THE FRACTIONATION OF EXECUTIVE FUNCTIONING AND ITS RELEVANCE TO THE ASSESSMENT OF CAPACITY

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ABSTRACT

THE DEVELOPMENT AND PSYCHOMETRIC PROPERTIES OF A NEW TEST OF DECISION-MAKING FOR USE IN PEOPLE WITH ACQUIRED BRAIN INJURY

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Literature Review

Executive function is an ‘umbrella’ term for higher levels of cognitive functioning such as decision making, planning, monitoring, inhibition, and working memory, but to name a few. This literature review examines theories of executive functioning and the associated assessment instruments. The review of theories allowed for a heuristic aggregate of discrete processes to be established, acting as a thesaurus for the term executive function. In addition, the review examined how current measures of executive function might be able to help with the assessment of an individuals level of capacity to make decisions; based on the principle of understanding the information relevant to the decision, retaining the information, using/weighing the information as part of the decision making process, and communicating the decision (Department of Health, 2007). It was concluded that one test of executive function alone would not allow a clinician to conclusively establish that an individual either lacked or had the capacity to make decisions, due to the one-shot nature of current tests. Instead it was found that it would be beneficial for a test to exist that is available in parallel forms in order to allow test and retest to take place in a short place of time, to be used in conjunction with information from a clinical interview and the clinicians clinical judgement.

Research Report

The aims of this study were to develop a test of decision making that was sensitive to assessing for an acquired brain injury. The Escape Task was based on the executive function principle of 'task setting and rule governed behaviour', which monitored both spontaneous (uncued version of the task) and inductive (cued version of the task) reasoning in order for the task to be completed. The execution of the Escape Task was studied in 38 participants – 19 with an acquired brain injury, and 19 neurologically healthy controls. In the uncued version of the Escape Test, performance did not differentiate between those with a brain injury and neurologically healthy control participants. However, the cued version of the task did discriminate well between those with a brain injury and neurologically healthy controls. Task performance was found to not be particularly well associated with performance on an established measure of executive function (BADS), but was found to be relatively independent of general intellectual functioning and memory (i.e. these did not influence task performance). Preliminary findings have identified two error-making styles that could be associated with brain injury (Impulsivity Index, and Total Error Index). The overall results demonstrated the clinical utility of the test when assessing for whether an individual belongs to a healthy or brain injured group, and whether spontaneous or inductive reasoning was superior.

Critical Appraisal

Includes reflections on the research process including: the development of the test, conducting the study, future research and implications.

DEDICATION

For my father – I dedicate this thesis to you.

Thank you for letting me follow my dreams.

I am the person I am today because of you.

I hope I have made you proud.

I miss you.

ACKNOWLEDGEMENTS

I would primarily like to thank Professor Nick Alderman and Chris Jones for all your support, enthusiasm, and constructive supervision throughout the research. Your humour, and ability to make me laugh, even throughout times of doom and gloom, was priceless. To my academic supervisor Chris Jones, I am grateful for the guidance and advice you gave me, and for allowing me to pester you, even on Sundays!

I am also grateful to the participants of the study for their time and interest in the research, and without whom this work could not have taken place. I am also grateful to all of the Assistant Psychologists at the Kemsley Division (St Andrews Healthcare, Northampton), and especially Miguel, Natalie and Dawn who all worked tirelessly to provide me with background information, and whose regular applications of lunches and gossip reminded me that there was life outside of my thesis. To my fellow trainees, thank you for all of your support.

To my husband Michael, thank you for putting up with me, even in my grumpiest hours! Your constant support and faith in my abilities kept my going. To my sisters Sunita and Jeevan, and brother-in-law David, thank you for making things simple, and being there for me. To my parents – thank you for everything and for having faith in and supporting me. To Mum, thank you for the emotional support. To Dad, you were the best.

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ABSTRACT

Executive function is an ‘umbrella’ term for higher levels of cognitive functioning such as decision making, planning, monitoring, inhibition, and working memory, but to name a few. This literature review examines theories of executive functioning and the associated assessment instruments. The review of theories allowed for a heuristic aggregate of discrete processes to be established, acting as a thesaurus for the term executive function. In addition, the review examined how current measures of executive function might be able to help with the assessment of an individuals level of capacity to make decisions; based on the principle of understanding the information relevant to the decision, retaining the information, using/weighing the information as part of the decision making process, and communicating the decision (Department of Health, 2007). It was concluded that one test of executive function alone would not allow a clinician to conclusively establish that an individual either lacked or had the capacity to make decisions, due to the one-shot nature of current tests. Instead it was found that it would be beneficial for a test to exist that is available in parallel forms in order to allow test and retest to take place in a short place of time, to be used in conjunction with information from a clinical interview and the clinicians clinical judgement.

FRACTIONATION OF EXECUTIVE FUNCTIONING AND ITS RELEVANCE TO THE ASSESSMENT OF CAPACITY

In order to obtain relevant articles for the literature review, a literature search was conducted, of which details can be found in Appendix 1.

INTRODUCTION

The frontal lobe constitutes the largest section of the human brain; it represents over 20% of the neocortex (Stuss & Benson, 1986). Due to the significant amount of brain area the frontal lobes occupy, the incidence of damage to this area of the brain is increased (Miller, 2006). Damage to the frontal lobes can significantly inhibit an individual's ability to carry out everyday activities, even when psychometric and/or brain imaging evidences minimal or no abnormality (Cripe, 1996).

After frontal lobe damage, frequently, individuals may experience changes in their personality, behaviour and social capabilities; along with this, memory, attention, concentration, and thinking – but to name a few – may also be affected (National Institute of Neurological Disorders and Stroke, 2008). These concepts can all be related to impairments within "executive functioning", and can affect one's ability to maintain employment (Felmingham, Baguley, & Crooks, 2001), relationships (personal and professional, and both distant and close) (Wood, Liossi, & Wood, 2005), independence, and can hinder rehabilitation (Lequerica, Rapport, Loeher, Axelrod, Vangel, & Hanks, 2007).

