refers to a broad range of higher order cognitive processes that control and regulate other processes, such as language and memory (Lezak, 1982). Theoretical and factor analytic research carried out to identify these cognitive and behavioural functions have identified several discrete cognitive domains that underpin executive function (e.g., Burgess *et al.*, 1998; Miyake *et al.*, 2000; Simblett & Bateman, 2011). These include the processes of planning, task switching, inhibiting behavioural responses, prospective memory and goal management which are commonly used to negotiate multiple goals and changing circumstances often seen in everyday life. Research has shown that people with acquired brain injury, particularly those with damage to the frontal lobes, will often display deficits in one or more of these areas of executive functioning while other cognitive domains may be unaffected (Shallice & Burgess, 1991).

Many questions remain regarding the dimensions that underpin executive functions and the assessment of these deficits under laboratory conditions has proved problematic. There is a growing recognition that neuropsychological assessment tools need to simulate more complex and realistic environments that require the use of multiple executive processes simultaneously, in order to be more predictive of real-world performance (Burgess *et al*., 2006). Increasing the ecological validity of neuropsychological assessments provides the patient with the opportunity to cognitively and behaviourally respond as they would if they were in the real world. This makes identifying specific processes involved in executive function and the development of specific "real-life" assessment measures for these processes a valuable area of interest.

Assessment measures such as the Behavioural Assessment of Dysexecutive function (BADS; Wilson, Alderman, Burgess, Emslie & Evans, 1996) have been developed to address

the ecological short-comings of their predecessors. However, despite being the most widely used in clinical practice, the BADS still remains limited in predictive ability of daily functioning in people with brain injury (Wood & Lossi, 2006). Other assessment approaches have incorporated the use of questionnaire measures such as the The Dysexecutive Questionnaire (DEX) in order to gain a more accurate reflection of daily functioning. The DEX questionnaire comes in both a self-report and relative/carer report version and is contained within the BADS. It is a 20-item measure which covers a wide range of specific problems (e.g., memory, awareness, emotional regulation) and is sensitive to the changes in daily functioning that often follow acquired brain injury (Bennet, Ong & Ponsford, 2005). However, the utility of questionnaire measures is debateable with previous research showing that people with brain injury may lack the self-awareness necessary to accurately report on their everyday difficulties (Bennet *et al.*, 2005, Burgess, Alderman, Evans, Emslie, & Wilson, 1998). Similarly, responses on informant–rated measures may be influenced by the stage of adjustment to impairment (Ponsford & Kinsella, 1991) and may ask informants to report on aspects of cognition that are not readily observable, such as rating how often the individual "does the first thing that comes to mind" (Simblett & Bateman, 2011).

Researchers have also developed performance-based assessments that incorporate daily activities in a real-world setting which aim to capture the individual's ability to maintain goals in a constantly changing environment similar to those they encounter in day to day life. One such task is the Multiple Errands Test (MET; Alderman, Burgess, Knight, & Henman, 2003; Shallice & Burgess, 1991), a complex test of executive abilities which aims to assess difficulties which are not adequately captured by traditional neuropsychological tests. During this task participants are brought to a local shopping centre and given 12 tasks to perform while adhering to 9 rules (e.g. don't go over budget). Six tasks require the

participant to purchase specific items, 4 tasks involve writing down specific pieces of information and the final two tasks require the participant to do something at a specific time and to tell the examiner when they are finished the test. The MET is described by Burgess (2003) as a test with, “the most obvious ecological validity in current use”, one that is “highly sensitive both to brain damage in general and to specific executive problems”. However, despite its ecological strengths clinicians are reluctant to incorporate the MET into routine clinical practice given its time consuming nature and the difficulties in standardisation associated with conducting assessments in naturalistic environments.

Evidently, there are many challenges in the assessment of executive functions and their underlying processes. During the past decade, computerised assessments of executive function have become more popular (Josman, Klinger & Kizony, 2008) and tasks such as the MET have been adapted for administration in virtual environments. This move towards ecologically valid, but practical, assessment tools increases the likelihood that cognitive and behavioural responses captured during testing are those that would occur in every-day situations (Burgess *et al.*, 2006). It may also support a greater delineation of the components of executive function and allows behaviour to be measured in a safe environment while maintaining strict methodological control (Rizzo, Buckwalter, & Van der Zaag, 2002).

Despite an increasing literature base examining the utility of computerised measures of executive functions in people with brain injury, no systematic review to date has examined the validity of these tools and the methodological quality of studies conducted in the area.

Aims

To systematically review the effectiveness of computerised multiple errands tests at assessing executive functions in people with an acquired brain injury in papers published between 1980 and April 2014. In terms of technological development, 1980 was chosen as the point before which the development of realistic computerised environments would not have been possible.

Research Question

Do computerised multiple errands tests provide an ecologically valid method of assessing executive function difficulties in people with acquired brain injury?

Method

Search strategy

A number of search strategies were used to identify published studies on the assessment of executive functions using computerised multiple errands tests in an ABI population. Firstly, relevant articles were identified by a search of the following electronic databases: Ovid Medline 1980-2014; Embase 1980-2014; CINAHL Plus; PsychINFO; Psychology and Behavioural Sciences Collection and Web of Science. Reference sections of relevant papers were also examined to identify further articles of relevance.

The following search terms were developed:

1. Head injur* or brain injur* or head trauma or stroke or ABI or TBI

AND

2. Executive Function* (cognition, memory, attention, planning)

AND

3. Virtual Reality; or computer* and test*; or computer* and assessment; or video gam* or computer* simulation or virtual or user-computer interface

Inclusion Criteria

1. Types of studies: Studies that aimed to validate a computerised multiple errands type task to measure executive functions. Only studies reported in peer-reviewed journals were included. Studies that used interventions such as cognitive rehabilitation were included only when baseline measures were provided.

2. Types of instruments: Only studies that compared performance on a computerised multiple errands task with performance on at least one other validated measure of executive function were included. This included studies incorporating neuropsychological tests and self-report or independently rated questionnaires.

3. Type of participants: Children and adults of any age who had an acquired brain injury of any severity. Studies were included if at least one of the experimental groups consisted entirely of participants with ABI. The employed definition of acquired brain injury is taken from the Scottish Needs Assessment Programme report (2000): "ABI implies damage to the brain that was sudden in onset and occurred after birth and the neonatal period. It is thus differentiated from birth injuries, congenital abnormalities and progressive or degenerative diseases affecting the central nervous system."

Exclusion Criteria

1. Review articles, book chapters, case studies, conference abstracts and studies that were not available in the English language.

Cognitive Assessment Using Computers

A joint position paper produced by the American Academy of Clinical Neuropsychology and the National Academy of Neuropsychology defined computerised neuropsychological assessment devices as "any instrument that utilises a computer, digital tablet, handheld device, or other digital interface instead of a human examiner to administer, score, or interpret tests of brain function and related factors relevant to questions of neurologic health and illness." (Bauer *et al.*, 2012).

Computerised environments can range from basic rooms for navigation tasks to detailed spaces (e.g. shopping centre, office) to assess more complex activities. This review included all types of computerised and virtual reality technologies that have been used to assess cognitive function. These include non-immersive computer screens using a mouse, joystick or sensor-based gloves; semi-immersive three-dimensional screen displays using shutter glasses and fully immersive environments with a "green screen" and head-mounted display.

Study Evaluation

A number of published guidelines for conducting systematic reviews were considered when constructing the quality rating for this systematic review (e.g. QUADAS Tool, PRISMA Statement). These guidelines were largely developed with medical tests in mind and on the whole required comparison of the index test to a reference test that was 100% accurate.

After careful consideration it was decided that these guidelines would not be appropriate for assessing studies in the area of computerised assessment which often compare performance with reference tests that have varying degrees of accuracy.

One of the most widely recognised and accepted criteria for examining psychological research was developed by Cook and Campbell (1979; cited in Ellis, Ladany, Krengel, & Schult, 1996). Cook and Campbell (1979) outlined threats associated with four classes of validity - statistical conclusion, internal, construct and external validity. Ellis *et al.* (1996) combined Cook and Campbell's threats to four classes of validity with Wampold *et al.*'s (1990) threats to hypothesis validity to create a rigorous framework for assessing methodological quality. This framework has been used successfully by Millar (2005) to address potential methodological weaknesses in studies examining the ecological validity of neuropsychological tests of executive function. Each aspect of validity was assessed as yes definitely a threat (0 points), a possible threat or not enough information provided (1 point) and no threat (2 points).

Hypothesis Validity

Hypothesis validity examines the "interrelation of theory, research hypotheses and statistical hypotheses" (Wampold *et al.*, 1990, p. 361). The elements of hypothesis validity which were evaluated were:

Hypothesis ambiguity. This refers to the creation of a testable hypothesis that is based on clear theoretical foundations.

- Providing a clear specific hypothesis and/or outlining the conditions under which the hypothesis will fail or succeed (no threat)

- Vague hypothesis (possible threat)
- No clear hypothesis (threat)

Diffuse/Exploratory Statistical Hypothesis. This refers to the use of multiple statistical tests per hypothesis or statistical analysis which does not adequately minimise the influence of extraneous variables (Ellis *et al.*, 1996).

- Analysis based on hypothesis (no threat)
- Use of diffuse statistical approach but includes discussion of limitations (possible threat)
- Use of diffuse or exploratory hypothesis with no discussion of limitations (threat)

Internal Validity

Internal validity refers to the ability to demonstrate a causal relationship between two variables while minimising the possibility that systematic error occurred. A sample of threats to internal validity outlined by Cook and Campbell (1979) were incorporated to systematically monitor the effects of extraneous variables.

History. This refers to the adequate evaluation of pre-morbid behaviour and/or cognitive factors that may influence results such as IQ and level of education.

- pre-morbid cognitive or behavioural functioning was assessed and if necessary included in analyses (no threat)
- pre-morbid cognitive or behavioural functioning was assessed and described but not included in analyses where necessary (possible threat)
- pre-morbid cognitive or behavioural functioning was not assessed (threat)

Selection*.* This refers to the threat posed by selecting participants who do not represent the population on which the research question was based and by not matching the patient group to controls where applicable.

- Participants were representative of the population on which the research question was based (no threat)
- Participants may not be representative (possible threat)
- Participants were not representative (definite threat)

Control Participants.

- Controls matched to patient group on a number of variables (no threat)
- Controls matched to patient group on a single variable (e.g. age, education) (possible threat)
- Control not matched to patient group (definite threat)

Co-morbid confounds. This refers to threats to methodological robustness that occur when the influence of significant variables is not taken into account. In brain injury research factors such as depression, language disorder and visuospatial disorder have potential to influence performance on cognitive measures.

- Possible co-morbid factors assessed and accounted for in analysis (no threat)
- Possible co-morbid factors assessed and described (possible threat)
- Possible co-morbid factors not assessed (definite threat)

External Validity

External validity "refer(s) to the approximate validity with which conclusions are drawn about the generalizability of an observed causal relationship to and across populations of persons, settings, and times" (Cook & Campbell, 1979, p. 39). For the purpose of this review, external validity is conceptualised as the ability of the computerised assessment to identify deficits that occur in everyday life in a sample with brain injury. Therefore, the greater the ecological validity of the assessment method against which the computerised task is measured, the more generalizable the results are to tasks of everyday living.

Reliance on other measures.

- Use of real world equivalent of computerised test (no threat)
- Use of self and/or carer reports (possible threat)
- Use of traditional neuropsychological tests only (definite threat)

Acknowledgement of limitations.

- Detailed acknowledgement of limitations (no threat)
- Passing acknowledgement of limitations (possible threat)
- No acknowledgement of limitations (definite threat)

Construct Validity

This refers to "the degree to which a test measures what it claims, or purports, to be measuring" (Cronbach & Meehl, 1955). In research, the construct of executive function has been measured using a variety of methods including performance on real-life tasks, performance on paper and pencil neuropsychological measures and ratings on self and informant questionnaires. Confidence in the ability of the computerised measure to

adequately assess executive function will be achieved by looking at its relationship with alternative measures that are known to be related to the construct. Construct validity of the computerised tool is maximised when it displays significant relationships with a variety of alternative assessment approaches.

- Evaluation involved measurement from different perspectives (no threat)
- Over reliance on single measurement type (definite threat)

Statistical Conclusion Validity

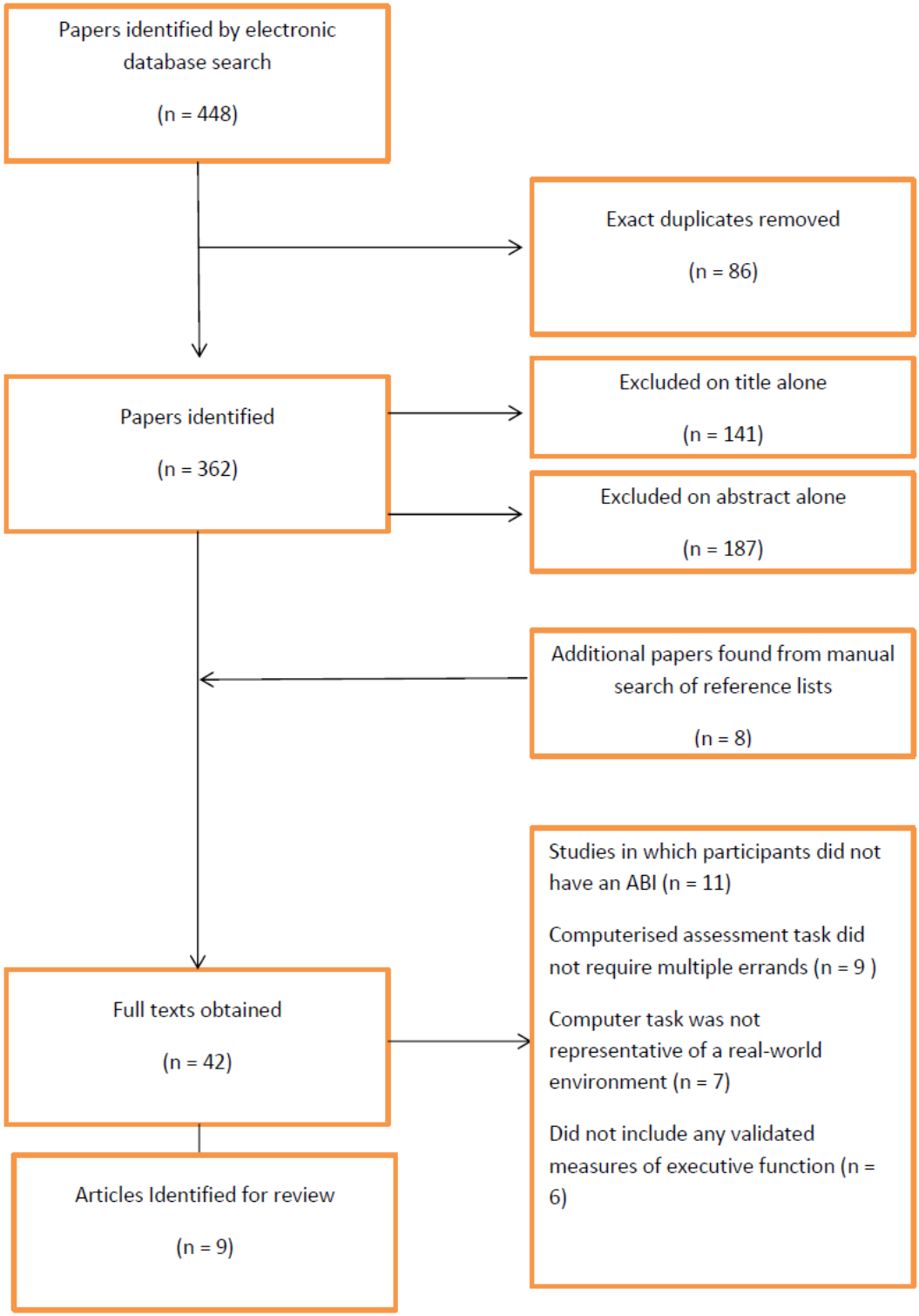
This refers to how well the analyses would be able to detect effects if they existed.

- Sample size adequate when any of the significant relationships were used (no threat)
- Sample size adequate using most significant relationship (possible threat)
- Sample size inadequate when least significant relationship is considered (definite threat)

Results

The search strategy initially yielded a total of 448 papers (Figure 1). The titles and abstracts were screened and 227 papers were excluded based on the exclusion criteria. The main search was supplemented by manual searches from the reference lists of retrieved articles which yielded a further 8 papers. Full texts were obtained for 42 papers and on reading 33 were excluded for a variety of reasons, the most common of which was the absence of an ABI sample of participants. The final number of articles identified as suitable for inclusion in this review was 9.

Figure 1. Flow diagram illustrating search process



Data extraction strategy

Data was extracted by the author and also by a second independent- rater (see Appendix 1.2 for scoring sheet). There was initially 85% inter-rater agreement, with the main area of disagreement surrounding the number of study limitations required to classify it as superficial or detailed. Disagreements were resolved through discussion, in which it was agreed that a study would have to fully outline a minimum of two distinct limitations to be classified as a detailed acknowledgement.

The study characteristics (Table 1) and methodological threats (Table 2) of the selected papers are presented in table form.

Table 1

Design characteristics and main findings of reviewed papers

Study	Sample Characteristics	Computerised Test of EF	Comparison Measures of EF	Main Analysis	Main Findings
Erez *et al.* (2013)	Patient Group – Children with TBI *n* = 20, mean age = 11.8, *SD* = 2.4 Control Group *n* = 20, mean age = 13.0, *SD* = 2.8	Virtual Supermarket Test (VMall)	Zoo Map subtest (BADS)	- Mann-Whitney U tests (group differences) - Correlation (association between VMall performance and Zoo Map subtest	- No correlation between performance on Zoo Map and performance on virtual supermarket test for patient or control group.
Jovanovski *et al.* (2012)	Patient Group – Adults with TBI *n* = 13, mean age = 58.4, *SD* = 10.8 Control Group *n* = 30, mean age = 19.4, *SD* = 1.5	Multi-tasking in the City Test (MCT)	Frontal Systems Behaviour Scale (self and family rating) Controlled Oral Word Association, Semantic Fluency (Animals), Wisconsin Card-Sorting Test, Modified Six Elements Test (MSET; BADS), Digit Symbol, Block Design and Digit Span (WAIS-III); Judgement of Line Orientation, Rey-Osterreith Complex Figure Test, California Verbal Learning Test (2nd ed.), Logical Memory I and II	- Correlation (non-parametric) between MCT performance and performance on comparison measures of EF - Mann-Whitney U tests (group differences) for presentation of MCT order effects	- Significant correlation between Plan score on MCT and informant FrSBe [Total (*r* = - .66) and Executive Dysfunction scale (*r* -.59)]. - Semantic fluency correlated with informant FrSBe (*r* = -.60) but not MCT (*r* = .49). - All EF measures (except the two verbal fluency measures) correlated with MCT scores in the patient sample (*r* = .60 - .84). - Correlation between MSET and MCT Plan score in both patient (*r* = .80) and control groups (*r* = .40).