It is evident that executive functioning plays an important part in human cognition, however difficult the concept may be to define. In the following sections, the definition and fractionation of executive functioning will be explored, as will the adequacy of currently available tests of executive functioning with particular attention to the assessment of capacity as described in the Mental Capacity Act (2007).

DEFINING EXECUTIVE FUNCTION

Within both psychological and medical literature, many definitions of executive function have been provided, with an overlap being noticeable in certain definitions. There seems to be a general consensus that executive function relates to “higher level” cognitive processes that allow an individual to organise thoughts, plan tasks, manage time, solve problems, and to make decisions (Lezak, 1995).

At the functional level, behavioural signs of executive dysfunction may be obvious in that an individual does not tend to their hygiene, cannot manage their finances, or cannot do things that they used to (such as making a cup of tea). At other times, problems are less noticeable and can be based on an inability to make decisions or problem-solve, and can hence lead to the issue that the individual is malingering.

Three types of theory relating to executive function have been put forward (Burgess and Simons, 2005). These theories are all considered to provide frameworks for attempting to understand executive function.

Single System Theories

Norman and Shallice (1986) introduced the concept of a “supervisory attentional system” (SAS) taking on a role similar to that described as being executive function. The theory depicted schema as being selected in an automatic way after being triggered by external stimuli, hence resulting in routines of behaviour. Graffman (Structured Event Complex Theory, 1995, 2002) added to the literature and further described a hierarchy of schema (or managerial knowledge units) stored in the prefrontal cortex. The hierarchy is thought to consist of the most general (abstract) items at the top, with the more specific sub-units beneath them. The structured event complex (SEC) in itself is the knowledge representation of all the actions and sequences of events that allow a goal to be completed.

An example of the theory in practice might relate to something as simple as making a cup of tea. The managerial knowledge unit for this will initially be the intention (i.e. “to make a cup of tea”), and then the sequence of actions may be considered (i.e. place tea in pot, boil water, pour water into pot, pour tea into cup, finally add milk). The sequence of actions could also be sequenced further in a lower level of the hierarchy (e.g. lift tea pot, place spout above tea cup, etc).

Although Grafmans theory (1995, 2002) can be easily understood due to its simplicity, scientifically, it is evident that the frontal lobes could not provide a store for the entire hierarchical representation that is implied by the concept of managerial knowledge units (as this would render redundant a large proportion of the posterior cortex). Therefore it is wise to assume that the frontal cortex stores the higher aspects of the hierarchy, and when activated, illicit further action sequences of related schema representations in the posterior cortex. In turn, this separation of the abstract sequential aspects of event complexes from concrete knowledge schemas allows for a processing distinction between dysexecutive sequencing error, dyspraxia, and semantic dementia.

Construct-Led Theories

The Working Memory Model proposed by Baddeley (1986) and Baddeley & Hitch (1974), created the concepts of the central executive, and two slave systems - the phonological loop and visuo-spatial sketchpad. The central executive is seen as the key component, closely resembling attention; having a limited capacity in order to deal with cognitively demanding tasks. The slave systems, the phonological loop and visuo-spatial sketchpad, are responsible for the storage of audio and visual information respectively – both having limited capacity. It was proposed that the central executive divided attentional resources, and the more complex the task, the greater the demand on the central executive to allocate resources quickly in order to cope with multiple pieces of information.

The model also provides the assumption that if two tasks use the same component (i.e. either the phonological loop or the visuo-spatial sketchpad), they will not be successfully performed, or, if two tasks use different components they should be performed well both together, and alone. Numerous dual task studies have provided supporting evidence for this model (see McDowell, Whyte, & D’Esposito, 1997; Leclercq, Couillet, Azouvi, Marlier, Martin, Strypstein, & Rousseaux, 2000). Therefore, it could be concluded that any form of brain injury leading to damage to the central executive would lead to the individual being unable to co-ordinate multiple tasks, which in itself is a ‘symptom’ of dysexecutive syndrome.

Although the Working Memory Model (Baddeley, 1986) seems plausible, Norman and Shallice (1986) introduced the concept of a “supervisory attentional system” (SAS) that takes on a role similar to that described as being executive function. Norman and Shallice (1986) proposed that humans have two levels of control over situations: (i) where routines and habits enable actions to be run off automatically via existing schema (termed “contention scheduling”, and (ii) where novel tasks require resources to be distributed via the supervisory attentional system (hence deliberate and willed control is required). This model allows for the interruption of existing schema to take place, in order for actions to be modified and more controlled to adapt to a novel or complex task.

Evidence exists for the support of automatic actions in terms of action slip studies whereby mistakes can still be made, even if an action is being carried out by existing schema and automatically (Reason & Mysielska, 1982). In terms of executive function, Norman and Shallice (1986) argue that problems seen in individuals with executive function impairments actually arise from impairments within the SAS. With the SAS impaired, any actions are based solely on contention scheduling even when the individual is presented with a novel task (Bargh & Chartrand, 1999; Bargh & Ferguson, 2000). In turn, this can lead to perseveration, impulsivity and distractibility, but to name a few traits, which are consistent with characteristics displayed by individuals with both executive function difficulties and frontal lobe lesions – again making the theory plausible.

An interesting aspect of construct-led theories is they make the most significant connection between function and neuroanatomy. Links are consistently made between the working memory, dorsolateral pre-frontal cortex and dopaminergic systems (See Diamond, 1998). In turn, if systems such as the dopaminergegic are considered to be linked, this would lead to the assumption that drug related therapy would be suitable as part of a rehabilitation package for an individual with a brain injury (e.g. Kolb, 2002).

A review of single account theories (Burgess & Robertson, 2002) provided potential issues that may arise. Findings from studies suggest that when patients with frontal lobe injuries carry out the same executive tasks, they all show different errors (Stuss et al, 2000). More recently, functional imaging studies relating to the frontal lobe have indicated the executive system is fractionated (see Picton, McIntosh & Alain, 2002; D'Esposito & Postle, 2002).

Burgess and Robertson's (2002) review suggest that although executive processes may be used in day-to-day and novel situations, both single process and construct led theories cannot provide a complete account of explaining the whole of the frontal system. Due to this, more complex models have been considered that allow for the fractionation of the executive system to be considered.

Multiple Process Theories

Multiple process theories of executive function differ from single process and construct led theories in there is an emphasis upon multiple, functionally and anatomically distinct, processing modules. According to this definition "executive function" is an umbrella term for a series of functionally discrete processes, independent of sensory experience which guide, co-ordinate and direct the processing of sensory experience in a goal directed manner. This definition echoes the popular distinction between the processes of the posterior cerebral cortex (which is often depicted in terms of the processing of sensory experience) and the anterior cerebral cortex (which is often depicted in terms for processing of goal directed behaviour).

For example, Stuss, Shallice, Alexander, and Picton (1995) attempted to explain the fractionation of the executive system by concentrating on the concept of attention. It was proposed that executive function fractionated into seven individual attention functions, with each possessing a distinct neuronal correlate –

- *Sustaining attention* being served by the right frontal cortex;
- *Concentration* by the cingulated;
- *Sharing* by the cingulated and orbito-frontal cortex;
- *Suppression* being served by the dorso-lateral prefrontal cortex (DLPFC);
- *Switching* by the DLPFC and medial frontal cortex;
- *Preparation* by the DLPFC; and
- *Setting* by the left DLPFC.

The multiple process theories have certain conceptual advantages over single process and construct led accounts of executive functioning. Firstly, given its emphasis on discrete executive processes, with relatively unique anatomical correlates, the multiple process theories are better suited to account for the patent of dissociations observed in tests of executive functioning following a traumatic or acquired brain injury (Fournier-Vicente, Larigauderie, & Gaonac'h, 2008). Secondly, the multiple process theories allow for specific and dissociable prediction of functional impairment consequent upon specific neuronal damage. Finally, multiple process theories provide a broader and more nuanced description of the variety and interactive complexity of the component processes that comprise the term “executive function”. However, multiple process theories leave us with one, very distinct, difficulty; that is, to provide a description of the fractionation of executive functions into a subset of discreet processing modules.

FRACTIONATION OF EXECUTIVE FUNCTION

Several accounts of the fractionation of executive function exist in the empirical and conceptual literature. Generally, such accounts have focused upon a broad functional description of executive functioning. Earlier accounts have provided executive functioning concepts such as the central executive, phonological loop, and visual spatial sketchpad (Baddeley& Hitch, 1974), volition, planning, purposeful actions and effective performance (Lezak, 1983), and the Supervisory Attentional System (Norman and Shallice, 1986).

More recent accounts of functional descriptions of executive functioning, have included the ability to manipulate information, cognitive flexibility, cue-directed behaviour (Lafleche & Albert, 1995), task analysis, strategy control/monitoring (Borkowsky & Burke, 1996), inhibition, problem solving, planning, impulse control, creativity (Delis et al., 2001), initiation, perseveration, alteration of behaviour (Hobson & Leeds, 2001), sequencing complex actions (Elliot, 2003), and finally the ability to analyse the success of strategies employed (Banich, 2004).

However, it should be noted that the above descriptions of executive function are couched at the functional level and, accordingly, do not provide a description of neurocognitive processes that underlie such functions.

Stuss and Benson (1986) proposed a subdivision of executive functioning in terms of anterior/posterior systems. A hierarchy of brain function was formulated, with the frontal areas being associated with the highest level of functions (see Figure 1).