			(Wechsler Memory Scale)		
Knight *et al.* (2006)	Patient Group – Adults with TBI *n* = 20, mean age = 45.0, *SD* = 11.9 Control Group *n* = 20, mean age = 44.0, *SD* = 11.9	Virtual Street Prospective Memory Task – High and Low Distraction Conditions	DEX Questionnaire (Self-report version) Logical Memory Subtest (Wechsler Memory Scale – III) Ruff 2 & 7 Selective Attention Test	- Mann-Whitney U Test (between group differences)	- No difference between groups on neuropsychological measures of memory (*d* = .23) - For patient group, performance during high distraction condition strongly correlated with total scores on the DEX (*r* = .60)
McGeorge *et al.* (2001)	Patient Group – Adults with brain injury *n* = 5, mean age = 36.8, *SD* = 8.4 Control Group *n* = 5, mean age = 36.0, *SD* = 8.5	Errand planning in Virtual Psychology Department	Errand planning in real life Psychology Department, Behavioural Assessment of Dysexecutive Syndrome, DEX Questionnaire	- ANOVA with group (patient or control) and environment (real or virtual) - Correlation between number of errands completed in real life vs. number completed in virtual environment	- High correlation between number of errands completed in virtual and real-life environments across both groups (*r* = .79). - No difference between groups on BADS (*d* = .02). - Patient group performed significantly worse than control group across both virtual and realy world errand planning.
Okahashi *et al.* (2013)	Patient Group – Adults with brain injury *n* = 10, mean age = 43.5, *SD* = 16.0. Matched Control Group *n* = 10, mean age = 47.1, *SD* = 20.1 “Old Healthy” Group *n* = 10, mean age = 68.9, *SD* = 3.9	Virtual Shopping Test (VST)	MMSE Star and Letter Cancellation Task Rivermead Behavioural Memory Test, Symbol Digit Modalities Test (SDMT), Serial reaction time (SRT), Everyday Memory Checklist, Zoo Map Test (BADS), DEX Questionnaire (self).	- Correlations (non-parametric) between VST and neuropsychological and questionnaire measures of EF - Mann-Whitney U test (group differences) for each outcome variable in VST	- no correlation between VST and Zoo Map Test - no correlation between VST and DEX - SDMT (*r* = -.80), SRT (*r* = -.89) and RMBT (*r* = -.65) correlated with VST scores - Difference on 7/10 VST variables between patient and control groups (*r* = -.67 to -.89)

	"Young Healthy" Group *n* = 10, mean age = 25.2, *SD* = 3.0				
Potvin *et al.* (2011)	Patient Sample - Adults with TBI *n* = 30, mean age = 32.3, *SD* = 10.6 Matched Control Sample *n* = 15, mean age = 30.4, *SD* = 8.4	Test ecologique de memoire prospective (TEMP; Ecological test of prospective memory) - Virtual City	Trail-making test, Modified Version of the Comprehensive Assessment of Prospective Memory (CAPM; self and independent rater versions)	- Mixed ANOVA with group (patient or control) and prospective memory performance during TEMP (event or time-based) - Independent T-tests with Bonferroni correction to compare self and independent rater CAPM in patient group	- Significant negative correlation between the TEMP total score and the independent rater version of the CAPM in TBI group (*r* = -.51) - No correlation between TEMP score and self-report CAPM in TBI group (*r* = .06) - Control group performed significantly better than TBI group on TEMP (η_p^2 = .29)
Rand *et al.* (2009)	Patient Sample – Adults post-stroke *n* = 9, mean age = 64.2, *SD* = 7.7 Older Healthy Group *n* = 20, mean age = 64.0, *SD* = 9.6yrs Younger Healthy Group *n* = 20, mean age = 26.3, *SD* = 2.7	Multiple Errands Test in Virtual Shopping Centre (VMET)	Real world Multiple Errands Test –Hospital Version (MET) Zoo map subtest (BADS) Instrumental Activities of Daily Living Scale	- Correlations (non-parametric) between scores on MET and VMET for each group separately - Correlations (non-parametric) between scores on MET and VMET with Zoo Map subtest and IADL in post-stroke patients. - Correlations (parametric) between MET and VMET performance for entire sample - Kruskal-Wallis H Procedure to compare performance on MET and VMET between post-stroke	- Moderate to high correlations in patient sample between MET and VMET outcomes on total number of mistakes (*r* = .70), non-efficiency mistakes (*r* = .73) and partial mistakes (*r* = . 88) - Significant moderate correlations in older healthy group between MET and VMET outcomes for total number of mistakes (*r* = .66), complete mistakes of completing task (*r* = .58), partial mistakes (*r* = .61) and non-efficiency mistakes (*r* = .66). -No significant correlation between MET and VMET outcomes in younger healthy group -High correlation between Zoo Map profile scores and non-efficiency mistakes in VMET in patient sample (*r* = -.86) - High correlation between percent independence on IADL and total number of mistakes on VMET in patient sample (*r* = -.76)

Raspelli *et al.* (2012)	Patient Sample – Adults post-stroke *n* = 9, mean age = 62.0, *SD* = 7.83 Older Healthy Group n = 10, mean age = 55.0, *SD* = 6.0 Healthy Young Group *n* = 10, mean age = 26.0, *SD* = 1.9yrs	Virtual Multiple Errands Test (VMET)	Test of Everyday Attentional Performance (TEA), Stroop Colour-Word Test, Iowa Gambling Task, Dysexecutive Questionnaire, Activities of Daily Living Questionnaire, Instrumental Activities of Daily Living	- Correlations (non-parametric) between scores on neuropsychological tests and scores of the VMET for each group separately. - Kruskal-Wallis to compare scores on neuropsychological tests between patient and healthy samples - Mann-Whitney U test to determine source of significance between groups	- Significant correlations between VMET subtests and subtests in TEA (*r* =.71 to .81) - No other significant relationships emerged.
Renison *et al.* (2012)	Patient Sample – Adults with TBI *n* = 30, mean age = 37.6, *SD* = 12.2 Control Group *n* = 30, mean age = 35.3, *SD* = 12.3	Virtual Library Task (VLT)	Real Library Task (RLT), Benton Verbal Fluency Task, Wisconsin Card Sorting Test, Brixton Spatial Anticipation Task, Zoo Map, Modified Six Elements, DEX Self-rated and independent-rated	- Correlations (non-parametric) to compare performance on VLT and RLT; to compare intra and inter-rater reliability of VLT and RLT; to compare VLT scores and EF measures; to compare VLT scores and DEX - Independent t-tests to compare control and TBI groups - ANCOVA to examine group difference in VLT scores after controlling for covariates	- Strong correlation between scores on VLT and RLT (*r* = .68) - No correlation between RLT and VLT performance on Interference and Dual Task Management subtest (r = -.10) - Moderate correlations between VLT and 3/5 EF measures (*r* = .32 to -.41) - VLT significantly predicted sel-rated DEX scores (*r* = -.27 to -.45).

Table 2

	Hypothesis Validity			**Internal Validity**			**External Validity**		**Construct Validity**	**Statistical Validity**	**Total Points per study**
Study	Hypothesis Ambiguity	Exploratory Hypothesis	Pre-morbid Assessment	Matching of Controls	Represent ativeness	Co-morbid Confounds	Type of Measure	Acknowledgement of Limitations	Variety Measurement Methods	Adequacy of Sample Size	
Erez *et al.*	1	0	1	2	1	2	0	1	0	1	9
Jovanovski *et al.*	2	1	2	0	1	1	1	2	2	0	12
Knight *et al.*	2	2	1	2	2	0	1	0	0	1	11
McGeorge et	1	0	0	2	2	0	2	0	2	0	9
Okahashi et	1	0	0	0	1	0	1	1	0	0	4
Potvin *et al.*	2	0	2	2	2	2	0	1	0	1	12
Rand *et al.*	0	0	0	0	1	1	2	0	2	0	6
Raspelli *et al.*	1	0	0	0	1	1	1	1	2	0	7
Renison *et al.*	2	2	2	0	1	0	2	1	2	2	14
Total Points	12	5	8	8	12	7	10	7	10	5	-

Legend: definite threat = 0 points possible threat = 1 point not a threat = 2 points n/a = not applicable

Summary of Results

Overall, most studies in this review scored poorly across the five validity domains. The most common threats to vaidity were inadequate sample sizes, the use of exploratory hypotheses, limited acknowledgement of study limitations and not accounting for co-morbid confounds. In contrast, most studies displayed strong internal validity in terms of the representativeness of the sample and strong hypotheis validity by outlining clear hypotheses at the study outset. Renison *et al.* (2012) achieved the highest score (14 points out of 20) by clearly outlining their aims and hypotheses, conducting a thorough assessment of pre-morbid factors, incorporating a real-world assesment task and employing a relatively large sample size. Okahashi *et al.* (2013) received the lowest score (4 out of 20) as threats or possible threats to validity were identified on each one of the 10 validity factors assessed in this review.

Discussion

The studies described above have evaluated the relationship between performance on computerised tests of executive function based on real-world environments and other measures that aim to capture executive difficulties in daily life. Overall, this review provides evidence that there is a relationship between performance on computerised neuropsychological tests of executive function and difficulties in everyday tasks as assessed by questionnaire measures (Jovanovski, Zakanis, Ruttan, Campbell, Erb, Nussbaum, 2012; Knight, Titov, & Crawford, 2006; Rand, Rukan, Weiss & Katz, 2009; Renison, Ponsford, Testa, Richardson, & Brownfield, 2012 & Potvin, Rouleau, Audy, Charbonneau, & Giguere, 2011)

and real-world task performance (McGeorge *et al.*, 2001; Rand *et al*., 2009 & Renison *et al.*, 2012).

Of the three studies that displayed the highest methodological rigour (i.e. score ≥ 12), all found that performance on the computerised measure was correlated with performance on other measures of executive function (Renison *et al.*, 2012; Poitvin *et al.*, 2011 & Jovanovski *et al.*, 2012). Renison *et al.* (2012) gained the highest score of all the studies reviewed (14 points) by possessing a number of strengths including a large sample size and inclusion of a real-world equivalent to their virtual library task. Results offered strong support for the ecological validity of their task by displaying robust relationships with a real-life equivalent task (r = .68) and an independently-rated questionnaire measure (DEX; r = -.38). Additional support for the construct validity of the virtual library task was evidenced by its superior ability to differentiate between an ABI group and healthy controls relative to traditional executive function measures. This finding remained even after controlling for covariates such as age and intelligence. The results of Poitvin *et al.* (2011) and Jovanovski *et al.* (2012) provided further support of the ecological validity of computerised testing by evidencing strong correlations between computerised tasks and questionnaire measures of everyday dysfunction rated by a significant other.

In terms of ecological validity, the gold standard for examining the ability of a computerised environment to detect subtle executive function difficulties that occur in everyday life is to compare performance on the task with its real world equivalent in a naturalistic setting. Of the 9 studies reviewed, 3 compared performance on everyday tasks in computerised environments with its real-world equivalent (McGeorge *et al.*, 2001; Rand, *et al.*, 2009; Renison *et al.*, 2012). All three studies found a relationship between computerised and real world assessment of executive functions with correlations ranging

from *r* = .70 to *r* = .79. These findings support the assertion that computerised environments are capturing the complexity and functional demands of their real world equivalents. Similarly McGeorge and colleagues (2001) have shown using the Virtual Multiple Errands Test that the performance of individuals with brain injury who did not meet the BADS criteria for executive impairment significantly differed from that of controls, suggesting that VR assessments may be more sensitive to "real life" impairments. This suggests that the constantly changing environment and renegotiation of goals and sub-goals required from everyday tasks performed in computerised environments is capturing unique elements of executive function that cannot be accessed by traditional tests.

Eight of the nine studies (Jovanovski *et al.,* 2012*;* McGeorge *et al*., Okahashi, Seki, Nagano, Luo, Kojima & Futaki, 2013; 2001 Raspelli *et al.,* 2012; Potvin *et al.*, 2011; Rand *et al.,* 2009 & Renison *et al.,* 2012) included a questionnaire measure of executive function and/or activities of daily living. One of these studies (McGeorge *et al.,* 2001) did not include scores in analyses without offering any explanation. Of the five studies that included self-report measures (e.g. DEX, Activities of Daily Living Scale, Instrumental Activities of Daily Living Scale and the Comprehensive Assessment of PM) only two found correlations with scores on the computerised assessment (Knight *et al., 2006* & Rand *et al., 2009*). Previous research has found that patients often report fewer problems than their carers or relatives on questionnaire measures of executive function such as the DEX (Bennet *et al.*, 2005; Burgess *et al.*, 1998 & Wilson *et al.*, 1996). This disparity is thought to reflect the lack of self-awareness which can characterise individuals with frontal brain damage (Prigatano & Klonoff, 1998) and may explain why the majority of the studies in this review did not find a relationship between self-report and computerised measures of executive function. In support of this assertion, all three studies that included questionnaire measures of

executive function rated by a carer or family member (Jovanovski *et al.*, 2012; Potvin *et al.*, 2011 & Renison *et al.,* 2012) found significant correlations ranging from *r* = .27 and *r* = .66 between these independently rated measures of difficulties in everyday life and scores on the computerised measures.

In terms of traditional neuropsychological tests, eight of the nine studies reviewed included at least one paper and pencil test of executive function (e.g. Trail-making test, Test of Everyday Attention, Stroop Colour-Word Test, Wisconnsin Card Sorting Task, Iowa Gambling Task) with all but three (Erez *et al.*, 2013; Knight *et al.*, 2006 & Potivin *et al.,* 2011) finding a relationship between scores on these traditional measures and performance on computerised assessment.

The BADS is a neuropsychological battery specifically developed to assess difficulties that reflect those experienced in everyday life. Studies by Alderman *et al.* (2003) and Wilson *et al.* (1996) demonstrated that performance on the BADS was predictive of relative's rating of day-to-day executive functioning difficulties in a sample of neurologically impaired participants. Three of the five studies that included neuropsychological measures from the BADS (MSET and/or Zoo Map) found relationships between these and computerised task performance with correlations ranging from .29 to .87 (Rand *et al.*, 2009; Jovanovski *et al.*,2012 & Renison *et al*., 2012). Erez *et al*. found no correlation between the Zoo Map test scores and performance in a virtual shopping task in a sample of children with brain injury, however they hypothesise that the Zoo Map test (BADS-C) may have been too difficult for the children resulting in floor effects. This assertion is supported by the absence of group differences in Zoo Map scores between the brain-injured sample and the controls. Okahashi *et al.* (2013) also found no relationship between scores on the Zoo Map test and performance in a virtual shopping task, although it should be noted that only 10 participants

with brain-injury were included in the study making it possible that it suffered from a lack of power.

Although the vast majority of studies in this review found a relationship between computerised assessment and other methods of executive function assessment, the empirical quality of these studies is crucial for the accurate interpretation of these results. This review found that the hypothesis validity, internal validity, external validity and construct validity of the studies examined was typically modest ranging from 4 to 14 points out of a possible 20 (see table 2).

In order for tests to have clinical utility they must be able to inform the clinician of specific cognitive processes with which the individual is experiencing difficulty and the severity of these difficulties. This allows the identification of specific areas of deficit and directs the level and type of support that the individual may require on a day to day basis. The extent to which the results of these studies reflect predictions based on the interplay of underlying constructs is known as "hypothesis validity". Although the majority of studies chose paper and pencil tests that have been shown to have higher ecological validity (such as the BADS and RMBT), across all studies there was typically little explanation regarding the rationale for the inclusion of a particular test and the aspect of daily life to which it relates. Consequently, analyses were often exploratory in nature or based on vague hypotheses. The approach used in the majority of the studies was largely reliant on looking for relationships between the computerised assessment measure and any other measure included in the study. Even when the expected direction of the relationship appeared obvious, only 5 of the 9 studies in this review made explicit apriori hypotheses based on underlying theoretical constructs. In addition, sample sizes for 8 of the 9 studies were deemed a threat or potential threat to statistical validity with only Renison *et al.* (2012) judged to have an adequate

number of participants for robust statistical comparisons. As only one of the studies reviewed (Poitvin *et al.,* 2011) made corrections for multiple comparisons, the possibility of the null hypothesis being incorrectly rejected (Type I error) cannot be overlooked.

The heterogeneity of tasks used across studies also makes an evaluation of validity and reliability of specific measures problematic. Ceiling/floor effects in performance were found by some studies (e.g. Erez *et al*., 2013) and often specific executive function domains were measured based on a single or small set of responses which significantly reduced the sensitivity of the outcome measure by limiting variability. Given the small to moderate sample sizes of all the studies in this review a limited number of executive function tests were included with several studies using the Zoo Map and MSET. It is possible that other measures not included in these studies may have shown greater sensitivity to dysexecutive problems in everyday tasks.

Implications, Limitations and Future Directions

Overall, the findings of this review suggest that performance of everyday tasks in computerised environments may be an effective way of identifying difficulties individuals with brain injury display completing tasks in their daily lives. Additional support for this conclusion is provided by examining results of the more methodologically rigorous studies which all provided support for the ecological validity of computerised assessment. However, it is important to note that a number of methodological weaknesses pervade studies in this area including limited sample sizes, analyses that were exploratory in nature and the omission of a real-world task with which to compare performance on computerised measures. Despite these limitations, the accumulating evidence supports the continued development of computerised tools as an ecologically valid assessment of executive

difficulties in people with brain injury. This is important as computerised assessment has greater clinical utility and allows greater experimental control than assessment in real world settings. Computerised real-world environments offer a number of additional advantages in that they are more accessible for people with mobility problems and can be varied for repeated use. Potential exists for computerised tasks to not only be used as an assessment tool but to also be adapted for use in rehabilitation settings (Rand *et al.*, 2005). Lastly, findings support the assertion that use of traditional neuropsychological tests such as Verbal Fluency and WCST should be avoided if the aim of assessment is to identify cognitive-behavioural deficits that impact functional abilities in day-to-day tasks.

It is important to acknowledge the limitations of this review. Firstly, as this review only included studies that were published in English it is possible that publication and reporting biases could have occurred. Studies using computerised assessment to measure executive function were not included in the current review if they had not included participants with acquired brain injury in their sample. Also, the majority of studies in this review compared performance on executive function tasks between a group with brain injury and healthy controls. Using this methodology does not allow any specific conclusions about the types of difficulties that people with brain injury experience as they are limited to simply detecting that brain injury impairs performance.

The studies included in this review were evaluated using a framework covering threats to five areas of validity. Although most of the studies reported positive findings, many suffered from theoretical and methodological weaknesses. According to the American Academy of Clinical Neuropsychology ([AACN], 2007) neuropsychological tests must achieve a number of standards to be deemed psychometrically adequate. These standards include

• acceptable levels of reliability

• demonstrated validity in relation to other tests and/or to brain status, including evidence that the test or measure assesses the process, ability, or trait it purports to assess

• normative standards that allow the clinician to evaluate the patient's scores in relation to relevant patient characteristics, such as age, gender, and socio-demographic or cultural/linguistic background.