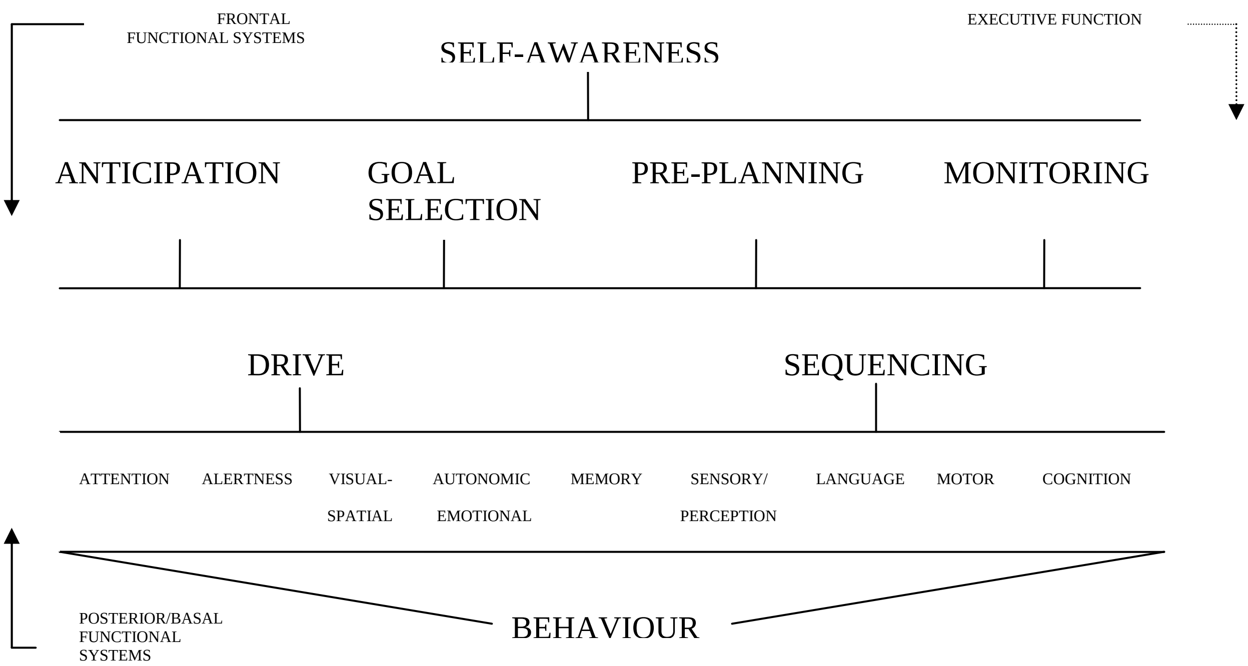

Figure 1: Hierarchy of brain functions (adapted from Stuss & Benson, 1986)

As can be seen from Figure 1, executive function is situated at the top of the hierarchy, allowing for anticipation, goal articulation, planning in novel situations, and monitoring of ongoing behaviour.

Within the domain of attentional control Stuss and Alexander (2007) reviewed anterior lesion studies and suggested three principle attentional control processes; *energisation* associated with the superior medial prefrontal cortex, *task setting* associated with the left dorsolateral prefrontal and *monitoring* associated with the right lateral prefrontal cortex. Stuss and Alexander (2007) defined *energisation* as an individual's ability to initiate and sustain a response. It was proposed if external triggers or appropriate motivational conditions are not available, the ability to initiate or sustain a response may be inhibited. In turn, upon external triggers being present, or the individual becoming motivated, schemata would need to be (re)energised, in order for initiation and then a sustained response to occur. Research indicates energisation can be affected after bilateral superior medial frontal lesions.

Task setting involves the ability to formulate a stimulus-response relationship, based on the principles of trial and error in order to learn and consolidate information – learning to drive a car would involve task setting in the initial stages. This stimulus-response relationship could account for when automatic processes are carried out so smoothly, as the response is so well learnt, that when the correct stimulus is presented, the correct response is carried out. It has been indicated that left frontal damage of the brain can cause disruption to the process of task setting, indicating the frontal region is involved within this process. *Monitoring* was defined (Stuss & Alexander, 2007) as the ability and process of checking how a task is advancing, in order to establish ‘quality control’, and whether behaviour needs to be adjusted. Lesions within the RL prefrontal cortex were thought to lead to an impairment in the ability to monitor successfully. Although functionally the theory is able to describe the functional aspects of the fractionation of executive function, it still fails to consider the impact of emotion and executive abilities.

Based on phylogenic considerations, Ardila (2008) considered two closely related (although still different) sets of executive function abilities that are served by the prefrontal lobe. The first set of functions, the "metacognitive executive functions", relate to problem solving, planning, concept formation, strategy development and implementation, controlling attention, and working memory. The second set of functions, the "emotional/motivational executive functions", relate to the coordinating of cognition and emotion/motivation (that is, the attainment of needs derived from biological evolution or current goal state). The "metacognitive executive functions" is dependant upon the dorsolateral prefrontal areas, whereas the "emotional/motivational executive functions” are associated with orbitofrontal and medial frontal areas.

Within Psychology, the metacognitive executive functions are assessed particularly well due to the fact that traditional tests of executive functioning tap into these particular abilities. However, emotional/motivational executive functions, which are required for solving everyday problems, as of yet remain un-testable. An ideal psychometric test assessing for emotional/motivational executive functions would require the respondent to follow acceptable strategies and to inhibit ‘selfish’ impulses. In turn, this could potentially lead to the individual arriving at a solution that initially may not seem ideal due to the fact that selfish behaviour has been inhibited.

Although Ardila (2008) adds a new concept to the literature of executive functioning, it may also seem quite reductionist in that executive function is deemed as being derived of two main components. Also, the term "emotional/motivational executive functions" is explained, however little information exists on how one would test the concept in order to establish a disability in the area. Potentially it may be useful to first consider what existing tests of executive functioning assess for, and to then define the broad over-arching executive abilities, or to simply consider executive functioning in terms of one of its sub-components, such as problem solving.

From a latent variable analysis of a large number of executive tasks Fournier-Vicente, Larigauderie and Gaonac'h (2008) identified a six factor model that accounted for intercorrelations between the executive tests. This six factor model included (1) verbal storage-and-processing coordination, (2) visuospatial storage-and-processing coordination, (3) dual-task coordination, (4) strategic retrieval, (5) selective attention and (6) shifting. The relationship between these factors and the tests of executive functioning is summarised in Figure 2.

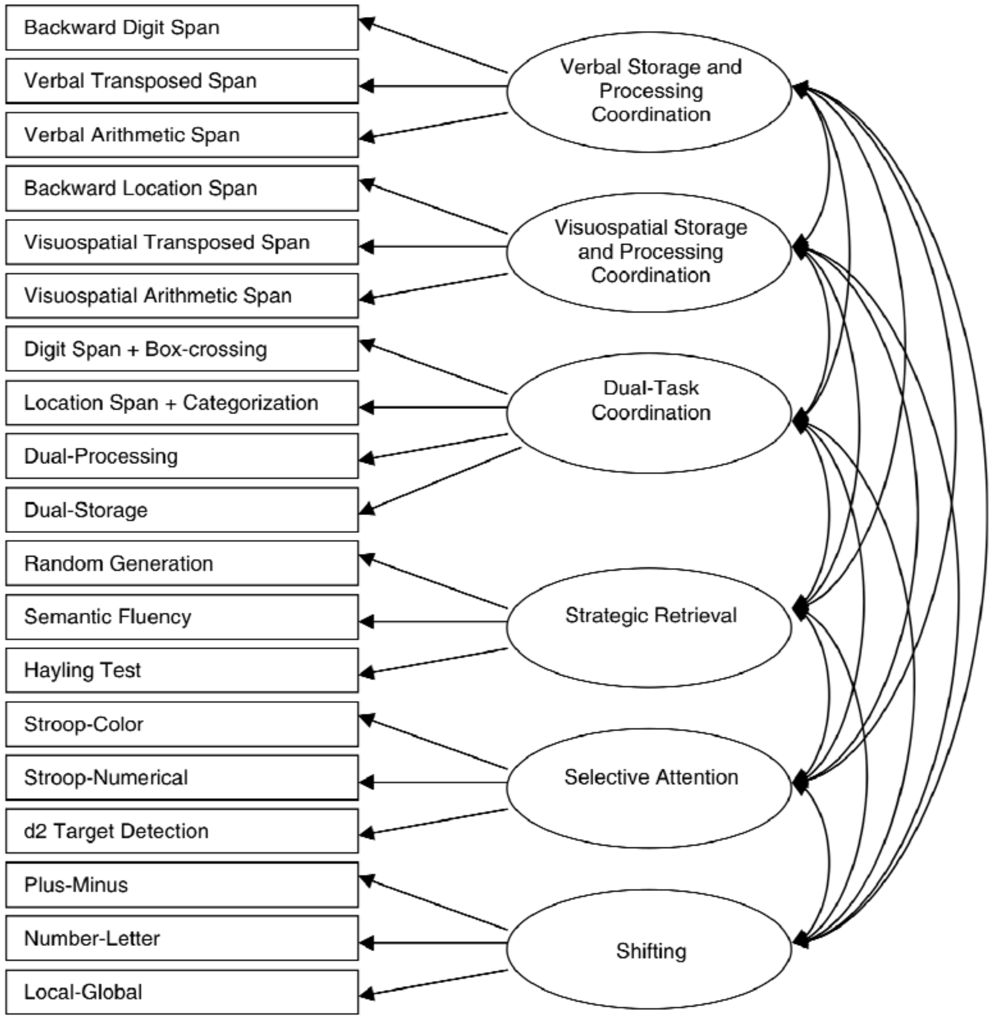

Figure 2: The relationship between the six factors and the tests of executive functioning.

Alternatively, Shallice and Burgess (1996) proposed a model of executive functioning, which emphasized the role of the executive systems in problem solving. The Shallice and Burgess model (1996) proposes three main stages in problem solving. The first stage involves the construction of a temporary new schema on the basis of induction, recall of previous solutions or a spontaneous (novel) solution. These processes are sensitively dependent upon the persons abilities to set goals and strategies (either from retrieval from episodic memory, inductive reasoning or novel schema generation). The second stage involves implementing the selected strategy over time and is therefore dependent upon working memory. The third stage involves the assessment of the success of the strategy. This stage involves the monitoring of environmental feedback in terms of goal relevance. Accordingly, the Shallice and Burgess (1996) model implies specific roles for working memory and attentional control systems (i.e., supervising the engaging, monitoring and disengaging of attentional resources). Figure 3 depicts this model.

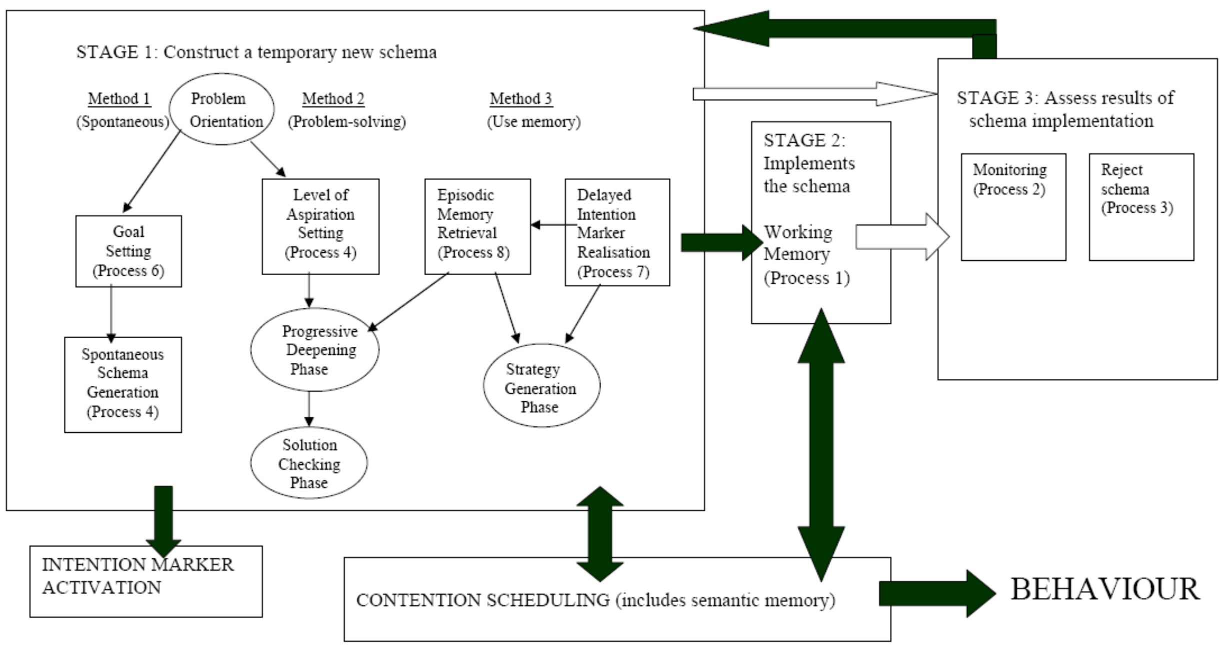

Figure 3: Shallice and Burgess (1996) model of executive functioning, emphasizing the role of the executive systems in problem solving.