This review has attempted to establish the validity of computerised tests of executive function but studies need further psychometric data on temporal stability, test-retest reliability, criterion validity and responsiveness before they are ready for use to inform clinical opinion. Future research should focus on validating computerised assessment measures on larger groups and in additional populations.

Conclusion

Findings support the ecological and construct validity of computerised assessment and suggest that there are similarities between performance in computerised and real-life environments in terms of complexity and functional demands. However, the published studies examined in this review exhibited a number of empirical and statistical weaknesses including small sample sizes, multiple statistical comparisons and vague apriori hypotheses regarding the expected relationship between computerised and other measures of executive function. The challenge for neuropsychology is to identify the key components of executive functions that are captured by these novel computerised tasks and how these clearly relate to performance on everyday activities.

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Chapter 2: Major Research Project

Development of Novel Computerised Tools to Assess Memory and Planning in People with Brain Injury

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Plain English Summary

Background: People with damage to the front part of their brain often display difficulties on tasks that involve planning, problem-solving and memory. It is thought that the front part of the brain may control these important processes which are also known as executive functions. Researchers have difficulty trying to create reliable ways of measuring executive functions because daily tasks usually involve a number of executive processes working together to achieve a goal. A research paper by Shallice and Burgess (1991) examined the executive functions of three people who had acquired a brain injury. They were surprised to find that these people performed well on paper and pencil tests of memory and planning but poorly on a "real world" test of these. The real world test involved bringing the person to a shopping centre and giving them a list of things to buy within a certain time frame and budget. The results suggested that a lot of the paper and pencil tests commonly used to measure executive functions are not capturing the unique demands that people have to deal with when carrying out daily tasks. Although the shopping task appears to be an effective assessment method, bringing people to a supermarket is a costly and labour intensive exercise. This study looks at the effectiveness of a computerised version of the shopping task in identifying planning and memory problems in people with brain injury.

Methods: Twenty-two people recruited from community and in-patient brain injury centres took part in the study. Participants completed a computerised shopping centre task and other more commonly used paper and pencil tests of planning and memory. In addition, participants and their friend or family member completed questionnaires that assess everyday difficulties. The strength of the relationship between performance on the computerised shopping centre task was compared to performance on the paper and pencil tests and scores on the questionnaires. In addition, participants' performances on the

computerised shopping task were compared to the performance of another group without brain injury.

Results: Scores on the computerised task showed a relationship with two of the three paper and pencil tests that were included in the study. People that scored better on the computerised task scored better on the paper and pencil tests that assess executive functions. The relationship between the questionnaires and the computerised task was opposite to the one that was expected. Furthermore, the people who reported more everyday difficulties on the questionnaire performed better on the computerised task. The group with brain injury had much poorer performance on the computerised task when compared to the group without brain injury.

Conclusions: The results of this study suggest that the computerised shopping task is good at measuring the same kind of processes as other paper and pencil tests of executive functions. However, it was not able to predict the level of difficulty that individuals with brain injury experience with planning and memory in everyday life. Previous research has shown that sometimes people with brain injury are not very aware of their difficulties and it is possible that some participants were not very accurate at reporting their everyday difficulties. Future research into computerised shopping tasks should include a more accurate way of measuring everyday difficulties such as comparison to performance on a real-world shopping task.

Abstract

Background: Many studies have found little relationship between performance on traditional neuropsychological tests and measures of everyday functioning in people with brain injury. Computerised assessment measures incorporating more complex and life like scenarios may provide greater accuracy and ecological validity. The aim of this study was to investigate the ability of a computerised measure of executive function to assess planning and prospective memory deficits in a sample of people with brain injury when compared to questionnaire and traditional neuropsychological measures.

Methods: Twenty-two individuals with acquired brain injury completed a computerised multiple errands test (C-MET), questionnaire measures of everyday difficulties (e.g. Dysexecutive Questionnaire; DEX) and traditional measures of executive functions including the Zoo Map test and The Stockings of Cambridge (SOC). Exploratory analysis compared relationships between performance on planning and prospective memory subcomponents of the C-MET with the other measures of executive function included in this study. Further analysis compared performance of the brain injury group with data from a sample of 46 healthy controls collected as part of a normative study.

Results: C-MET was positively correlated with both the Zoo Map and Stocking of Cambridge tests. Compared with a sample of healthy controls, the brain injury group performed significantly worse on C-MET planning and PM measures and the Zoo Map test. Performance on C-MET Planning and PM and self-rated questionnaire measures were significantly correlated, but contrary to hypotheses, better performance on C-MET was associated with increased reports of difficulty in daily life.

Conclusions: Results of this study offer support for the construct validity of C-MET as a measure of executive functioning. However the C-MET's ability to distinguish between PM

and Planning constructs and to predict difficulties that individuals with brain injury experience in everyday life was not supported.

Introduction

Executive function is a broad term that encompasses a variety of cognitive processes including initiation, planning, attention, problem solving and behavioural control (Baddeley & Wilson, 1988). Everyday executive functioning involves the maintenance of multiple goals and sub-goals, with priorities that change over time requiring self-initiative, self-monitoring and self-regulation. Despite the lack of clarity over the precise processes that constitute executive function, agreement exists over the importance of this construct in human adaptive behaviour (Jurado & Rosselli, 2007). Executive processes allow us to adapt to a constantly changing environment, initiating plans and persevering till completion of tasks in a goal directed fashion. Impairments in these domains are common in patients that have experienced brain injury, particularly those with frontal brain damage due to stroke or traumatic brain injury (Burgess, Veitch, Costello & Shalice, 2000).

Miyake *et al.* (2000) emphasised the importance of fractioning executive function into its component skills in order to make it a more theoretically and clinically useful construct. Prospective memory (PM) is one theorised aspect of executive function and refers to remembering to do something in the future within a specified time frame or within certain limits (Ellis, 1996; Ellis & Freeman, 2008). Examples include remembering to attend a doctor's appointment or to ring a friend on their birthday. PM has been conceptualised as comprising of many cognitive processes involving the formation, retention, delayed initiation and execution of intentions (Kliegel *et al.*, 2008). In particular, laboratory studies have identified attention, memory and executive processes as having an important role in successful prospective remembering (e.g. Marsh, Hicks, & Cook, 2005). Although execution of PM tasks primarily involves remembering to do something in the future, it also necessitates recall of what needs to be done, thereby implicating retrospective memory in

the process (Cohen, West, & Craik, 2001). PM failure is reportedly one of the most common and disabling functional deficits that individuals with brain injury experience and can have a catastrophic impact on everyday functioning (Groot, Wilson, Evans, & Watson, 2002; Kinsella, Murtagh, Landry, Homfray, Hammond *et al.*, 1996; Mathias, & Mansfield, 2005; Schmitter-Edgecombe & Wright, 2004).

Traditionally the assessment of executive abilities such as prospective memory or planning has been carried out using clinical or laboratory protocols, typically involving the use of paper-and-pencil tests. In general, paper-and-pencil tasks within a clinical setting give limited opportunity for choice and decision-making and may not be accurate methods of assessing the cognitive difficulties that people experience in their everyday lives (Burgess *et al.*, 2006; Lo Priore, Castelnuovo, Liccione & Liccione, 2003). The "functional and predictive relationship between the patient's performance on a set of neuropsychological tests and the patient's behaviour in a variety of real-world settings" (p. 16, Sbordone, 1996) is known as ecological validity and has been identified as a critical issue in neuropsychology.

In their seminal study, Shallice and Burgess (1991) highlighted the difficulties with using traditional neuropsychological measures by examining the ability of 3 participants with frontal lobe damage to perform a variety of cognitive tests. Results revealed that although participants exhibited marked impairment in planning and memory in their everyday functioning, performance on most traditional measures of executive function was normal or above-normal. Executive function deficits were only captured by two neuropsychological tests, namely the Six Elements Test (SET; Shallice & Burgess, 1991) and the Multiple Errands Test (MET; Shallice & Burgess, 1991). Shallice and Burgess concluded that most traditional measures did not capture the subtle executive processes necessary for everyday multi-tasking.

New assessment measures such as the Behavioural Assessment of Dysexecutive function (BADS; Wilson, Alderman, Burgess, Emslie & Evans, 1996) were developed to address the ecological short-comings of their predecessors and offer a more standardised approach to measurement. However, despite being widely used in clinical practice and displaying greater accuracy than other measures in detecting executive function difficulties, the BADS still remains limited in its ability to predict everyday functioning in people with brain injury (Norris & Tate, 2000; Wood & Lossi, 2006). Other assessment approaches have incorporated the use of psychometric measures such as The Dysexecutive Questionnaire (DEX), in order to gain a more accurate reflection of daily functioning. The DEX questionnaire comes in both a self-report and relative/carer report version and is contained within the BADS. It is a 20-item measure which covers a wide range of specific problems (e.g. memory, awareness, emotional regulation) and is sensitive to the changes in daily functioning that often follow acquired brain injury (Bennet, Ong & Ponsford, 2005).

Researchers are increasingly recognising the utility of life-like, complex real-world assessment measures which require a number of executive domains to work in conjunction at the same time (Schwartz, Reed, Montgomery, Palmer, & Mayer, 1991; Shallice & Burgess, 1991; Wilson, Alderman, Burgess, Emslie, & Evans, 1996). The Multiple Errands Test (Shallice & Burgess, 1991) is a relatively unstructured, open-ended task which takes place in a busy shopping precinct and requires participants to complete a number of tasks (e.g. check the closing time of the library, buy one cookie) within a designated time. Before starting the task, participants are provided with a number of rules including “spend as little money as possible” and “do not enter a store other than to buy something”. Errors were categorised as: 1) inefficiencies—not applying the optimum strategy; 2) rule breaks—breaking any of the rules mentioned at the start or a breaking a social rule, 3) interpretation failure—

misunderstanding the requirements of a task and 4) task failure—not completing a task. Participants with frontal lobe damage had higher overall errors and more rule breaks and task failures on the MET than healthy controls (Shallice & Burgess, 1991). However, despite successfully demonstrating the ecological validity necessary to identify executive deficits in individuals with frontal lobe damage, the task has limited clinical utility due to its cumbersome and time-consuming nature. As the task traditionally takes place in a public environment, additional difficulties in maintaining strict experimental control over stimulus delivery may emerge making it difficult to standardise results and eliminate extraneous variables.

In order to address these shortcomings, the MET has been adapted for administration in virtual and computerised environments. These include the Virtual Errands Test (VET; McGeorge *et al.*, 2001) which assesses planning abilities associated with multi-tasking, the Virtual Mall (VMALL; Erez, Weiss, Kizony, & Rand, 2013) and the Virtual Multiple Errands Test (VMET; Rand, Rukan, Weiss & Katz, 2009). Of the four studies that have examined the validity of a computerised MET in a sample with brain injury, three found significant relationships with traditional neuropsychological measures of executive function (Okahashi, Seki, Nagano, Kojima & Futaki, 2013; Rand *et al.*, 2009 & Raspelli *et al.*, 2012) and one found no relationship (Erez *et al.*, 2013). Three of these studies also included self-rated questionnaire measures of everyday difficulties (Okahashi *et al.*, 2013; Rand *et al.*, 2009 & Raspelli *et al.* 2012; &) with only Rand *et al.* (2009) finding a significant relationship with computerised performance. None of these studies included informant-rated questionnaire measures making it difficult to ascertain the level of insight participant's had into their daily functioning. Overall, these findings suggest that using computerised shopping environments

may potentially offer a way of identifying the executive function difficulties that people with brain injury may display in their day-to-day lives.

The present study improves on previous research by including informant-rated questionnaire measures of everyday difficulties and attempting to delineate the components of executive function more clearly by specifically focusing on two specific processes. The overall aim is to examine the efficacy of a computerised version of the MET when compared with traditional neuropsychological and questionnaire measures in assessing the planning and prospective memory domains of executive functions. Findings could have important implications for improving the ecological validity of executive functioning assessments.

Aims and Hypotheses

The main aim of this study is to investigate if a significant relationship exists between performance on the planning and prospective memory components of a computerised multiple errands task (C-MET) using a supermarket context and traditional neuropsychological and questionnaire measures of planning and prospective memory.

Main Hypothesis

There will be a significant correlation between participants planning and PM performance on the C-MET task and reported planning and prospective memory difficulties in daily living as assessed by questionnaire measures.

Secondary Hypotheses

- There will be a significant correlation between performance on the planning and prospective memory domains of the C-MET task and planning and prospective memory as measured by traditional neuropsychological measures.
- The ABI group will score significantly lower than healthy controls on the planning and prospective memory domains of the C-MET task.

Methodology

Participants

A total of twenty-two participants with ABI were recruited from a number of in-patient and community settings around Glasgow and Ayrshire. As part of a separate normative reference study conducted at another site, 46 healthy controls with no history of neurological impairment were recruited from the general community.

Inclusion

Individuals were eligible if they were aged over 18 and had an ABI that was sustained after the age of 16 for at least 6 months before testing. Only participants with the ability to consent were approached. As some of the measures used in this study have only been reliably validated on English speaking samples, only those speaking English as a first language were recruited. Only participants who provided consent to having their test and questionnaire results shared with their G.P and clinical team (where applicable) were eligible to participate in the study.

Exclusion Criteria

Individuals were excluded if they had a severe mental illness, current substance abuse, learning disability or any physical disability likely to impact on their performance.

Recruitment Procedures

Participants were recruited from a number of community, inpatient and voluntary-sector settings across the West of Scotland. Clinicians/team members from these organisations were presented with information about the study and asked to present this information to individuals who fulfilled the inclusion criteria. At their next appointment participants were invited to participate via the letter of invitation (Appendix 2.2) and were also given an information sheet about the study (Appendix 2.3). At this time participants interested in taking part could give permission for the clinician to pass on their contact details to the researcher. Alternatively, participants were invited to return a free post reply form or contact the researcher by phone or e-mail if they wished to participate. Where appropriate, group-based presentations were used to explain what the study would involve and to answer queries potential participants had. Once participants had indicated their interest in partaking in the study, they were contacted by telephone and screening questions were administered to determine suitability.

Measures

Background Neuropsychological Assessment

The following tests were administered in order to characterise the sample:

- Test of Premorbid Functioning (TOPF): The Test of Premorbid Function (TOPF) (Delis, Kaplan, & Kramer, 2009) provides an estimate of premorbid cognitive functioning in adults from 16 to 90 years of age.
- Speed of Information Processing and Motor Speed from the Brain Injury Rehabilitation Trust Memory and Information Processing Battery (Coughlan, Oddy & Crawford, 2007).
- Line Orientation Subtest from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr & Chase, 1998). As this is a test of visuospatial ability and not executive function, scores on this measure will be used as a test of divergent validity.

In addition, participants were asked to complete the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983). The HADS is a commonly used screening measure for depression and anxiety. Participants were also asked to rate their familiarity with computers on a scale of 1-10.

A retrospective estimate of post-traumatic amnesia (PTA) was made by asking the participant about the first thing they remember following their brain injury and asking them to estimate how long after the injury this was. McMillan, Jongen and Greenwood (1996) found that the retrospective estimate of PTA correlated significantly with other measures of brain injury severity. As this measure is only validated for use in samples with traumatic brain injury (TBI), only participants who have experienced a TBI were be asked about PTA.

Question*nn*aire Measures of Everyday Difficulties

Measures included a revised version of both the self-rated and independent rater versions of the Dysexecutive Questionnaire (DEX, Burgess *et al.*, 1996). The original DEX

Questionnaire is a 20 item scale which examines the social, motivational, cognitive and emotional changes that a person with dysexecutive problems may exhibit. One version of this questionnaire is completed by the patient while the other is completed by a caregiver or family member who knows the participant well. Responses are rated on a 5-point Likert scale ranging from 0 (never) to 4 (very often). The DEX has been shown to possess strong psychometric properties (Burgess *et al.*, 1998; Chan, 2001; Chaytor, Schmitter-Edgecombe & Burr, 2006) and is a sensitive measure of executive dysfunction after brain injury (Bennett, Ong & Ponsford, 2005).

Simblett and Bateman (2011) used Rasch analysis to examine the DEX responses of 363 people with ABI. They reported that the DEX is best understood as a multi-dimensional measure which captures 3 underlying constructs, namely behavioural-emotional self-regulation, metacognition and executive cognition. The executive cognition construct encompasses high-level functions which are responsible for "controlling and directing lower level automatic functions through planning, monitoring, activating, switching and inhibiting" (Simblett & Bateman, 2011). This construct is assessed by combining scores on 4 DEX items (temporal sequencing, planning, distractibility and abstract thinking; see appendix 2.3). As all these factors are associated with successful planning, it is predicted that the executive cognition construct will show a strong relationship with the planning aspects of the C-MET. On the basis of their findings, Simblett and Bateman created a revised version of the DEX (DEX-R) which includes additional items. As the DEX-R is not yet a validated measure, only those items that relate to the original DEX and the executive cognition construct identified by Simblett and Bateman in their Rasch analysis will be included for analysis.

Participants also completed the Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford, Maylor, Della Sala, & Logie, 2003). The PRMQ is a 16-item

questionnaire which measures prospective and retrospective failures of memory in everyday life. The informant version of the PRMQ (which is almost identical to the self-rated version) was completed by a family member or friend. A prospective memory and retrospective memory score and a total score were derived for both the self and informant rated versions. Both the self and informant questionnaire have been shown to exhibit acceptable internal reliability (Cronbach's α of .80 to .89 and .83 to .92 respectively; Crawford *et al.*, 2003, 2006).

Traditional Measures of Planning and Prospective Memory:

- *Zoo Map Test from the Behavioural Assessment of Dysexecutive Syndrome (Wilson et al., 1996)*: This test assesses the ability to independently formulate and implement a plan (high demand condition) and to follow a preformulated plan (low demand condition). It involves plotting or following a route through a map that does not contravene a set of rules. The score is based on the successful implementation of the plan. Penalties are imposed for rule breaks and lack of speed.
- Stockings of Cambridge Subtest from the Cambridge Neuropsychological Test Automated Battery (CANTAB; Sahakian *et al.*, 1988): Stockings of Cambridge is similar to other "Tower" tests of planning and is a measure of planning efficiency.
- Computerised Number Task: This is a computerised measure of prospective memory based on a task developed by Burgess, Scott & Frith (2003). During the ongoing condition, pairs of digits ranging from 1-9 were presented on a computer screen and participants were instructed to decide whether the number on the left or right was greater by pressing the appropriate response key. During the prospective memory condition participants were given an additional instruction to press a different

response button when both numbers presented were even. The ongoing condition was three minutes in duration and the PM condition lasted six minutes. Participants are given a PM score ranging from 0-100 based on their accuracy at correctly adhering to the additional instruction in the PM condition.