It is therefore evident that the term “executive function” refers to a variety of functionally discrete processes. Although there are differences in terminology, there remains considerable commonality in the various conceptual articulations of executive functioning. However no one theory has, as yet, encapsulated the full range of functioning depicted in the literature. Figure 4 provides a heuristic aggregate of the discrete processes that have been included in the descriptions of executive functioning.

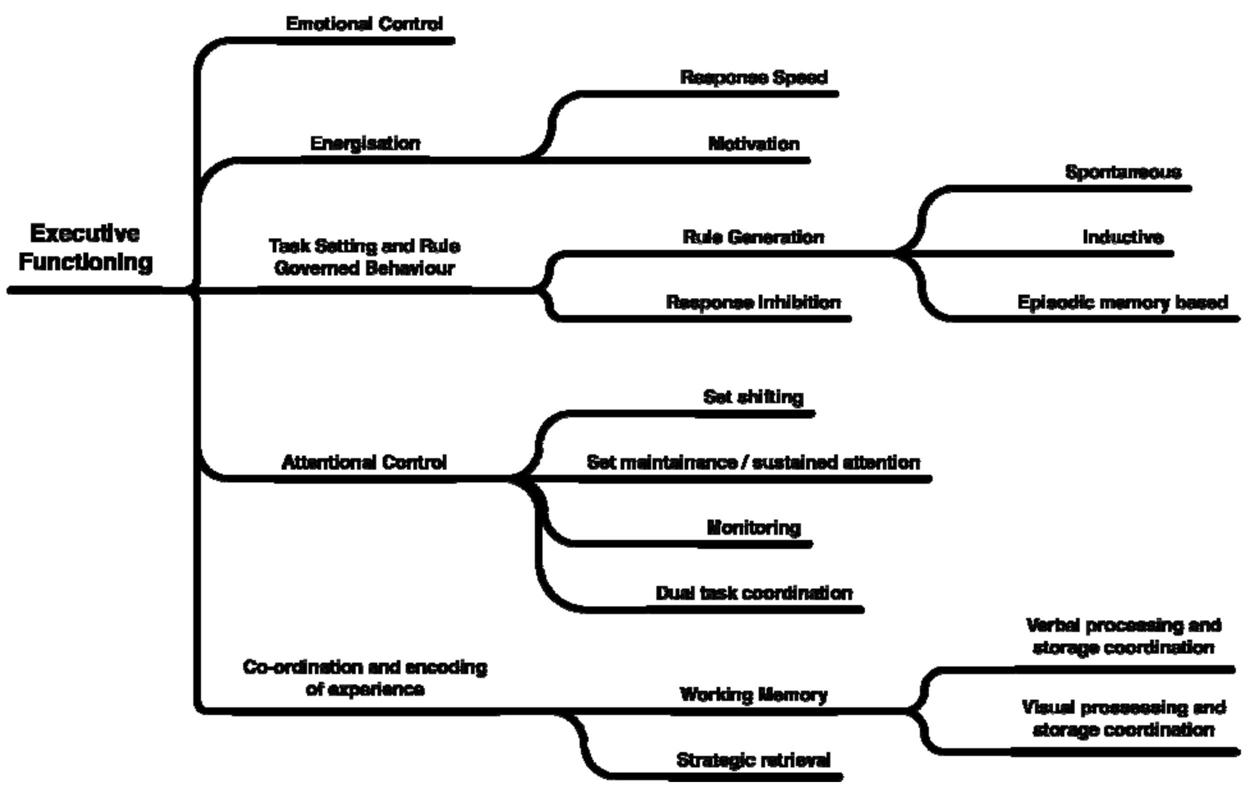

Figure 4: Heuristic aggregate of the discrete processes that have been included in the descriptions of executive functioning.

In order to define psychometric tests that consider each area, it is first important to define each concept. The Heuristic Aggregate shown above considers concepts from many other models. Emotional Control is based on Ardila's (2008) concept of "emotional/motivation executive function", and ones ability for response inhibition (i.e. control). Energistaion can be attributed to Stuss and Alexanders (2007) concept, in which it depicts ones ability to initiate and sustain a response by using either appropriate external triggers or via motivation. Again, for Task Setting and Rule Governed Behaviour, Stuss and Alexanders (2007) concepts are particularly useful; forming stimulus-response relationships in order to generate rules whilst inhibiting spontaneous responses. Attentional Control, in this case refers to ability to switch between several tasks and appropriately carry out the task without confusion, the ability to maintain focused attention on a particular task, the ability to monitor progress in order to maintain or change behaviour, and finally the ability to carry out two tasks simultaneously (Norman and Shallice, 1986). Finally, the Co-ordination and Encoding of Experience is based on Baddeley and Hitch's (1974) Working Memory Model, whereby, verbal and visual information are processed, stored and retrieved independently.

The heuristic aggregate of discrete processes, depicted in Figure 4, was not only derived from concepts relayed within the theories mentioned above. In order to take into account processes such as decision making, planning, problem solving, attention, organising thoughts, managing time, and the numerous other functions depicted within the literature, it was seen whether these would fit into the five main arms within the aggregate. For example, it was suspected that decision-making, planning, and problem solving could fall within the arm of 'Task Setting and Rule Governed Behaviour'. The various attention types (focused, selective, etc.) were thought to fit within the 'Attentional Control' arm of the aggregate, organising thoughts could fall within the 'Co-ordination and Encoding of Experience'.

Traditionally, models of memory function have incorporated "executive" processes acting upon the encoding and retrieval of memory traces. For example, the encoding of context information is dependent upon the interpretation and expectations of the to-be-remembered stimuli and the retrieval of such information is effected not only by the congruency between the retrieval environment and the encoded context information but also by the ability of the individual to self-generate retrieval cues. These "executive" aspects of memory are therefore concerned with the super-ordinate aspects of the to-be-remembered stimuli (see Graffman's notion of Structured Event Complexes, 2002), the control and maintenance of attentional resources and the ability to self-generate retrieval cues. Accordingly, this thesis is concerned with executive functions that may also impact upon memory function but are conceptually separate to memory.

Taking into account the heuristic aggregate of discrete processes, it is clear that memory has its own 'arm', and is discreet from the other four arms within the description. As it stands, the cannon of tests assessing for memory issues is adequately armed. The strand of the heuristic aggregate of discreet processes, where there seems to be scope for new tests to be developed, is that of 'Task Setting and Rule Governed Behaviour', and in particular, Rule Generation in order to complete a task spontaneously and inductively. Within the empirical paper, it is clear that the Escape Task falls within this remit, and clearly does not fall into the arm dealing with memory. A good test should measure what it sets out to measure, without being impacted by other cognitive variables, hence the relationship to general intellectual functioning and memory were examined to ensure the Escape Task was not dependent on these being intact for successful completion to take place.

THE ASSESSMENT OF EXECUTIVE FUNCTIONING

Given the fractionated nature of executive functioning it is evident that one, single test would be insufficient to capture the diversity of processing deficits associated with anterior lesions. Many different tests of executive functioning exist, of which most tap into several cognitive abilities under the realm of executive functioning. It is important that the most appropriate executive functioning measure is chosen in order to gain an accurate account of difficulties that may be present. Equally, if less appropriate tests are chosen, and subsequently further testing is required, the respondent may become fatigued. Figure 5, depicts the heuristic aggregate of discrete executive processes with the current tests of executive function available for assessment.

Executive Function

- Emotional Control
  - Behaviour Rating Inventory of Executive Function (BRIEF), Frontal Systems Behaviour Scale (FrSBe), DEX questionnaire (BADS)
- Energisation
  - Response Speed: Controlled Oral Word Association Test, Hayling Sentence Completion Test
  - Motivation: Test of Memory and Malingering
- Task Setting and Rule Governed Behaviour
  - Rule Generation: Brixton Spatial Awareness Test, WCST, Modified Card Sorting Test, Delis-Kaplan Executive Function System (D-KEFS),
  - Response Inhibition: Controlled Oral Word Association Test, Stroop Test, Hayling Sentence Completion Test , Trail Making Test, WCST, Modified Card Sorting Test, BADS, BRIEF, D-KEFS, FrSBe
- Attentional Control
  - Set Shifting: Trail Making Test, WCST, Modified Card Sorting Test, BADS, BRIEF, Cambridge Neuropsychological Test Automated Battery (CANTAB), D-KEFS
  - Sustained Attention: WCST, Modified Card Sorting Test, CANTAB
  - Monitoring: Tower of London/Hanoi, D-KEFS
  - Dual-Task: Digit Span + Box crossing, Dual-processing, Location Span + Categorisation
- Co-ordination and Encoding of Experience
  - Working Memory: Backward Digit Span, Verbal Transposed Span, Verbal Arithmetic Span, Backward Location Span, Visuospatial Transposed Span, Visuospatial Arithmetic Span
  - Strategic Retrieval: Random Generation, Semantic Fluency, Hayling Test

Emotional Control

Standardised measures of emotional control have tended to be self or other ratings of behaviour. For example, the Behaviour Rating Inventory of Executive Function (BRIEF) consists of eight sub-scales of which each is reflective of an aspect of executive function. It is a self-rated questionnaire that assesses for inhibition, shifting, emotional control, the ability to initiate, working memory, planning/organizing, organization of materials, and the ability to monitor. Of particular importance is emotional control as few psychometric tests assess for this. That particular subscale analyses the individual's ability to modulate their emotional responses (whereby an overblown emotional reaction to a seemingly minor event would indicate a deficit).

A further self questionnaire examining various elements of behaviour and emotional control is the Dysexecutive Questionnaire (DEX, from the BADS). This consists of 20 questions examining personality or emotional changes, and motivational, behavioural and cognitive changes. The questionnaire exists in two versions – one for the individual (DEX-Self), and one for a relative/caregiver (DEX-Other), which can then be compared for results of any deficits.

Psychometric measures examining for emotional control are sparse, and at present there is room for new tests to be developed. Those that exist are based on self ratings, which as is known can be problematic – especially within a population with a brain injury, whereby individuals believe they do not have any problems and are still 'normal'.

Energisation

Standard measures of energisation have mostly related to psychometric tests involving the individual to initiate and sustain a response, and inadvertently an individuals response speed, and motivation to carry out the testing at hand. Motivation potentially can be seen as being the willingness to complete a task, and can depend upon what the outcome may be. For example, in the case of an individual pursuing compensation for a head injury claim, it could be understood that the greater the deficit, the more compensation will be given. In this case, the individual might not be motivated to complete the test to their best ability. In this instance, tests of effort, such as the Test of Memory and Malingering could be useful in assessing effort, and hence, also motivation.

In terms of response speed, psychometric tests such as the Hayling Sentence Completion Test, examine not only whether a response to a question is correct or not, but also how long in seconds it took to complete the sentence. In order for this to occur, the individual first needs to understand the content of the sentence, what is being implied, and then use previous knowledge to complete the sentence. Word generation tasks are also able to assess for response speed due to the fact that most of these tests provide a time limit within which the individual must name as many task related items as they can. However, it needs to be noted that response speed can also apply to non verbal tasks such as the block design from the WAIS-III whereby individuals have a time limit within which to copy a design with blocks.