Computerised Multiple Errands Test

A computerised shopping centre task was created based on the 'Multiple Errands Task' (Shallice & Burgess, 1991), a validated measure of executive function. It was developed by Dr. David Millar, Consultant Clinical Neuropsychologist (david.millar@neurocog.co.uk). This assessment is delivered via a laptop computer and presents the participants with a novel shopping centre environment which they navigate around using a joystick (Figure 1).

*Figure 1***.** Screen shot of C-MET shopping centre

To successfully complete the C-MET participants are required to accomplish five tasks and adhere to a number of rules.

- Tasks: The first task required participants to purchase nine items (e.g. shampoo, stamps), the second involved finding out the name of the film coming to the cinema. The third and fourth tasks required participants to post a birthday card before the last collection and to pick up lottery tickets when the shop opened at 1pm. The final task for the participant was to leave the shopping centre by 1.15pm to attend a dentist appointment.
- Rules: Participants were instructed to adhere to two rules, namely that they were not to spend more than their budget of £40 and they should try to complete the task as quickly as possible without rushing unnecessarily.

Participants could access a number of onscreen functions at any time by pressing coloured buttons on the joystick control panel. These allowed the participant to view the "to do" list (Appendix 2.4), the shopping centre map (Figure 2), the shopping centre clock and their shopping bag (i.e. items purchased). To purchase an item, the participant simply points the joystick in the direction of the product at which time they are prompted onscreen to "Press the green button if you wish to purchase this item".

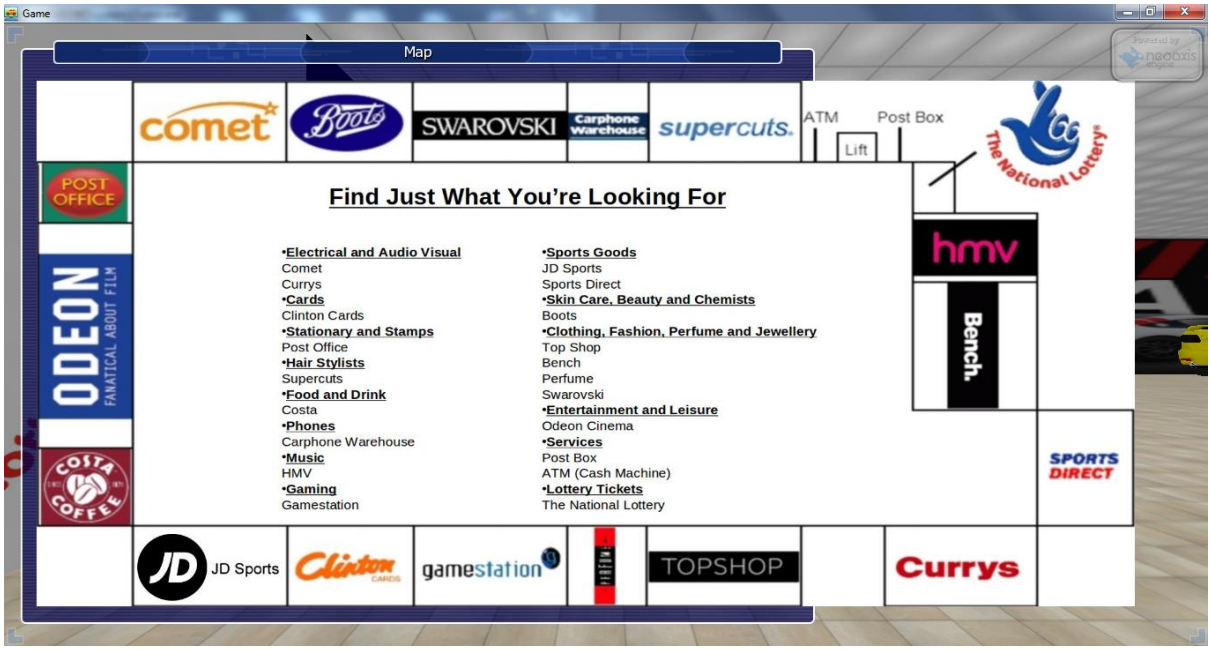

Figure 2. Map of Shopping Centre

The C-MET task begins in the car park of the computerised shopping centre at which time the clock reads 12.50pm. At 12.55pm participants receive an additional errand in the form of a "text message" on screen which asks them to buy a lottery ticket when the shop opens at 1pm. The task terminates when the participant returns to their car and chooses to exit using the joystick controls. Participants can also choose to terminate the task at any time by telling the experimenter that they are finished. If participants had not finished the task within 35 minutes of starting, the experimenter intervened to terminate the test.

The C-MET computer programme automatically records the number and type of items purchased, time spent in the simulation, money spent, card posted on time and lottery tickets collected. A score of 1 was given for each task successfully completed.

Prospective memory (PM) and planning, thought to be key executive function processes, were examined in further detail. Through discussion leading to a consensus view between the author, test creator Dr. Millar and research supervisor Professor Evans, tasks

within C-MET which required prospective memory (PM) or planning were identified and an operationalised scoring criteria was developed to assess participants on both of these processes.. The planning score was composed of the number of tasks completed (0-12) multiplied by the time taken to complete the task in minutes. Both time taken to complete the task and number of tasks completed were thought to be indicative of planning ability. Therefore, individuals who completed a higher number of errands in a shorter amount of time were considered to be better planners as they had completed the task in a more efficient manner.

In order to maintain the accuracy of the planning variable, scoring on the number of tasks completed was reversed (i.e. a score of 0 meant that all tasks had been successfully completed while a score of 12 meant that no tasks were successfully completed). Therefore, a higher score on the planning variable was indicative of poorer performance. The PM score was composed of performance on three C-MET tasks, namely leaving on time for the dentist appointment, posting the birthday card before the last collection and purchasing a lottery ticket when the shop opened. A score of 2 was given for successful completion of each of these tasks with a maximum score of 6 representing successful completion of all three PM tasks (see Appendix 2.5).

Design

This study employed a mixed design incorporating both within group and between group analyses. Each individual performed the C-MET task and completed other traditional neuropsychological and psychometric measures (modified DEX, PRMQ) of executive function.

Research Procedures

Participants who expressed an interest in taking part in the study were invited to attend a testing session at a time that was convenient. The assessment process was conducted by the researcher in a quiet room within the setting from which the individual had been recruited. Prior to attendance at the testing session, participants were mailed the questionnaire measures (DEX and PRMQ; self and independent versions) and asked to bring the completed forms to the session. The assessment process lasted approximately 1 hour and 15 minutes and was broken into three sections:

1. Completion of background measures (i.e. TOPF, speed of processing and motor speed task)
2. Completion of the traditional neuropsychological tests (i.e. Zoo Map test, computerised picture, number task, line orientation, Stockings of Cambridge)
3. C-MET practice period and task.

Participants were given a 5-minute break between section 1 and 2 and another 5 minute break in between section 2 and 3. An additional 10 minutes was added to testing time to allow for the completion of the DEX and PRMQ if the participant has forgotten to complete them at home. The order of administration of sections 2 and 3 were counterbalanced across all participants to control for practice effects. Administration procedures and scoring protocols as outlined by test manuals were followed for all standardised tests.

The C-MET task was delivered via a laptop computer and participants controlled their movement around the shopping centre by using a joystick. Before beginning a practice period the researcher demonstrated use of the joystick, use of all the function buttons and

showed participants how to purchase a product. All participants were then given an opportunity to familiarise themselves with the controls during a practice period in the C-MET shopping centre during which they were required to buy two items listed on a sample "to do" list. If participants appeared to have difficulty during the practice period the researcher gave additional guidance at this time. All participants were able to purchase the two items required with time taken to achieve this ranging from 1 to 5 minutes. On completion of the practice period, the task scenario was read out to the participant from a script and repeated if necessary (Appendix 2.6). The participants were instructed to begin the task and to indicate to the researcher when they were finished.

Control Group Data

As part of a separate normative study, data was available for the C-MET in addition to the self-rated DEX, self-rated PRMQ, the TOPF and the Zoo Map test.

Justification of Sample Size

A number of studies have found correlations between computerised assessment measures and self-report measures of everyday difficulties such as the DEX in a sample with brain injury (e.g. Knight, Titov & Crawford, 2006 & Rand *et al.*, 2009). Significant correlations ranging from $r = .27$ and $r = .66$ between questionnaires rated by a carer or family member and scores on the computerised measures have also been found (Jovanovski *et al.*,2012; Potvin, Rouleau, Audy, Charbonneau, Giguere, 2011 & Renison,Ponsford, Testa Richardson & Brownfield, 2012). A number of studies have also found relationships between computerised measures and traditional tests of executive function (e.g., Rand *et al.*, 2009). For example, Renison *et al.* (2012) found a moderate effect size between performance on a

virtual library task (comparable to the C-MET) and scores on the Zoo Map test (r = .29) and Modified Six Elements Test (r = .32) using a brain-injured sample. They also found that the brain-injured sample did significantly worse on the virtual library task when compared to healthy controls. Also using a brain-injured sample, Scott and Evans (2013) found a medium- large effect size between PM and planning performance on a computerised office-based task and traditional measures of these constructs (r = .59 & r = .33, respectively).

Given the previous research there is justification for assuming that correlations between traditional and questionnaire measures of executive functions and performance on C-MET will provide a medium-large effect. Using Cohen's (1988) guidelines, a sample size calculation was conducted using G*Power (Faul, Erdfelder, Buchner & Lang, 2009). For a two-tailed hypothesis with an alpha of 0.05 and using correlation as the method of analysis, G*Power suggested using a sample size of 46 participants to obtain a medium-large effect size of 0.4 and power level of 0.80. Previous research evidence also suggests that comparing performance on the C-MET between a group with brain injury and healthy controls will yield a large effect size. For a one-tailed hypothesis with an alpha of 0.05 and using between groups t-test as the method of analysis, G*Power suggested using a sample size of 21 participants per group to obtain a large effect size.

Ethical Approval

This study was reviewed and approved by the West of Scotland Research Ethics Committee, NHS Ayrshire & Arran Research and Development and NHS Greater Glasgow & Clyde Research and Development departments (see Appendices 2.7-2.9).

Statistical Analyses

Data analyses were carried out using PASW Statistics 19 (SPSS, Chicago). Descriptive statistics were used to characterise the demographic and neuropsychological features of the sample. Two-tailed correlational analyses were conducted to examine the relationships between traditional, psychometric and computerised measures of PM and planning to ascertain ecological and convergent validity. As the C-MET is a novel task and the current study is exploratory in nature, no corrections were made for multiple comparisons as is consistent with the approach taken by other studies in this area (e.g. Renison *et al.*, 2012; McGeorge *et al.*, 2001). Additionally, a one-tailed between groups analysis was conducted to examine differences in performance on traditional and computerised measures of PM and planning between the group with brain injury and the healthy controls. Where parametric assumptions of testing were violated, equivalent non-parametric tests were used.

Results

Prior to analysis, variables were screened for outliers and normality of distribution using the Shapiro-Wilk test. For the ABI group, two outliers in the C-MET 'planning' score were identified and excluded from any analyses involving this variable. The 'planning' (Shapiro-Wilk = .88, p = .02) and PM score from C-MET (Shapiro-Wilk = .88, p = .02), the Zoo Map score (Shapiro-Wilk = .84, p < .01) and the PM numbers task scores (Shapiro-Wilk = .75, p < .01) violated the rule of normal distribution. For the control group, the C-MET planning score (Shapiro-Wilk = .77, p < .001), the C-MET PM score (Shapiro-Wilk = .50, p < .001) and the Zoo Map test (Shapiro-Wilk = .80, p < .001). Therefore Spearman's non-parametric correlations were employed instead of Pearson's when entering these variables into

analyses. For comparisons between groups, the Mann-Whitney U-test was employed instead of the independent t-test when analysing these variables.

Participants

Twenty-two individuals with Acquired Brain Injury (ABI) were recruited for this study and their performance compared with data from a sample of 46 healthy controls recruited as part of a normative data collection study. The data from two individuals in the ABI group was not included in the study as they could not engage fully with testing due to their level of impairment. The final ABI group consisted of 14 men and 6 women with a mean age of 36.1 years (*SD* = 12.84, range = 22.5 – 53.3). Aetiology of injury was either traumatic brain injury (TBI; *n* = 9), viral infection (*n* = 4), stoke/CVA (*n* = 2) or brain tumour (*n* = 5). Mean time since injury was 4.2 years (*SD* = 3.0 years; range 0.8-10.8yrs).

As the use of PTA as a proxy of brain injury severity is only validated in samples with TBI, only the 9 participants who had experienced a TBI were included in its calculation.

The mean length of post-traumatic amnesia (PTA) was 11.5 days (*SD* = 13.5; range = 0-46 days) and indicates that most participants were in the severe to very severe brain injury category (i.e. PTA of 1 day to 4 weeks; Hannay, Howieson, Loring, Fischer & Lezak, 2004). The healthy control group consisted of 20 men and 26 women with a mean age of 25.6yrs (*SD* = 10.6, range 18-58). Independent samples t-test revealed a significant difference in age between the ABI and control groups ($t = 3.5$, $p = .001$). Futher analysis revealed no significant correlations between age and C-MET Planning or PM performance in the ABI or control group or in the sample as a whole. Similarly, no relationship between age and zoo map performance or age and self-rated questionnaire measures emerged.

Neuropsychological Characteristics

Participants' performances on background neuropsychological measures is summarised in Table 1. There were no significant differences between the ABI and Control groups for Pre-morbid IQ (t = -1.52, p = .13). Highly significant correlations were found between C-MET PM and Planning and processing speed (r_s = .78, p < .001 and r_s = -.59, p < .01, respectively).

Table 1

Mean Pre-Morbid IQ and Processing Speed for ABI and Control Groups (with Standard Deviations in Parentheses)

Measure	**ABI Group**	**Control Group**
Pre-morbid IQ – TOPF	95.7 (7.7)	99.0 (10.7)
Range	77-121	81-123
Processing Speed – BIRT subtest*	32.9 (9.6)	---
Range	18-49	

*T scores reported for processing speed

Descriptive Statistics

Participants' performances on traditional and C-MET measures of planning and PM ability are summarised in Table 2.

Table 2

Mean performance on Planning and PM for ABI and Control Groups (with Standard Deviations in Parentheses)

Domain	Measure	Mean (*SD*)	Range	Max Score Possible
Planning	SOC*			
	ABI Group	6.2 (2.9)	0-11	11
	Controls	---	---	
	Zoo Map			
	ABI Group	1.4 (1.5)	0-4	4
	Controls	2.8 (.8)	0-4	
	C-MET Planning			
	ABI Group	378.7 (304.4)	116.6 – 1174.2	-
	Controls	142.2 (42.0)	100.7 - 262.2	
Prospective Memory	Numbers Task			
	ABI Group	34 (38)	1-100	100
	Controls	---	--	
	C-MET PM			
	ABI Group	3.1 (2.2)	0-6	6
	Controls	5.6 (.82)	4-6	
Executive Function	C-MET Total No of Errands Completed			
	ABI Group	8.2 (3.8)	0-12	12

Domain	Measure	Mean (*SD*)	Range	Max Score Possible
	Controls	10.5 (.98)	7-11	
	C-MET Total Time (mins)			
	ABI Group	19.0 (8.0)	5.0-35.5	--
	Controls	12.1 (2.1)	5.0-17.6	

* SOC = Stockings of Cambridge Absolute Number of Problems Solved in Minimum Moves

A significant difference between the ABI and control groups was found for number of errands completed (U = 138.0, p < .001) and time spent in the simulation (U = 138.0, p < .001). In addition, a significant difference between groups on C-MET planning was found (U = 204.0, p = .004) with those in the control group (M = 142.2, SD = 42.0) performing better than those in the ABI group (M = 378.7, SD = 304.4). Similar results were found for C-MET PM (U =152.5, p < .001) with those in the control group (M = 5.6, SD = .9) remembering significantly more than the ABI group (M = 3.1, SD = 2.2). Participants in the control group also scored higher on the Zoo Map test (M = 2.8, SD .8) than those in the ABI group (M = 1.4, SD = 1.5; U = 718.5, p < .001).

Questionnaire Measures of Everyday Functioning

Mean profile scores for the self and informant-rated questionnaires of the ABI group and self-rated questionnaires of the control group are presented in Table 3. Four participants in the ABI group did not return the informant rated PRMQ measure and three did not return the informant rated DEX. Informant measures were completed for 13 of the participants by a family member while the remaining 3 were completed by psychologists involved with the

individual's care within an inpatient setting. Scores on the self-report PRMQ indicated that on average the ABI group reported both their PM and RM abilities to be in the low average range [T = 40, Confidence Intervals (CI) 35-48] and T = 38 [CI 33-47] respectively). The control group reported their PM and RM abilities to be in the average range [T = 49, CI = 43-55] and T = 51 [CI 44-57] respectively). Statistical comparison of the means revealed that the ABI group reported significantly more deficits in PM (U = 222.0, p < .001) and RM (t = 4.01, p < .001) than the control group. For the ABI group, informant ratings of participant PM and RM were in the borderline ability range (T = 32 [CI = 29-41 and T = 33 [CI = 29-43 respectively]. Significant correlations existed between individual and informant ratings of PM (r = .63, p = .04) and RM (r = .60, p = .05) but a large amount of unexplained variance remains. On average participants rated their memory problems as less severe than informants.

The mean score for the ABI group on the self-rated DEX (M = 34.0, SD = 7.92) indicated that, on average, participants reported experiencing dysexecutive problems at a level similar to other adults with brain injury (50^{th} – 75^{th} percentile; Wilson *et al.*, 1996). Interestingly, there was no correlation found between Informant-rated (M = 47.1, SD = 10.1) and self-rated DEX scores once again highlighting the large amount of variance between participant and significant others' ratings of daily difficulties. Control group scores on the self-rated DEX (M = 20.9, SD = 13.9) were significantly lower than those of the ABI group (t = 4.7, p < .001). The most frequent median response across the 6-item DEX executive cognition component was "often". No relationship was found between self and informant ratings on this construct with significant others rating participants as having greater difficulty with executive cognition. The majority of depression and anxiety scores were in the normal to mild range.

Table 3

Mean Scores on Questionnaire Measures for ABI and Control Groups (with Standard Deviations in Parentheses)

		ABI Group (*n* = 20)		Control Group (*n* = 46)
	Questionnaire	**Self-Rating**	**Informant-Rating**	**Self-Rating**
PRMQ*	*PM + RM Total*	39	32	50
	Range	24-57	13-51	17-72
	PM	44	32	49
	Range	14-33	17-52	17-72
	RM	40	30	51
	Range	17-52	13-55	22-71
DEX	*DEX Total*	34.0 (7.9)	47.1 (10.1)	20.9 (4.1)
	Range	19-58	21-73	0-52
	Executive Cognition	9.6 ± 2.5	13.7 (3.0)	5.2 (1.8)
	Range	6-16	6-20	0-15
HADS	*Anxiety*	7.9 (1.9)	---	5.6 (1.2)
	Range	2-13		1-12
	Depression	7.9 (2.3)	---	2.8 (1.1)
	Range	1-17		0-9

***** PRMQ reported as T-scores

Relationship between Traditional, Computerised and Questionnaire Measures

Results of the correlational analysis for the ABI group are depicted in Table 4 below. When examining the correlations between C-MET measures and questionnaire measures for PM, a significant correlation (medium-large effect size) was found between C-MET PM and self-rated PRMQ PM (r_s = .48, p = .04). A significant correlation (large effect size) was also found

between the self-rated DEX executive cognition construct and PM performance on the C-MET (r_s = .53, p < .05). The direction of these correlations suggests that as reports of difficulties as assessed by questionnaire measures increased, performance on the C-MET improved. C-MET planning scores also correlated significantly with both the self-rated PRMQ PM scale (r_s = -.55, p = .02) and the self-rated DEX planning construct (r_s -.58, p = .01) in addition to the overall self-rated DEX score (r_s = -.54, p = .02). The Zoo Map test was the only traditional assessment measure to correlate significantly with questionnaire measures of everyday function by displaying a significant relationship with the executive cognition construct from the DEX completed by a significant other (r_s = -.62, p = .01).

Table 4

Relationship between Questionnaire Measures and PM and Planning

Questionnaire	**Correlations**				
Measure	**C-MET Planning**	**Stockings of Cambridge**	**Zoo Map**	**C-MET PM**	**Numbers Task**
DEX-Self Total	-.54*	.26	-.24	.48	-.06
DEX-Self Executive Cognition	-.58*	.25	-.14	.53*	-.02
DEX Informant Total	.00	-.25	-.36	.00	.32
DEX Informant Executive Cognition	.08	-.09	-.62*	.08	.38
PRMQ Self PM	-.55*	-.10	-.06	.48*	-.10
PRMQ Self Total	.42	-.20	-.12	.36	-.20
PRMQ Other PM	-.23	-.13	-.25	-.23	-.24
PRMQ Other Total	-.23	-.06	-.23	.14	-.39

*Spearman's Rho used for all analyses except those pertaining to SOC where Pearson's correlation was employed. * correlation is significant at the 0.05 level (2-tailed)*

No significant correlations were found between questionnaire measures and C-MET Planning and PM for the control group. Similarly, no relationship was found between questionnaire measures, C-MET planning and PM and Zoo Map scores in the control group.

Convergent and Divergent Validity

Examination of the relationships between performance on the computerised planning scores with performance on traditional measures revealed a significant correlation between the C-MET planning and SOC planning (r_s = -.56, p < 05). No significant correlations were found between Zoo Map and C-MET Planning. Significant correlations were also found between C-MET PM and the Zoo Map test (r_s = .50, p < .05) and C-MET PM and SOC planning (r_s = .74, p < .001). No significant relationships were found between C-MET PM and the numbers task. While examining scores on the numbers task it was noted that half the sample (n = 10) scored 0 on this task whilst the other half displayed accuracy for the PM target ranging from 63-100%. No significant between groups difference was found for performance on C-MET PM between those scoring 0 on the numbers task and those scoring above 0. In terms of divergent validity, the relationship between performances on the computerised measures with performance on the line orientation subtest revealed no significant correlations for the ABI group or control groups.

Controlling for Potential Confounders

For the ABI group, Spearman's correlations indicated that there was no significant relationship between performance on the C-MET measures of planning and PM and participant's self-rated familiarity with computers, age, gender, PTA, length of time since injury or type of injury.

Discussion

The overall aim of this study was to determine whether a computerised multiple errands task would be sensitive to the types of difficulties that many people with brain injury report experiencing when completing tasks in everyday life that make demands on executive functions such as planning and prospective memory. The results provide some evidence for the validity of the C-MET, but not all results were consistent with apriori hypotheses. The C-MET task did distinguish between a group of controls and a group of people with ABI. Performance on some of the C-MET measures correlated significantly with other measures considered to demand planning skills (Zoo Map and Stockings of Cambridge). However, the ecological validity of the C-MET was not supported and no relationships were found with independently-rated questionnaire measures of everyday difficulties. In addition, although self-report questionnaire measures were significantly correlated with C-MET, the direction of this correlation was contrary to that expected with increased reports of difficulties in daily life associated with *better* performance on the C-MET. These findings suggest that C-MET may not be adequately capturing the unique cognitive demands required for completing similar tasks in the real world.

Previous research has shown the DEX to be strongly associated with performance on real-world tests of executive function in individuals with brain injury (Wilson *et al.*, 2003; Lamberts, Evans & Spikeman, 2010). However, research comparing DEX scores to performance on computerised measures of real world tasks has been mixed with some studies finding medium to strong correlations between the two (Renison *et al.*, 2012; Knight et al, 2011) and others finding no relationship (Okahashi *et al.*, 2013; Raspelli *et al.* 2012). One of the most surprising results of this study was the finding that as performance scores on C-MET Planning and PM improved, participants' self-reports of dysexecutive problems as

assessed by the DEX increased. These findings are similar to those of Alderman, Burgess, Knight and Henman (2003) who found that participants who rated themselves as having fewer executive problems on the DEX also tended to perform poorly on a real-world MET.

Alderman *et al.* hypothesised that this was more suggestive of a wider problem with accurately assessing executive abilities and participant's level of insight. Indeed, previous research has shown that many individuals with brain injury show a lack of awareness of their cognitive deficits and impaired interpersonal skills (Bergquist & Jackets, 1993; Damasio & Anderson, 1993), with increased severity of brain injury making lack of insight more marked. For example, Wilson *et al.* (1996) found that poor awareness of deficits as assessed by the DEX was associated with poor executive functioning as assessed by the BADS. Participants in this sample displayed a wide range of brain injury ranging from mild to very severe. Unfortunately it was not possible to obtain Glasgow Coma Scale scores for the entire sample and length of post-traumatic injury was used as a proxy of brain injury severity. Although no correlation between PTA and self-report DEX scores emerged, it is plausible that severity of injury influenced individual's level of insight into their everyday difficulties. Therefore, those with more severe injuries reported less difficulties on self-report measures due to lack of insight but consequently exhibited poorer performance on the C-MET. Contrarily, those with mild brain injury may possess greater awareness of their cognitive deficits but perform well on executive tests relative to those with more severe impairment. The assertion that participants may have lacked insight is somewhat supported by the absence of significant correlations between self-report measures and the traditional neuropsychological measures included in this study. In addition, participants reported having significantly fewer difficulties with everyday tasks on both the DEX and PRMQ when compared to the ratings given by an informant. These findings are consistent with

previously reported research (Wilson *et al.*, 1996, Bennet, Ong & Ponsford, 2005; Burgess *et al.*, 1998) and support the assertion that participants may not have been accurate in their reports.

Interestingly, informant ratings were not related to C-MET performance and only one significant relationship with traditional measures emerged. Previous research has also shown mixed findings (e.g., Jovanovski *et al.* 2012; Okahashi *et al.*, 2013, Knight *et al.*, 2006) and previous authors have hypothesised that informants may find it difficult to adequately report on aspects of executive dysfunction that are not readily observable (Simblett & Bateman, 2011). For example, item 2 on the DEX informant version refers to acting impulsively and "doing the first thing that comes to mind", a thought process with is not readily apparent to an observer. Additional variables such as relationship with individual (Cavello, Kay & Ezrachi, 1992) and stage of adjustment to the impairment (Ponsford & Kinsella, 1991) may also influence an informant's report on level of dysfunction.

Highly significant correlations between self-reported DEX planning and self-reported PM with both C-MET components also suggests that C-MET Plan and C-MET PM are not measuring two unique components and actually assess common underlying executive processes. C-MET Planning was the result of an algorithm containing weighted scores for the number of errands successfully completed multiplied by time taken to complete the task. The score for number of errands successfully completed included the two PM errands in the C-MET, namely posting the birthday card before the last collection and collecting lottery tickets when the store opened at 1pm. The C-MET PM score included 'leaving for the shopping centre in time for dentist's appointment', a variable that is strongly influenced by overall time taken to complete the task. This may explain why C-MET Planning and C-MET PM were significantly correlated with each other and with questionnaire measures of

Planning and PM. C-MET planning and PM were found to moderately with a measure processing speed although this is not surprising given that processing speed underpins many higher-order executive function domains (Hillary *et al.*, 2010). Examination of the dataset revealed a number of instances whereby individuals with low processing speed scores performed at an average or above average range on the C-MET task and vice versa. This suggests that although scores on the C-MET are influenced by processing speed, for some individuals C-MET performance may provide valuable information about strengths and difficulties that are not accounted for by other general cognitive factors such as speed of information processing.

At a theoretical level the distinctive features of PM remain debatable and the construct remains weakly developed (Graf & Uttl, 2001). This has contributed difficulties in accurately measuring PM under laboratory conditions and remains a challenge for researchers in the area (Einstein & McDaniel, 1990; Kvavilashvili, 1987). Self-initiated recall, an inherent component of PM, is difficult to elicit in a clinical environment without salient events or cues to prompt the participant. This also presented a challenge for the present task in which only three errands relating to PM were included. It was unclear how to include further items relating to PM without overloading the participant with tasks to be remembered. It is possible that as C-MET PM is only comprised of performance on 3 task variables, that the limited range of scores may have been insufficient for accurate assessment of PM difficulties which were instead overshadowed by broader executive function deficits.

Although the results of this study do not provide strong support for the ecological validity of C-MET it still possesses a number of advantages over traditional tests of executive function. Traditional tests have been criticised for their inability to adequately simulate the

competing demands and multiple processes required to complete everyday tasks. Similar to real-world tasks, successful completion of the C-MET requires sustained attention and the integration of a number of executive processes to achieve multiple goals in a changing environment. Additionally, the face validity of this computerised measure is maximised by incorporating a task that is engaged in by all individuals in their everyday lives, namely shopping for errands. The importance of this should not be overlooked as patients are more likely to engage with feedback regarding their cognitive deficits if they feel the assessment tool is reflective of their everyday environment. Support for the construct validity of C-MET as a measure of executive function was evidenced by its medium to large correlations with the Stockings of Cambridge and the Zoo Map test. In addition, the lack of significant correlation between C-MET measures and visuospatial ability, age, pre-morbid IQ and motor speed provide support for the discriminant validity of this measure.

The present study is not without its limitations. The results highlight the importance of including a real-world equivalent when assessing the ecological validity of computerised assessments. It was not feasible to include a real-world performance condition in the present study, but it is clear that the inclusion of such a condition in the study would have provided more objective evidence of day to day difficulties than subjective measures such as questionnaires.

Given the sample size and time constraints, it was only possible to include a limited number of executive function measures. Although measures designed with ecological validity in mind such as the Zoo Map were included in this study, it is possible that other measures may have displayed greater sensitivity. Additionally the DEX is not without its limitations and as previously mentioned the ratings of friends and family members can be influenced by a number of factors. Another methodological weakness related to the number

of correlational analyses conducted involving the same outcome variable and thereby increasing the chance of incorrectly rejecting the null hypothesis (Type I error). Consistent with previous research in the area it was decided not to employ a statistical correction as it is likely that the variables being examined were not independent and the implementation of corrections may have resulted in overly conservative significance levels. Despite most significant relationships between variables in this study exhibiting a medium to large effect size it is possible that some analyses did not possess sufficient power to detect genuine effects. Future research should incorporate larger sample sizes to address this issue.

It should also be noted that two participants could not complete the testing session as they lacked the ability to adequately engage with neuropsychological testing. These difficulties were not specific to the C-MET and even individuals who rated their computer experience as minimal did not display any problems engaging with the interface. The shopping environment displayed in the C-MET is one which all participants would be familiar with and may have the advantage of ameliorating test anxiety. In addition, the lack of ceiling/floor effects in task performance for the brain injury sample suggests that the shopping task displayed a level of difficulty that was appropriate for a sample of individuals with moderate to severe brain injury.

One of the main strengths of this study is that it used a broad sample of patients with varying ranges of brain injury severity from a number of different causes. This demonstrates that computerised measures can be administered to individuals with moderate to severe brain injury. Future research should consider the inclusion of matched controls to identify patterns of relationships.

Conclusion

Overall, the findings of this study support the construct validity of the C-MET as a measure of executive functioning. However, the C-MET's ability to predict difficulties that individuals with brain injury experience in daily life was not supported. Future research on the ecological validity of computerised measures would benefit from incorporating a measure of performance in a naturalistic environment.

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Chapter 3: Advanced Clinical Practice 1, Reflective Critical Account

Reflective Journey in Ethics and Communication

Tracey Quinn

Submitted in part fulfilment of the requirements for the qualification of Doctorate in Clinical Psychology

Abstract

During the course of clinical psychology training many opportunities to develop my skills in reflection have emerged. A reflective journey undertaken in the realms of ethics and communication are examined in the present account which incorporates a number of frameworks to structure the reflective process. Communication is a core competency for the clinical psychologist as outlined by the British Psychological Society but an also an area which can present challenges and requires a unique set of skills. In this account, Gibb's reflective cycle (1988) is used to structure an analysis of communication within the therapeutic relationship and examine the difficulties with that can emerge when the openness of the therapeutic alliance is threatened. In addition, this account incorporates reflections in the area of ethics. Rolfe's *et al.*'s (2001) framework for reflective practice is used to examine some of the ethical dilemmas that emerge when risk to a client or others becomes apparent. Parallels between working in forensic setting where risk management is a frequent necessity are contrasted with experiences from other training placements such as CAMHS. In both communication and ethics the reflective process has resulted in a beneficial change in practice and a further development of core reflective skills.

Chapter 4: Advanced Clinical Practice 2, Reflective Critical Account

Reflective Journey in Research and Management

Tracey Quinn

Submitted in part fulfilment of the requirements for the qualification of Doctorate in Clinical Psychology

Abstract

With ever growing pressures on service delivery in the face of the HEAT targets, increasing access to psychological therapies has become the main driver for recent changes. Strategies implemented to increase capacity have implications for the practice of clinical psychology and impact on clinician's own feelings of satisfaction and autonomy. This account uses an integrative approach to the reflective process to examine issues within the realms of organisational management. Additionally, the impact research has on professional development is explored by contrasting the subtle skills required for research within a purely academic context with those required for researching within a clinical environment.

The reflective journey from pre-training to present is explored using elements of both Gibb's Reflective Model and Rolfe's Framework for Reflection. Both of these models prompt the reflector to describe and analyse the situation of concern and explore the feelings that it evokes. The third and final stage is considered the most important and encourages the clinician to reflect on the outcomes of their actions and to consider ways of improving the situation in the future.

Using the reflective process, the intricacies and sensitivities of clinical research are explored and ways of changing practice based on these reflections is outlined. The impact of management on clinical practice is also examined and the potential implications of these reflections on shaping future clinical practice are explored. Amongst these implications is a greater need for the organisation to acknowledge the unique contribution that reflective practice makes to clinician's day to day practice despite it being largely unquantifiable. By engaging in reflective practice to promote increased self-awareness and sensitivity I hope to improve the quality of care I provide and close the gap between theory and practice.

Systematic Review Appendices

Appendix 1.1 Instructions to authors for submission to Journal of the International Neuropsychology Society

JOURNAL OF THE INTERNATIONAL NEUROPSYCHOLOGICAL SOCIETY

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Dialogues: Maximum of 2,000 words for each segment (not including abstract, tables, figures, or references) and a 150 word abstract, with a maximum of two tables or two figures, or one table and one figure and 20 references. Dialogues provide a forum for two distinct positions on controversial issues in a point-counterpoint form. Dialogues must be preapproved by the Editor-in-Chief. For consideration, please e-mail your abstract to jins@cambridge.org.

Symposia: Maximum of 5,000 words (not including abstract, tables, figures, or references) and a 250 word abstract for each article (same as Regular Research Articles). Symposia consist of several thematically linked research articles which present empirical data. Symposia must be pre-approved by the Editor-in-Chief. For consideration, e-mail your proposal to jins@cambridge.org to receive prior approval.

Letters to the Editor: Maximum of 500 words (not including table, figure, or references) with up to five references and one table or one figure. Letters to the Editor respond to recent articles in *Journal of the International Neuropsychological Society*.

Book Reviews: Maximum of 1000 words in length. Include name and affiliations, a title for the review, the author(s)/editor(s), title, publisher, date of publication, number of pages and price. For consideration, e-mail jins@cambridge.org.

Manuscript Preparation and Style The entire manuscript should be typed double-spaced throughout using

a word processing program. Unless otherwise specified, the guideline for preparation of manuscripts is the *Publication Manual of the American Psychological Association* (6th edition) except for references with 3 or more authors (see References section). This manual may be ordered from: APA Order Dept., 750 1st St. NE, Washington, DC 20002-4242, USA.

Pages should be numbered sequentially beginning with the Title Page. The Title Page should contain the full title of the manuscript, the full names and institutional affiliations of all authors; mailing address, telephone and fax numbers, and e-mail address for the corresponding author; and the word count for the abstract and manuscript text (excluding title page, abstract, references, tables, and figures). At the top right provide a short title of up to 45 characters preceded by the lead author's last name. Example: Smith-Memory in Parkinson's Disease. This running head should be repeated at the top right of every following page.

Page 2 should include an Abstract and a list of at least six keywords or mesh terms. Note: structured abstracts must be included with papers submitted after January 1, 2014. A structured abstract must include four header labels: *Objective*, *Method*, *Results*, and *Conclusions*. A total of six mesh terms (http://www.nlm.nih.gov/mesh/) or keywords should be provided and should not duplicate words in the title.

The full text of the manuscript should begin on *page 3*. For scientific articles, including *Regular Research Articles, Brief Communications, Rapid Communications,* and *Symposia,* the format should include a structured Abstract, Introduction, Method, Results, and Discussion. This should be followed by Acknowledgments, References, Tables, Figure Legends, Figures, and optional Appendices and Supplemental Material.

The use of abbreviations, except those that are widely used, is strongly discouraged. They should be used only if they contribute to better comprehension of the manuscript. Acronyms should be spelled out at first mention. Metric system (SI) units should be used.

Appendices and Supplemental Materials may be submitted. Appendices include material intended for print and should be included with the manuscript file. Supplementary material will appear only online and should be submitted as a separate file.

The Acknowledgements Section should include a disclosure of conflicts of interest (see above) and all sources of financial support for the paper. In documenting financial support, please provide details of the sources of financial support for all authors, including grant numbers. For example, "This work was supported by the National Institutes of Health (grant number XXXXXXX)". Multiple grant numbers should be separated by a comma and space and where research was funded by more than one agency, the different agencies should be separated by a semicolon with "and" before the final funding agency. Grants held by different authors should be identified using the authors' initials. For example, "This work was supported by the Wellcome Trust (A.B., grant numbers XXXX, YYYY), (C.D., grant number ZZZZ); the Natural Environment Research Council (E.F., grant number FFFF); and the National Institutes of Health (A.B., grant number GGGG), (E.F., grant number HHHH)."

Tables and Figures should be numbered in Arabic numerals. Figures should be numbered consecutively as they appear in the text. Figures should be twice their intended final size and authors should do their best to construct figures with notation and data points of sufficient size to permit legible photo reduction to one column of a two-column format.

Please upload figure(s) in either a .doc or .pdf format. There is no additional cost for publishing color figures. When uploading figures (color or black and white) they need only be a high enough resolution for the reviewers and editors to identify the information you are trying to convey.

The approximate position of each table and figure should be provided in the manuscript: [INSERT TABLE 1 HERE]. Tables and figures should be on separate pages. Tables should have short titles and all figure legends should be on separate pages.

References should be consistent with the Publication Manual of the American Psychological Association (6th Edition). In-text references should be cited as follows: "… Given the critical role of the prefrontal cortex (PFC) in working memory (Cohen et al., 1997; Goldman-Rakic, 1987; Perlstein et al., 2003a, 2003b)…" with multiple references in alphabetical order. Another example: "…Cohen et al. (1994, 1997), Braver et al. (1997), and Jonides and Smith (1997) demonstrated…" References cited in the text with two authors should list both names. References cited in the text with three, four, or five authors, list all authors at first mention; with subsequent citations, include only the first author's last name followed by et al. References cited in the text with six or more authors should list the first author et al. throughout. In the reference section, for works with up to seven authors, list all authors. For eight authors or more, list the first six, then ellipses followed by the last author's name. Examples of the APA reference style are as follows:

Online/Electronic Journal Article with DOI:
Dikmen, S., Machamer, J., Fann, J. & Temkin, N. (2010). Rates of symptom reporting following traumatic brain injury. *Journal of the International Neuropsychological Society, 16,* 401–411. doi:10.1017/S1355617710000196

Scientific Article:
Giovannetti, T., Britnell, P., Brennan, l., Siderowf, A., Grossman, M., Libon, D.J., Seidel, G.A. (2012). Everyday action impairment in Parkinson's disease dementia. *Journal of the International Neuropsychological Society, 18,* 787–798.

Book:
Lezak, M.D., Howieson, D.B., Bigler, E.D., Tranel, D. (2012). *Neuropsychological Assessment.* New York: Oxford University Press.

Book Chapter:
Mahone, E.M. & Slomine, B.S. (2008). Neurodevelopmental disorders. In J.E. Morgan, & J.H. Ricker (Eds.), *Textbook of Clinical Neuropsychology* (pp. 105–127). New York: Taylor & Francis.

Report at a Scientific Meeting:
Weintraub, S. (2012, June). Profiles of dementia: Neuropsychological, neuroanatomical and neuropathologic phenotypes. International Neuropsychological Society, Oslo, Norway.

Manual, Diagnostic Scheme, etc.:
American Psychiatric Association (1994). *Diagnostic and Statistical Manual of Mental Disorders (4th ed.).* Washington, DC: American Psychiatric Association Press.

English Editing The Research and Editing Consulting Program (RECP) within the International Neuropsychological Society's International Liaison Committee is designed to provide English language editing and statistical consulting to international colleagues who wish to publish their research in English language journals. For additional information see http://www.the-ins.org/the-research-and-editing-consulting-program.

Proofs The publisher reserves the right to copyedit manuscripts. The corresponding author will receive PDFs for final proofreading. These should be checked and corrections returned within 2 days of receipt. The publisher reserves the right to charge authors for excessive corrections.

Offprints and PDF Files The corresponding author will receive a free pdf. This pdf can also be mounted on the authors' web pages. Offprints must be ordered when page proofs are returned. The offprint order form with the price list will be sent with your PDF.

Open Access Papers In consideration of payment of the Open Access fee specified by Cambridge University Press, the contribution will be published in the *Journal of the International Neuropsychological Society* within an Open Access environment, freely accessible to those who wish to browse, read, print, save, copy, display or further disseminate the contribution. Please see the Open Access Transfer of Copyright Agreement for the proper procedures at http://journals.cambridge.org/action/displayMoreInfo?jid=INS&type=tcr. The processes will depend on your source of funding, permissions to use material owned by an outside source, etc.

Appendix 1.2 Methodological Quality Assessment Scoring Sheet

Systematic Review Rating Scale

Please tick appropriate box for each category	
1. Hypothesis Ambiguity	
Clear specific predictions made	
Vague Hypothesis	
No specified hypothesis	
2. Diffuse/Exploratory Statistical Hypothesis	
Analysis based on hypothesis	
Use of exploratory hypothesis but recognise limitations	
Use of exploratory hypothesis	
3. History	
Pre-morbid cognitive/behavioural functioning assesses and accounted for	
Pre-morbid cog/beh functioning assessed	
Pre-morbid functioning not assessed	
4. Selection	
Participants representative of population research question based on	
Participants may not be representative	
Participants not representative	
5. Control Subjects	
Controls matched to patient group	
Controls matched on some criteria eg age, gender, level of education	
Controls not matched to patient group	
6. Co-morbid confounds eg depression, language disorder, visuoperceptual disorder	
Co-morbid factors assessed and accounted for in analysis	
Co-morbid factors assessed and described	
Co-morbid factors not assessed	
7. External Validity	
Use of real world equivalent as assessment	
Use of self and/or carer report	
Use of only neuropsychological tests	
8. Limitations	
Detailed acknowledgement of limitations	
Superficial acknowledgement of limitations	
No acknowledgement	
9. Construct Validity	
Evaluation involved measuring from different perspectives	
Over reliance on single measurement type	
10. Statistical Conclusion Validity	
Sample size adequate for any significant relationship	

Sample size adequate for most significant relationships	
Sample size inadequate when least significant relationship considered	

Major Research Project Appendices

Appendix 2.1 Invitation to Participate

Version 1.0 14/10/13

INVITATION FOR PEOPLE ATTENDING THE BRAIN INJURY REHABILITAION TRUST TO TAKE PART IN A RESEARCH PROJECT

Title of the research: Developing new computerised tools for assessing memory and planning in people with brain injury

Dear Sir/Madam

We are psychologists from the Institute of Health and Wellbeing at the University of Glasgow, working with colleagues in NHS Greater Glasgow and Clyde and NHS Ayrshire & Arran. We work with people who have had a brain injury and we are contacting you to invite you to take part in a research study. We are particularly interested in how brain injury affects memory, and in particular remembering to do things.

The study is testing out a new way of measuring problems with memory and planning that people with brain injury sometimes experience in their everyday lives. We hope to use the information from this study to improve our understanding of how to accurately measure these problems and to help us develop better forms of rehabilitation.

For this study we need people who don't feel they have difficulties as well as those who do have difficulties. This will allow us to see how good the new computerised tool is at assessing these sorts of difficulties.

If you take part in this study, you would meet with the researcher at a venue and time that is convenient for you. This meeting would last about two and a half hours (with breaks) and involve doing some puzzle type tasks and a short computer task. The researcher will also ask you and a relative, or someone who knows you well, to complete some questionnaires.

You are not obliged to take part in the study and are free to withdraw at any time. You can choose not to participate in the study or decide to withdraw at any time without needing to give a reason. Your decision will not affect the care you receive in any way.

If you are interested in taking part or just finding out more about the study you can do this in any of the following ways:

(1) Let a member of the team at the Brain Injury Rehabilitation Trust know and they will pass on your contact details
(2) Return the reply slip below using the Freepost address (no need for a stamp)
(3) Call me on 077 48660105
(4) Email me on t.quinn.2@research.gla.ac.uk

Yours sincerely,

Tracey Quinn.

Version 1.0 14/10/13

Contact details:

Ms. Tracey Quinn
University of Glasgow
Mental Health and Wellbeing
Gartnavel Royal Hospital, G12 0XH
Email: t.quinn.2@research.gla.ac.uk
Phone: 0141 211 0607

Professor Jonathan Evans
University of Glasgow
Mental Health and Wellbeing
Gartnavel Royal Hospital, G12 0XH
Email: Jonathan.Evans@glasgow.ac.uk
Phone: 0141 211 3978

Appendix 2.2 Participant Information Sheet

PARTICIPANT INFORMATION SHEET

I would like to invite you to take part in a research study. Before you decide you need to understand why the research is being done and what it would involve for you. Please take time to read the following information carefully.

Development of new computerised tools to assess memory and planning in people with brain injury

Purpose of the study

People who experience certain types of neurological illness or brain damage often display difficulties on tasks that involve planning, problem-solving and memory. It is thought that the frontal part of the brain may control these important tasks which are also known as executive functions. Researchers in the area of brain injury have difficulty trying to create reliable ways of measuring the problem because people mostly display these difficulties when carrying out daily tasks that might involve a number of these executive functions working together to achieve a goal. For example, people with executive function problems may perform well on "paper and pencil" tests of planning and memory often used by clinicians but may have difficulty planning what to buy in the supermarket or remembering appointments in everyday life. This suggests that a lot of the commonly used "paper and pencil" tests used to measure executive functions are not very accurate as they are not representative of the tasks that people have to deal with in their day-to-day lives. This study will explore the usefulness of using a computerised version of a task from everyday life compared to the commonly used "paper and pencil" tests.

What does taking part involve?

If you decide to take part you will be sent 3 short questionnaires to complete. These questionnaires will ask you about your mood, memory and the types of difficulties you may be experiencing in tasks of everyday life. You will also be invited to come along to the testing session which will last about 2 and a half hours (with breaks). During this session you will be asked to do a number of different tasks. During the session you will be asked to read out loud a list of words. You will then carry out a task on the computer which involves

completing a list of errands (e.g., buying milk) in a computerised shopping centre. This is accomplished using a joystick and pressing response buttons. After the computer task you will be asked to complete a short questionnaire asking you additional details about the task. You will also be asked to carry out "paper and pencil" tasks which involve different puzzle type activities and some memory tasks.

Does the research involve any medical examination or medication?
No

Do I have to take part?
No, taking part is voluntary. If you don't want to take part, you do not have to give a reason and no pressure will be out on you to try and change your mind. Your decision whether to participate or not has no effect on your access to, or care received from, these services. You are free to withdraw at any time during the study without explanation.

What happens to the information?
All the information you provide will be confidential and used for the purposes of this study only. The data will be collected and stored in accordance with the Data Protection Act 1998 and will be disposed of in a secure manner. The information will be used in a way that will not allow you to be identified individually. However, we must inform the clinician responsible for your care if something you have said leads us to believe, that either your health and safety, or the health and safety of others around you, is at immediate risk.

Will taking part have any advantages for me?
Taking part in the study will not benefit you directly but the information we get from the study will help our understanding of how best to assess memory and planning problems in people with brain injury, which will also help us develop better forms of rehabilitation.

Are there any disadvantages or risks of taking part?
There are no significant risks or disadvantages to taking part in this study. You may feel a little tired but you will be given regular breaks during the testing session in order to minimise this.

Will you contact my G.P.?
Contact with your G.P. is not a necessary requirement for participation in this study but with your permission we would like to send them a short letter to let them know that you are taking part. With your permission we will also send them the test results from the neuropsychological tests you do. This means that if you have similar tests in the future other clinicians can compare the test results.

Who is funding the research?
This research will be funded by the University of Glasgow Doctorate in Clinical Psychology programme.

Who is conducting the research?
This study is being conducted by Tracey Quinn (Trainee Clinical Psychologist) from the department of Mental Health & Wellbeing at the University of Glasgow. The research is supervised by Prof. Jonathan Evans (Professor of Applied Neuropsychology).

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

What if I have any further questions?
We will give you a copy of the information sheet and signed consent form to keep. If you would like more information about the study and wish to speak to someone **not** closely linked to the study, please contact Professor Tom McMillan, University of Glasgow, ph. 0141 211 0694

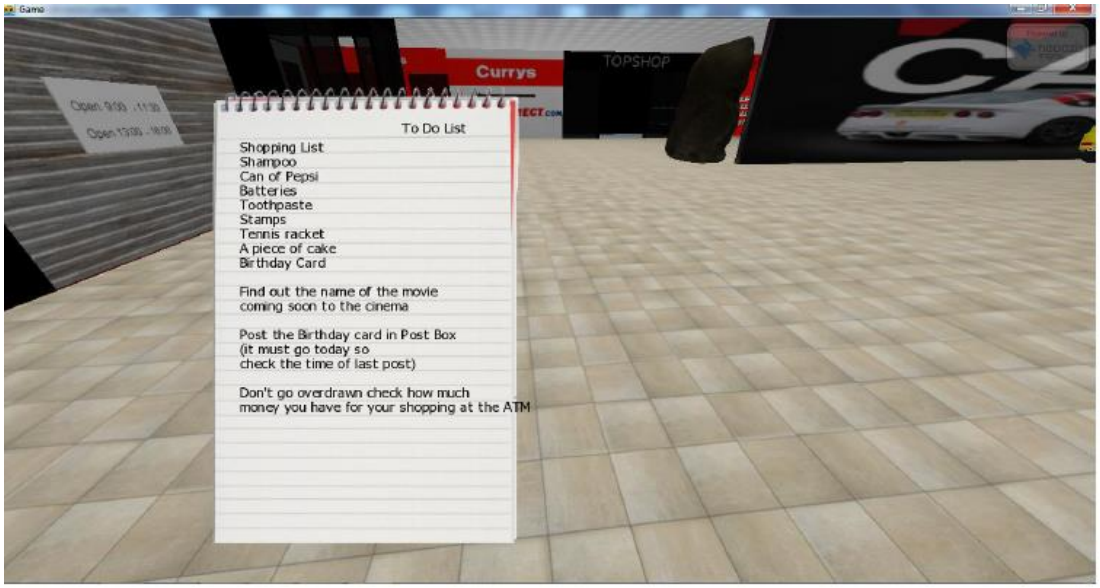
If I have any further questions?
If you have any questions or would like any further information please contact:
Tracey Quinn
(Trainee Clinical Psychologist)
Mental Health and Wellbeing,
Institute of Health and Wellbeing,
University of Glasgow,
1055 Great Western Road,
Glasgow, G12 0XH,
0141 2110607

Thank you for taking time to read this information

Appendix 2.3 Items on DEX Questionnaire related to Executive Cognition Construct

Item	
2.	“Acts without thinking, doing the first thing that comes to mind”
4.	“Has difficulty planning for the future”
5.	“Sometimes gets over-excited about things and can be a bit “over the top”
7.	“Has difficulty realising the extent of his/her problems and is unrealistic about the future”
9.	“Does or says embarrassing things when in the company of others”
10.	“Has difficulty thinking ahead”

Appendix 2.4 C-MET Shopping List



Appendix 2.5 C-MET PM Scoring Criteria

Construct	Task	Requirements	Score
Prospective Memory	Collect Lottery Ticket	Ticket bought	2
		Ticket not bought	0
	Dentist appointment	Remembers dentist appointment	2
		Does not remember any reason for leaving the shopping centre	0
	Post card before last collection at 1pm	Posts card before 1pm	2
		Does not postcard or posts after 1pm	0

Appendix 2.6 C-MET Administration Instructions

Practice Period

Imagine that a new shopping centre has opened up in your neighbourhood and this is your first visit. You need to buy some things and you can check your 'To Do' list by pressing the blue button (demonstrated by examiner). You can also check the shopping centre time by pressing the orange button, check your shopping bag by pressing the blue button and look at a map of the shopping centre by pressing the red button. In case you forget, a list of the commands and the corresponding button colours is printed on this piece of paper (experimenter points to list). We can see that there are two things on the shopping list to buy, a sandwich and a baseball cap. If you are unsure of where to buy something you may want to look at the map to see the types of things that the different shops sell (demonstrated by experimenter). To buy an item you must point the joystick in the direction of the item and press the green button (demonstrated by experimenter). This is just a chance to practice and get used to using the joystick before you start the proper task. See if you can find the two items on your shopping list. Let me know when you are finished or if you are having any trouble with the task.

Task Proper

This task is like the one that you have just practiced. You are now in the car park of the shopping centre and you can get to the shops on the 1st floor by entering the lift. Once you enter the lift the time on your clock will be 12.50pm. You can check the list of tasks to complete, the shopping centre time, your shopping bag and the centre map by pressing the same coloured buttons you used during the practice period. You should try to carry out all the tasks and work as quickly as possible. You have to attend a dentist's appointment at 1.30pm so will need to leave the shopping centre at 1.15pm at the latest. Once you have completed all the tasks you should return to your car in the underground car park where you began and press exit. Please let me know when you have finished and then tell me the reason why you have left the shopping centre. Do you understand what you have to do?

Appendix 2.7 West of Scotland Research Ethics (WoSRES) Approval Letter

WoSRES
West of Scotland Research Ethics Service

NHS
Greater Glasgow and Clyde

West of Scotland REC 4
Ground Floor, Tennent Building
Western Infirmary
38 Church Street
Glasgow
G11 6NT
www.nhsggc.org.uk

Date 19 February 2014
Direct line 0141-211-1722
Fax 0141-211-1847
e-mail Wosrec4@ggc.scot.nhs.uk

Ms Tracey Quinn
Trainee Clinical Psychologist
NHS Ayrshire and Arran
Institute of Health and Well-Being
College of Medical, Veterinary and Life Sciences
1st floor, Administration Building
Gartnavel Royal Hospital
1055 Great Western Road
Glasgow
G12 0XH

Dear Ms Quinn

Study title:	**Development of new computerised tools to assess memory and planning after brain injury**
REC reference:	**14/WS/0008**
IRAS project ID:	**131624**

Thank you for your letter of 06 February 2014, responding to the Committee's request for further information on the above research and submitting revised documentation.

The further information has been considered on behalf of the Committee by the Chair.

We plan to publish your research summary wording for the above study on the HRA website, together with your contact details, unless you expressly withhold permission to do so. Publication will be no earlier than three months from the date of this favourable opinion letter. Should you wish to provide a substitute contact point, require further information, or wish to withhold permission to publish, please contact the REC Manager Ms Evelyn Jackson, wosrec4@ggc.scot.nhs.uk.

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

NHS 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.

Management permission ("R&D approval") should be sought from all NHS organisations involved in the study 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 a NHS organisation's role in the study is limited to identifying and referring potential participants to research sites ("participant identification centre"), guidance should be sought from the R&D office on the information it requires to give permission for this activity.

For non-NHS sites, site management permission should be obtained in accordance with the procedures of the relevant host organisation.

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

Registration of Clinical Trials

All clinical trials (defined as the first four categories on the IRAS filter page) must be registered on a publically accessible database within 6 weeks of recruitment of the first participant (for medical device studies, within the timeline determined by the current registration and publication trees).

There is no requirement to separately notify the REC but you should do so at the earliest opportunity e.g when submitting an amendment. We will audit the registration details as part of the annual progress reporting process.

To ensure transparency in research, we strongly recommend that all research is registered but for non clinical trials this is not currently mandatory.

If a sponsor wishes to contest the need for registration they should contact Catherine Blewett (catherineblewett@nhs.net), the HRA does not, however, expect exceptions to be made. Guidance on where to register is provided within IRAS.

After ethical review

Reporting requirements

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
- Notification of serious breaches of the protocol
- 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.

Feedback

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.

Further information is available at National Research Ethics Service website > After Review

14/WS/0008	**Please quote this number on all correspondence**

We are pleased to welcome researchers and R & D staff at our NRES committee members' training days – see details at http://www.hra.nhs.uk/hra-training/

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

Yours sincerely

Evelyn Jackson

***For* Dr Brian Neilly**
Chair

Enclosures: *"After ethical review – guidance for researchers"*

Copy to: *Dr Karen Bell, R&D, NHS Ayrshire and Arran*

Appendix 2.8 Research & Development (NHS Ayrshire & Arran)

Research & Development
58 Lister Street
University Hospital Crosshouse
Kilmarnock
KA2 0BB

Ms Tracey Quinn
Trainee Clinical Psychologist
Mental Health & Wellbeing
Academic Centre
Gartnavel Royal Hospital
1055 Great Western Road
Glasgow
G12 0XH

Date 3 March 2014
Your Ref
Our Ref AG/KLB/NM R&D 2014AA007

Enquiries to Karen Bell
Extension 25850
Direct line 01563 825850
Fax 01563 825806
Email Karen.bell@aaaht.scot.nhs.uk

Dear Ms Quinn

Development of new computerised tools to assess memory and planning after brain injury

I confirm that NHS Ayrshire and Arran have reviewed the undernoted documents and grant R&D Management approval for the above study.

Approved documents:

Document	Version	Date
SSI form	Version 3.5	17/01/14 signed
R&D Form	Version 3.5	22/12/13 signed
Protocol	Version 1.3	25/01/14
Carer Consent Form	Version 1.1	04/12/13
Carer Info sheet	Version 1.0	01/12/13
GP Info Sheet	Version 1.1	25/01/14
Participant Consent Form	Version 1.4	25/01/14
Participant Info Sheet	Version 1.2	27/11/13
Invitation to participate – Ayrshire Brain Injury	Version 1.1	25/01/14
Hospital Anxiety and Depression Scale (1983)	No version	No date
OZC Dysexecutive Questionnaire	No version	No date
OZC Dysexecutive Questionnaire Revised Self-rating	No version	No date
PRMQ-English-1	No version	No date
Participant Information Sheet – GP and Clinical Team	Version 1.0	25/01/14
GP Info Sheet (Mod-Sev HADS)	Version 1.0	25/01/14
Clinical Team Info Sheet	Version 1.0	25/01/14
Participant Info Sheet - GP only	Version 1.3	25/01/14

The terms of approval state that the investigator authorised to undertake this study is: -

- Tracey Quinn, Trainee Clinical Psychologist

With no additional investigators.

PLEASE NOTE: If any member of the research team requires access to NHS Ayrshire and Arran premises/patients please contact the R&D office to arrange the necessary paperwork. Researchers will not be permitted access until the necessary paperwork has been issued.

The sponsors for this study are NHS Ayrshire & Arran and University of Glasgow.

This approval letter is valid until 3 March 2015.

Regular reports of the study require to be submitted. Your first report should be submitted to Dr K Bell, Research & Development Manager in 12 months time and subsequently at yearly intervals until the work is completed.

Please note that as a requirement of this type of study your name, designation, work address, work telephone number, work e-mail address, work related qualifications and whole time equivalent will be held on the Scottish National Research Database so that NHS R&D staff in Scotland can access this information for purposes related to project management and report monitoring.

In addition approval is granted subject to the following conditions: -

- All research activity must comply with the standards detailed in the Research Governance Framework for Health and Community Care www.cso.scot.nhs.uk/publications/ResGov/Framework/RGFEdTwo.pdf and appropriate statutory legislation. It is your responsibility to ensure that you are familiar with these, however please do not hesitate to seek further advice if you are unsure.

- Recruitment figures must be submitted to R&D on a monthly basis. If recruitment figures are not received timeously you will be contacted by a member of the R&D team to provide this data.

- You are required to comply with Good Clinical Practice (ICH-GCP guidelines may be found at www.ich.org/LOB/media/MEDIA482.pdf), Ethics Guidelines, Health & Safety Act 1999 and Data Protection Act 1998.

- If any amendments are to be made to the study protocol and or the Research Team the Researcher must seek Ethical and Management Approval for the changes before they can be implemented.

- The Researcher and NHS Ayrshire and Arran must permit and assist with any monitoring, auditing or inspection of the project by the relevant authorities.

- The NHS Ayrshire and Arran Complaints Department should be informed if any complaints arise regarding the project and the R&D Department must be copied into this correspondence.

- The outcome and lessons learnt from complaints must be communicated to funders, sponsors and other partners associated with the project.

- As custodian of the information collated during this research project you are responsible for ensuring the security of all personal information collated in line with NHS Scotland IT Security Policies, until the destruction of these data. Under no circumstances should personal data be stored on any unencrypted removable media e.g. laptop, USB or mobile device (for further information and guidance please contact the Information Governance Team based at Ailsa Hospital 01292 513693 or 513694).

If I can be of any further assistance please do not hesitate to contact me. On behalf of the department, I wish you every success with the project.

Yours sincerely

Dr Alison Graham
Medical Director

c.c.
Rani Sinnak, Consultant Clinical Neuro and Health Psychologist, NHS Ayrshire and Arran
Sharon Mulhern, Consultant Clinical Lead Neuropsychology, NHS Ayrshire and Arran
Pamela McColm, Consultant Clinical Psychologist, NHS Ayrshire and Arran
Professor Jonathan Evans, Academic Supervisor, University of Glasgow
Dr Karen Bell, Head of R&D, NHS Ayrshire and Arran (sponsor contact)
Debra Stuart, University of Glasgow (sponsor contact)
Lesley Douglas, Finance, Ailsa Hospital
Information Governance, Ailsa Hospital
NRS Coordinating Centre, Aberdeen

Appendix 2.8 Letter of Access (NHS Greater Glasgow & Clyde)

Coordinator/Administrator: Dr Erica Packard/Mrs Elaine O'Neill
Telephone Number: 0141 232 9448
E-Mail: erica.packard@ggc.scot.nhs.uk
Website: www.nhsggc.org.uk/r&d

R&D Management Office
Western Infirmary
Tennent Building
1st Floor, 38 Church Street
Glasgow, G11 6NT.

16 April 2014

Ms Tracey Quinn
Trainee Clinical Psychologist
Mental Health and Wellbeing
Gartnavel Royal Hospital
1055 Great Western Road
Glasgow G12 0XH

Dear Ms Quinn,

NHS to NHS - Letter of Access for Research

As an existing **NHS employee** you do not require an additional honorary research contract with this NHS organisation. We are satisfied that the research activities that you will undertake in this NHS organisation are commensurate with the activities you undertake for your employer. Your employer is fully responsible for ensuring such checks as are necessary have been carried out. Your employer has confirmed in writing to this NHS organisation that the necessary pre-engagement check are in place in accordance with the role you plan to carry out in this organisation. This letter confirms your right of access to conduct research through **NHS Greater Glasgow and Clyde** for the purpose and on the terms and conditions set out below. This right of access commences on **16/04/2014** and ends on **04/10/2014** unless terminated earlier in accordance with the clauses below.

You have a right of access to conduct such research as confirmed in writing in the letter of permission for research from this NHS organisation. Please note that you cannot start the research until the Principal Investigator for the research project has received a letter from us giving permission to conduct the project.

You are considered to be a legal visitor to **NHS Greater Glasgow and Clyde** premises. You are not entitled to any form of payment or access to other benefits provided by this organisation to employees and this letter does not give rise to any other relationship between you and this NHS organisation, in particular that of an employee.

While undertaking research through **NHS Greater Glasgow and Clyde** you will remain accountable to your employer **NHS Ayrshire and Arran** but you are required to follow the reasonable instructions of your nominated manager **Nicola Goudie/Ruth Sumpter** in this NHS organisation or those given on her/his behalf in relation to the terms of this right of access.

Where any third party claim is made, whether or not legal proceedings are issued, arising out of or in connection with your right of access, you are required to co-operate fully with any investigation by this NHS organisation in connection with any such claim and to give all such assistance as may reasonably be required regarding the conduct of any legal proceedings.

You must act in accordance with **NHS Greater Glasgow and Clyde** policies and procedures, which are available to you upon request, and the Research Governance Framework.

You are required to co-operate with **NHS Greater Glasgow and Clyde** in discharging its duties under the Health and Safety at Work etc Act 1974 and other health and safety legislation and to take reasonable care for

the health and safety of yourself and others while on **NHS Greater Glasgow and Clyde** premises. Although you are not a contract holder, you must observe the same standards of care and propriety in dealing with patients, staff, visitors, equipment and premises as is expected of a contract holder and you must act appropriately, responsibly and professionally at all times.

If you have a physical or mental health condition or disability which may affect your research role and which might require special adjustments to your role, if you have not already done so, you must notify your employer and the Board via the **HR Department** prior to commencing your research role at the Board.

You are required to ensure that all information regarding patients or staff remains secure and *strictly confidential* at all times. You must ensure that you understand and comply with the requirements of the NHS Confidentiality Code of Practice (http://www.dh.gov.uk/assetRoot/04/06/92/54/04069254.pdf) and the Data Protection Act 1998. Furthermore you should be aware that under the Act, unauthorised disclosure of information is an offence and such disclosures may lead to prosecution.

NHS Greater Glasgow and Clyde will not indemnify you against any liability incurred as a result of any breach of confidentiality or breach of the Data Protection Act 1998. Any breach of the Data Protection Act 1998 may result in legal action against you and/or your substantive employer.

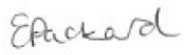
You should ensure that, where you are issued with an identity or security card, a bleep number, email or library account, keys or protective clothing, these are returned upon termination of this arrangement. Please also ensure that while on the premises you wear your ID badge at all times, or are able to prove your identity if challenged. Please note that this NHS organisation accepts no responsibility for damage to or loss of personal property.

We may terminate your right to attend at any time either by giving seven days' written notice to you or immediately without any notice if you are in breach of any of the terms or conditions described in this letter or if you commit any act that we reasonably consider to amount to serious misconduct or to be disruptive and/or prejudicial to the interests and/or business of this NHS organisation or if you are convicted of any criminal offence. You must not undertake regulated activity if you are barred from such work. If you are barred from working with adults or children this letter of access is immediately terminated. Your employer will immediately withdraw you from undertaking this or any other regulated activity and you MUST stop undertaking any regulated activity immediately.

Your substantive employer is responsible for your conduct during this research project and may in the circumstances described above instigate disciplinary action against you.

If your circumstances change in relation to your health, criminal record, professional registration or suitability to work with adults or children, or any other aspect that may impact on your suitability to conduct research, or your role in research changes, you must inform the NHS organisation that employs you through its normal procedures. You must also inform your nominated manager in this NHS organisation.

Yours sincerely



Dr Erica Packard
Research Co-ordinator

cc: **Craig Hannah (NHS A&A HR)**

Major Research Project Proposal

Appendix 3.1 Major Research Proposal

Development of new computerised tools to assess memory and planning in people with brain injury

Tracey Quinn

Word Count: 3838

Abstract

Background*:* Developing accurate assessment tools of executive function remains a challenge. Current tools often do not capture the nuances of day-to-day tasks that present a challenge to people with executive functioning difficulties. Computerised assessment measures may provide greater accuracy and ecological validity.

Aims: The primary aim of this study is to investigate the ability of a computerised measure of executive function to assess planning and prospective memory deficits in a sample of people with brain injury when compared to more traditional neuropsychological measures. The study will also explore the ability of the computerised measure to capture planning and prospective memory deficits associated with difficulties in everyday living tasks as assessed by questionnaires.

Methods: Individuals with cognitive impairment will be recruited from neurorehabilitation treatment centres around Glasgow and Ayrshire. Participants will complete a computerised multiple errands task (CT-MET) and other traditional validated measures of planning, prospective memory and executive functioning. The strength of the relationship between performance on the planning and prospective memory subcomponents of the CT-MET task and performance on traditional measures of these executive function domains shall be ascertained. Further exploratory analysis will compare scores on the planning, memory and executive function components of self and carer-rated psychometric questionnaires with those received in those domains using the CT-MET task.

Applications: The validation of the CT-MET could provide a more ecologically valid tool for the measurement of executive function. It may also support the use of such a tool in neurorehabilitation for people with brain injury.

Introduction

Executive functions is an umbrella term which refers to a broad range of higher order cognitive processes that control and regulate other processes, such as language and memory (Lezak, 1982). Theoretical and factor analytic research (e.g., Burgess *et al.*, 1998; Simblett & Bateman, 2011) carried out in order to identify these cognitive and behavioural functions have identified several discrete cognitive domains that underpin executive function. These include the processes of planning, task switching, inhibiting behavioural responses, prospective memory and goal management which are commonly used to negotiate multiple goals and changing circumstances often seen in everyday life. This assertion is somewhat supported by research showing that people with acquired brain injury will often display deficits in one or more of these areas while other cognitive domains appear unaffected (Shallice & Burgess, 1991).

Many questions still remain regarding the dimensions that underpin executive functions and the assessment of these deficits under laboratory conditions has proved problematic. Traditional neuropsychological testing in a clinical setting often does not provide opportunity for choice and decision-making (Burgess *et al.*, 2006) and is typically not representative of real-life situations that the individual encounters regularly. This makes identifying specific processes involved in executive function and the development of specific "real-life" assessment measures for these processes a valuable area of interest.

In their seminal study, Shallice and Burgess (1991) highlighted the difficulties in using traditional neuropsychological measures by examining the ability of 3 participants with brain-injury to perform a variety of cognitive tests. Results revealed that although patients with frontal lobe damage exhibited marked impairment in planning and memory in their everyday functioning, performance on most traditional measures of executive function was normal or above-normal. Executive function deficits were only captured by two neuropsychological tests, namely the Six Elements Test (SET; Shallice & Burgess, 1991) and the Multiple Errands Test (MET; Shallice & Burgess, 1991). Shallice and Burgess concluded that most traditional pen and paper measures did not capture the subtle processes necessary for everyday multi-tasking.

The MET is a relatively unstructured, open-ended task which takes place in a busy shopping precinct and requires participants to complete a number of tasks (e.g., check the closing time of the library, buy one cookie) within the designated time. Before going to the shopping centre, participants are provided with a number of rules including "spend as little money as possible" and "do not enter a store other than to buy something". Errors were categorized as: 1) inefficiencies—not applying the optimum strategy; 2) rule breaks—breaking any of the rules mentioned at the start or a breaking a social rule, 3) interpretation failure—misunderstanding the requirements of a task and 4) task failure—not completing a task. Participants with frontal lobe damage had higher overall errors and more rule breaks and task failures on the MET than healthy controls. However, despite successfully demonstrating the ecological validity necessary to identify executive deficits in individuals with frontal lobe damage, the task has limited clinical utility due to its cumbersome and time-consuming nature.

New assessment measures such as the Behavioural Assessment of Dysexecutive function (BADS; Wilson *et al.*, 1996) have been developed to address the ecological short-comings of their predecessors and offer a more standardised approach to measurement. However, despite being the most widely used in clinical practice, the BADS still remains limited in predictive ability of daily functioning in people with brain injury (Wood & Lossi, 2006). Other assessment approaches have incorporated the use of psychometric measures such as the The Dysexecutive Questionnaire (DEX) in order to gain a more accurate reflection of daily functioning. The DEX questionnaire comes in both a self-report and relative/carer report version and is contained within the BADS. It is a 20-item measure which covers a wide range of specific problems (e.g., memory, awareness, emotional regulation) and is sensitive to the changes in daily functioning that often follow acquired brain injury (Bennet, Ong & Ponsford, 2005).

Evidently, there are many challenges in the assessment of executive function and their underlying processes. During the past decade, computerised assessments of executive function have become more popular (Josman, Klinger & Kizony, 2008) and this has allowed for greater accuracy in the assessment of executive functioning in response to more real-world behavioural tasks. This move towards more ecologically valid assessment tools

increases the likelihood that cognitive and behavioural responses captured during testing are those that would occur in every-day situations (Burgess *et al.*, 2006). It may also support a greater delineation of the components of executive function and allows behaviour to be measured in a safe environment while maintaining strict methodological control (Rizzo, Buckwalter, & Van der Zaag, 2002).

The present study aims to examine the efficacy of a computerised version of the MET compared with traditional neuropsychological and questionnaire measures in assessing the planning and prospective memory domains of executive functions. Findings could have important implications for improving the ecological validity of executive functioning assessments and aid attempts to delineate the components of executive function more clearly.

Aims and hypotheses

The main aim of this study is to investigate if a significant relationship exists between performance on the planning and prospective memory components of a computerised supermarket task (CT-MET) and traditional tests of planning and prospective memory.

An exploratory aim of this study is to determine the relationship between performance in the domains of planning and prospective memory on the CT-MET task and measures of everyday functioning as assessed by traditional neuropsychological measures.

Main Hypotheses: There will be a significant correlation between performance on the planning and prospective memory domains of the CT-MET task and in planning and prospective memory as measured by traditional neuropsychological measures.

There will be a correlation between participants planning and PM performance on the CT-MET task and reported planning and prospective memory difficulties in activities of daily living as measured by psychometric measures.

The correlation between performance on the CT-MET task and measures of non-executive functions (i.e., visuospatial task) will be significantly lower than the correlation between the task and measures of executive functions.

Plan of Investigation

Participants

Forty-six men and women with Acquired Brain Injury (ABI) will be recruited for this study.

Inclusion

Participants with ABI will be recruited from a number of community settings. Individuals will be eligible if they are aged 18-65 and have had an ABI for at least 6 months before testing that was sustained after the age of 16. Only participants with the ability to consent will be approached. As some of the measures used in this study have only been reliably validated on English speaking samples only those speaking English as a first language will be recruited. Written information will be given to supplement all verbal instructions.

Exclusion Criteria

Participants will be excluded if they have a severe mental illness, current substance abuse, learning disability or any physical disability likely to impact on their performance. As assessment requires reading, illiterate participants will be excluded and previous use of a computer will be a requirement.

Recruitment Procedures

Potential participants will be identified initially by the clinical/support team working within the Glasgow Community Treatment Centre for Brain Injury (NHS Service), Douglas Grant Rehabilitation Centre (NHS service), Ayrshire Brain Injury Service (NHS Service), Headway (charity providing support services for people with brain injury), The Dirrans Centre (North Ayrshire Social Services), West Dunbartonshire Acquired Brain Injury Team (West Dunbartonshire Social Services), The Brain Injury Research Trust (charity organisation) and The Huntercombe Services Murdostoun - Brain Injury rehabiliation Centre (private Hospital).

Relevant team members will be briefed on the project by the researcher. Only potential participants deemed to meet the inclusion criteria will be offered the opportunity to participate in the study. Potential participants will be invited to participate in the study via the letter of invitation. This letter will explain the project, and make clear that there is no obligation to participate and that declining will not affect the service they receive. The letter of invitation will either be handed to participants attending for appointments or sent in the post. The contact details of the lead researcher will be included so the individual can ask any questions they have regarding the study. They will be invited to return a free post reply form or contact the researcher by phone or e-mail if they wish to participate.

Due to the nature of brain injury, individuals interested in participating in this study may have prospective memory problems which may result in failure to follow-through on intended actions such as posting the reply or contacting the researcher. In order to aid recall, at their next session at the relevant brain injury service participants will be handed a flyer reminding them of the project. The leaflet will state that if they are interested in participating in the research they can ask a member of the team they are seeing at the centre to pass on their details to the researcher who can contact them to discuss the project further. Team members at these sites are experienced in using this method of recruitment and will be fully briefed on the importance of not acting in any manner likely to lead to a patient feeling coerced into participation.

At Headway, The Dirrans Centre, Brain Injury Research Trust and The Huntercombe Services Murdostoun the recruitment procedure will be the same as above, but in addition, potential participants will be invited to attend an information session provided by the Chief Investigator to hear more about the project and answer any questions.

After the time and date of the testing session has been agreed with the participant, a letter confirming this date and time will be sent to the participant's home.

All potential participants will be clearly encouraged to ask questions about the study before consenting. It will be emphasised to participants that they can withdraw their consent at any time without explanation and without implications for their care.

Measures

Pre-Experimental Psychometric Measures: Initial measures will include a modified version of both the self-rated and independent rater versions of the Dysexecutive Questionnaire (DEX, Burgess *et al.*, 1996). The original DEX Questionnaire is a 20 item scale which examines the social, motivational, cognitive and emotional changes that a person with dysexecutive problems may exhibit. One version of this questionnaire is completed by the patient while the other is completed by a care-giver or family member who knows the participant well. Responses are rated on a 5-point Likert scale ranging from 0 (never) to 4 (very often). Simblett and Bateman (2012) used Rasch analysis to examine the DEX responses of 363 people with ABI. They reported that the DEX is best understood as a multi-dimensional measure and which captures 3 underlying constructs, namely behavioural-emotional self-regulation, metacognition and executive cognition. They also suggested minor changes to some items on the DEX such as re-phrasing or asking about one specific type of behaviour. This study will incorporate the suggested changes to produce a slightly modified DEX questionnaire which although not yet validated has been shown to improve precision in the measurement of executive functions (Simblett & Bateman, 2012).

Participants will also be required to complete the Prospective and Retrospective Memory Questionnaire (PRMQ; Crawford, Maylor, Della Sala, & Logie, 2003). The PRMQ is a 16-item questionnaire which measures prospective and retrospective failures of memory in everyday life. In addition, participants will be asked to complete the Hospital Anxiety and Depression Scale (HADS; Zigmond and Snaith, 1983). The HADS is a commonly used screening measure for depression.

Completion of questionnaires will take the participant approximately 15 minutes (5 mins DEX, 5 mins PRMQ, 5 mins HADS). The informant version of the DEX will take approximately 5 minutes for the carer to complete.

Background Neuropsychological Measures

The following tests will be administered in order to characterise the sample:

- Test of Premorbid Functioning (TOPF): The Test of Premorbid Function (TOPF) (Delis, Kaplan, & Kramer, 2009) provides an estimate of premorbid cognitive functioning in adults from 16 to 90 years of age.

- BIRT Speed of Information Processing: This subtest will be taken from the BIRT Memory and Information Processing Battery (Coughlan, Oddy & Crawford, 2007).

Post-traumatic Amnesia (PTA): A retrospective estimate of PTA will be made by asking the participant about the first thing they remember following their brain injury and asking them to estimate how long after the injury this was. McMillan, Jongen and Greenwood (1996) found that retrospective estimated of PTA correlated with other measures of brain injury severity.

Traditional Assessment Measures:

- *Behavioural Assessment of Dysexecutive Syndrome (Wilson et al., 1996)*: A test battery comprising of six subtests including the Zoo Map test (a planning task) and the Modified Six Elements Test, which is a simplified version of the Six Elements Test developed by Shallice and Burgess (1991) and taps planning/self-directed organisation; The BADS has excellent inter-rater reliability (0.90-1.00) and moderate test-re-test reliability (0.64-0.71).
  Administration time: 40mins

- Cambridge Prospective Memory Test (CAMPROMPT; Wilson *et al.*, 2005): The CAMPROMPT was developed to measure time and event-based prospective memory.
  Administration time: 30mins

- Stockings of Cambridge Subtest from the Cambridge Neuropsychological Test Automated Battery (CANTAB; Sahakian *et al.*, 1988): This measures ability to reason and plan.

Administration time: 7-10mins

- Line Orientation subtest from the Repeatable Battery for the Assessment of Neuropsychological Status (RBANS; Randolph, Tierney, Mohr & Chase, 1998): This is a test of visuo-spatial ability and not executive functions. Scores will be used as a test of divergent validity.
  Administration time: 6mins

Computerised Measures:

- *Computerised Multiple Errands Task (CT-MET):* A computerised shopping centre task was created based on the 'Multiple Errand Task' (Shallice & Burgess, 1993), a validated measure of executive function. The task begins with the participant parking their car in the virtual car park and taking the elevator to the shopping centre. Once there, participants are given a number of errands to complete within the designated time such as check the name of the new movie coming to the cinema, purchase a get well card and check the time of the last post.
  Administration time: Approximately 20mins

Two processes thought to be key executive function processes were drawn from the theoretical models to be examined in further detail, namely prospective memory (PM) and planning. Tasks within CT-MET which required prospective memory (PM) or planning have been identified and an operationalised scoring criteria has been developed to assess participants on both of these processes (see Appendix 3.4 for further details).

Design

This study will incorporate an experimental within group correlational design. Each individual will perform the CT-MET task and other traditional neuropsychological (CAMPROMPT, BADS) and psychometric measures (modified DEX, PRMQ) of executive function. The order of administration of the CT-MET task and the traditional

neuropsychological measures will be counterbalanced across participants to control for practice effects.

Research Procedures

Participants that express an interest in taking part in the study will be invited to attend the testing session at a time that is convenient to them and within a setting with which they are already familiar. Prior to attendance at the testing session, participant will be mailed the DEX, HADS and the PRMQ and asked to complete and bring them to the testing session. The assessment process will last approximately 2 and a half hours and will be broken into three sections. Participants will be given a 5-minute break between the BADS and CAMPROMPT and a 10-minute break will be given between sections 1 and 2. An additional 10 minutes may be added to testing time to allow for the completion of the DEX and PRMQ if the participant has forgotten to complete them at home. At the participants request, the assessment process can be conducted over more than one session if necessary.

These sections include:

1. Traditional neuropsychological tests (i.e., BADS, line orientation, CAMPROMPT, Stockings of Cambridge)

   Approximate administration time: 1hr 20mins

2. CT-MET Task and practice period (25 mins)

3. Background measures (i.e, TOPF, speed of processing task) (20mins)

The CT-MET task will be administered via a laptop computer and scoring is automatically recorded by the CT-MET programme.

Data Analysis

Descriptive statistics will be used to characterise the demographic and neuropsychological features of the sample. Correlational analysis will examine the relationships between these

domains as assessed by neuropsychological measures with those obtained using self-rated and other-rated psychometric measures (i.e., DEX and PRMQ). Correlational analyses will also be conducted between the traditional and computerised tests of planning, prospective memory and executive function and the self-rated and other-rated psychometric measures. If the parametric assumptions of testing are violated equivalent non-parametric tests will be used.

*Justificatio*n *of sample size*

The sample size estimates are based on the primary hypothesis which states that here will be a significant correlation between participants planning and PM performance on the CT-MET and their performance on traditional measures of these components of executive function. This approach will utilise Cohen's (1988) conventions for small (0.10), medium (0.30), and large (0.50) correlation (r) effect sizes.

A handful of previous studies have compared performance of a brain-injured sample on computerised or virtual measures of executive function and more traditional neuropsychological measures. Renison *et al.* (2012) found a moderate effect size between performance on a virtual library task (comparable to the CT-MET) and scores on the Zoo Map test (*r* = .29) and Modified Six Elements Test (*r* = .32) using a brain-injured sample. Rand, Rukan, Weiss and Katz (2009) found a large effect size (*r* = - .87) between non-efficiency mistakes on a virtual MET and scores on the Zoo map test in a sample of post-stroke participants. Also using a brain-injured sample, Scott and Evans (2013) found a large effect size (r = .59) between PM performance on a computerised office-based task (comparable to the CT-MET) and performance on the CAMPROMPT as well as a medium effect size (r = .33) between planning performance on the computerised task and scores on the Tower Test of planning (Delis, Kaplan & Kramer, 2001).

Given the previous research into the relationship planning and PM performance on computerised/virtual measures and traditional neuropsychological measures, there is justification for assuming that correlations between traditional measures of executive functions and performance on CT-MET will provide a medium-large effect Therefore, using Cohen's guidelines, a sample size calculation was conducted using G*Power (Faul, Erdfelder, & Lang, 2009). For a two-tailed hypothesis with an alpha of 0.05 and using correlation as

the method of analysis, G*Power suggested using a sample size of 46 participants to obtain a medium-large effect size of 0.4 and power level of 0.80.

Settings and Equipment

Equipment will include a joystick and an encrypted laptop computer to display the virtual shopping task and record data. The traditional neuropsychological measures, record forms and questionnaires mentioned above will also be required. Testing will be carried out in a quiet room at staffed organisational sites during normal working hours. If availability of testing space is a problem for sites in Glasgow testing may be carried out at the Health and Social Care Alliance hub in Glasgow city centre. Completed questionnaires and record forms will be stored in a secure location to ensure confidentiality.

7. Health and Safety Issues

Researcher Safety Issues

The procedures will be carried out at staffed organisational settings during normal working hours. Participants identified as having a history of aggression by the clinical team will not be eligible to participate in the study. The layout of the testing room will be such that the researcher will be positioned closest to the door. Other staff in the building will be informed of the researcher's presence and approximate finishing times for testing each day.

Participant Safety Issues

The safety of participants will be a priority and participants will be informed at the recruitment stage and the start of the testing session of their right to withdraw from the research at any time. The researcher will be present at all times and will monitor the participants for signs of distress. Further breaks will be provided or the testing session will be stopped necessary (see Appendix 3.5)

8. Ethical Issues (including where submissions will be made)

Ethical approval will be sought from the West of Scotland Research Ethics Committee, NHS Greater Glasgow and Clyde Primary Care Division Local Research Ethics Committee and NHS Ayrshire and Arran Research and Development departments. Only participants deemed to

possess capacity by members of the clinical team will be invited to take part in this study and written consent will be obtained from these individuals. Upon meeting the participant, the researcher will explain the written consent form in detail. If the researcher has any doubts about the participant's ability to understand, retain, or use the information as part of the decision making process then they will be excused from the study. In this situation and to avoid embarrassment, participants will be allowed to complete some initial tasks but their data will not be used.

Participants will be informed at the recruitment stage and the start of the testing session of their right to withdraw from the research at any time and will be reassured that this will not have any impact on their treatment. The principles of the Data Protection Act (1998) will be stringently followed throughout the course of this research and data will be stored securely on a Glasgow University laptop with full disc encryption in lie with GG&C and Ayrshire & Arran NHS guidelines. Data will be retained on a secure server for 10 years in accordance with University guidelines for conducting research.

9. Financial Issues

The overall cost of this study is estimated to be £489.40, which covers the purchasing of all the materials required for this study (See Appendix 3.6 for details).

10. Timetable

The study will be conducted between September 2013 and July 2014 (see Appendix for details).

11. Practical Applications

The results of this research could have a number of practical applications such as supporting the use of more ecologically valid measures of executive function. Results could also support the potential application of computerised executive function programmes to neuro-rehabilitation.

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Appendix 3.3 Plain English Summary

Title: Development of new computerised tools to assess memory and planning in people with brain injury

Background*:* People with damage to the frontal part of their brain often display difficulties on tasks that involve planning, problem-solving and memory. It is thought that the frontal part of the brain may control these important tasks which are also known as executive functions. Researchers in the area of brain injury have difficulty trying to create reliable ways of measuring the difficulties because people mostly display these difficulties when carrying out daily tasks that might involve a number of these executive functions working together to achieve a goal.

A research paper by Shallice and Burgess (1991) examined the executive functions of three people who had acquired a brain injury. They were surprised to find that these people performed well on paper and pencil tests of executive functions such as memory and planning but poorly on a "real world" test of these functions. The "real-world" test called the "Multiple Errands Test" involved bringing the person to a shopping centre and giving them a list of things to buy within a certain time frame and budget. The results suggested that a lot of the commonly used paper and pencil tests used to measure executive functions are not effective as they are not representative of the tasks that people have to deal with in everyday living. Although an effective assessment method, bringing people to a supermarket is a costly and labour intensive exercise. This study will evaluate the effectiveness of a computerised version of the multiple errands task in identifying planning and memory problems in people with brain injury.

Methods: Individuals with brain injury from neurorehabilitation treatment centres around Glasgow and Ayrshire will be asked if they would like to take part in the study. Participants will complete a computerised shopping centre task and other more commonly used paper and pencil of planning and memory. The strength of the relationship between performance on the planning and prospective memory parts of the computerised shopping centre task will be compared to performance on the paper and pencil tests. Further exploratory analysis will compare scores on the planning, memory and executive function components of the shopping centre tasks and people's reported difficulties in everyday life as measured by questionnaires.

Applications: If findings show that the computerised multiple errands task is effective at measuring planning and memory problems in people with brain injury, it may be a cost effective and reliable tool that can be easily used in a variety of settings. It would give us a better understanding of the tasks of everyday living with which people with brain injury may be struggling. A tool such as this may also be useful in rehabilitation settings as it would allow people with brain injury to identify the areas that they struggle with and allow them the opportunity to practice and adapt their behaviour.

References

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Appendix 3.4 PM Scoring Criteria for CT-MET

Construct	Task	Requirements	Score
Prospective Memory	Collect Lottery Ticket	Ticket bought	2
		Ticket not bought	0
	Dentist appointment	Remembers dentist appointment	2
		Does not remember any reason for leaving the shopping centre	0
	Post card before last collection at 1pm	Posts card before 1pm	2
		Does not postcard or posts after 1pm	0

Appendix 3.5 Health and Safety Form

WEST OF SCOTLAND/ UNIVERSITY OF GLASGOW

DOCTORATE IN CLINICAL PSYCHOLOGY

HEALTH AND SAFETY FOR RESEARCHERS

1. Title of Project	Validation of a Computerised Measure of Executive Function: The Multiple Errands Task
2. Trainee	
3. University Supervisor	Prof. Jon Evans
4. Other Supervisor(s)	N/A
5. Local Lead Clinician	
6. Participants: (age, group or sub-group, pre- or post-treatment, etc)	Participants with Acquired Brain Injury will be recruited from a number of community settings. Individuals will be eligible if they are aged 18-65 and have had an ABI for at least 6 months before testing that was sustained after the age of 16. Only participants with the ability to consent will be approached.
7. Procedures to be applied (eg, questionnaire, interview, etc)	Participants will be given questionnaires to complete and will undergo neuropsychological cognitive testing.
8. Setting (where will procedures be carried out?)	The procedures will be carried out at staffed organisational settings during normal working

i) General	hours. These will be clinical settings that the participant routinely attends.
ii) Are home visits involved	No

9. Potential Risk Factors Identified (see chart)	The procedures used in the study are similar to those used by clinical psychologists with these participants and are not normally associated with production of significant distress. Members of this participant group can occasionally display impulsive behaviour and poor emotional control.
. 10. Actions to minimise risk (refer to 9)	The researcher will be present at all times and will monitor the participants for signs of distress. Further breaks will be given where appropriate and participants will be informed at the recruitment stage and the start of the testing session that they are free to leave at any time. The clinician in charge of the care of the participant will be informed of the distress where appropriate. The researcher will always sit in a location closest to the door allowing for quick exit if required. Supervisor will be informed of each testing session.

Appendix 3.6 Financial Costs

Please complete the list below to the best of your ability

Item	**Details and Amount Required**	**Cost or Specify if to Request to Borrow from Department**
Stationary	Envelopes (A4): 70 Labels: 70	1 box of 250: £9.36 1 box (100 sheets): £11.42 (Will be split with other trainee to half cost) Subtotal: £20.78/2 = £10.39
Postage	Freepost (£0.69 x 70)	Subtotal: £48.30
Photocopying and Laser Printing (**includes cost of white paper**)	White Paper (5 sheets x 70= 350) Photocopying (4 sheets x 50 = 200) Demographic Recording sheet: 50 Adapted DEX Questionnaire: 50 (self-rated and other-rated) PRMQ Questionnaire: 50 Line Orientation (from RBANS) Record Form: 50 Hospital Anxiety and Depression Scale (HADS)	1 ream (500 A4 sheets) = £2.50 (£0.05 x 200) = £10.00 Create own (£0.05 x 50) = £2.50 Create own (£0.05 x 100) = £5.00 Free to copy (£0.05 x 50) = £2.50 Create own (£0.05 x 50) = £2.50 Free to copy (£0.05 x 50) = £2.50 Subtotal: £27.50

Equipment and Software	Laptop CANTAB	Borrowed from Department Borrowed from Department Subtotal: £0.00
Measures	BADS Record Form: 50 CAMPROMPT Record Form: 50 BIRT Speed of Information Processing Sheet Test of Premorbid Functioning Record Form	Pack of 25 = £39.60 x 2 = £78.40 Pack of 25 = £57.60 x 2 = £115.20 Pack of 25 = £44.00 x 2 = £88.00 Pack of 25 = £66.00 x 2 = £132.00 Subtotal: £413.60
Miscellaneous		Subtotal:
Total		£489.40

Appendix 3.7 Timetable for Project

Date	**MRP Tasks**
April 2013	Submission of MRP Proposal Submission of health and safety form Submission of equipment costing form
April – August 2013	MRP research supervision agreement Start research log book Approach potential testing centres Submit project for ethics approval Submit project for Research and Development Approval Order/create record forms and questionnaires Submit systematic review outline
September 2013	Research Progress Meeting
September 2013	Start data Collection
February 2014	Complete data collection Research Progress Meeting
March – April 2014	Complete data analyses Research Progress Meeting
May – July 2014	Submit draft project to supervisor
July 2014	Submit MRP
August 2014	Viva preparation
September 2014	Viva
September – November 2014	Submit corrections (if applicable)

Appendix 3.8 Addendum to Major Research Project Proposal

In order to reduce the length of the testing session for participants, the Numbers Task replaced the CAMPROMPT as a measure of PM.