Task Setting and Rule Governed Behaviour

This particular area of assessment consists of those psychometric tests assessing for the ability for rule generation and response inhibition. Both require advanced cognitive processes relating to executive function. In terms of rule generation, psychometric tests such as the Brixton Spatial Awareness Test (whereby one has to work out the rule as to where the circle will move to next in a series of circles), and the WCST (whereby one has to deduce which rule cards are being sorted by – shape, colour, number – by attending to feedback) adequately measure for an individuals ability to deduce a rule. However, not many psychometric tests assessing for rule generation exist, and there is currently room for further tests to be developed.

In terms of response inhibition, tests of this nature require that the individual is able to control there responses so as to not simply say the first thing that is thought of. Psychometric tests such as the Stroop Test (whereby the colour a colour word is written in must be identified), the Hayling Sentence Completion Test (the second part whereby a sentence has to be completed with a totally unrelated word), and the WCST (whereby individuals need to respond to feedback as opposed to persevering with their response), amongst other tests are able to adequately assess for response inhibition. However, due to the novel nature of such tasks, repeat testing may pose an issue as the individual may learn how the task must be tackled, hence improving upon not only answers, but also the time in which answers are made available. Therefore, once again, within the cannon of psychometric tests there is a need for new tests of task setting and rule governed behaviour.

Attentional Control

Standardised measures of attentional control are well documented within the cannon of psychometric tests. Such tests monitor for the ability to shift sets, to sustain attention, to monitor progress, and to dual-task. For example, within set-shifting, the Trail Making Test, the WCST and BRIEF all contain sub-components that assess for an individuals ability to shift between different patterns of thought. Sustained attention has also been well documented and researched. Sub-components within tests such as the Cambridge Neuropsychological Test Automated Battery (CANTAB) also allow for sustained attention to be assessed for.

The ability to monitor the progress and outcome of a task can be assessed for via psychometric tests such as the Tower of Hanoi / London which can either be stand alone tests, or as part of a greater battery, such as within the D-Kefs. Once again, tests such as these are novel, which precludes them for being used on the same individual several times. Hence, there is a need for tests to be developed that exist in many forms, although the task itself is semantically the same.

The concept behind dual-task tests is the individual must perform two tasks simultaneously, and errors are monitored to assess for the effectives and ability of the individual. Traditional dual-task tests include digit-span being carried out whilst the individual is crossing boxes, and location span whilst categorisation tests are taking place. Tests such as these are utilised, however, only when it needs to be decided if an individual is easily distracted by other cues.

Co-ordination and Encoding of Experience

Standardised measures assessing for co-ordination and encoding of experience are also well documented with the remit of psychometric tests. In this case the concept can be split into assessment of the working memory and strategic retrieval of information. For example, when assessing for working memory, tests such as backward digit span (the amount of numbers that can be repeated correctly backwards), backward location span, verbal arithmetic span, and similar tests are all adequate when assessing for the capacity of working memory. There is indeed no shortage of appropriate tests.

The strategic retrieval of information is also well tested for within this area. Tests such as the Haying Sentence Completion Test and Semantic Fluency all require the retrieval of information from memory. However, sub-tests such as Comprehension and Similarities from the WAIS-III also require for past knowledge about things to be retrieved in order to be able to answer the questions. Again, there seems to be a significant number of tests – too numerous too mention them all here – for the retrieval of information, and all seem to be adequate.

As can be seen, many psychometric tests exist for the assessment of the various aspects of cognitive function. When assessing for executive functioning difficulties, it is important to first be aware of what exactly needs to be assessed, and how the outcome might affect the individual with a brain injury. With the introduction of the Mental Capacity Act (2007), assessment of decision-making ability is now an important area of assessment for the neuropsychologist. The next section of this review examines assessment of capacity in greater detail, and assesses the adequacy of existing executive functioning tests to provide information about capacity assessments.

AN OVERVIEW OF THE CAPACITY ACT

The Mental Capacity Act (2007) came into force within England and Wales in 2007, with a premise of helping individuals over the age of 16 to make their own decisions. In terms of making decisions, the Act sets out rules on an individual's ability to make decisions with regards to their finances, health, and other pertinent matters. The following five principles are applicable when decisions need to be made:

a) To assume everyone can make their own decisions, unless proven otherwise

b) To give the person who needs to make the decision all the support that can be given in order to help the person come to a decision

c) A decision should not be stopped from being made because someone else thinks it is incorrect

d) If an individual does not have the capacity to make their own decisions, the individual who does must make a decision in the persons best interest

e) When a decision is made for another person, the freedom and rights of that person should not be too limited.

This Act is applicable to those people who both can and cannot make their own decisions. In terms of those people who cannot make their own decisions, this covers groups of people such as those with a learning difficulty, individuals with mental health problems, and those with physical and mental health problems such as individuals with a brain injury.

Functional Test of Capacity

In order to be able to decide whether or not an individual has the mental capacity to make a decision, the first thing to be established must be whether the individual has an impairment or disturbance (either temporary or permanent) in the functioning of the mind/brain. If an impairment/disturbance is present, the second question that must be answered is whether it makes the person unable to make the decision. The individual can only be deemed as being unable to make the decision if, after all the help and support has been provided, (s)he cannot:

- Understand the information relevant to that decision
- Retain the information
- Use/weigh the information as a part of the process of making the decision
- Communicate their decision (either by talking, sign language, pointing, or any other means).

Communication should not be the sole reason for deciding that an individual does not have capacity to make a decision – to lack capacity on this ground alone would be uncommon as even a blink of the eye, or a squeeze of the hand could convey an individual's decision (see McMillan, 1997).

The Relationship between Capacity and Executive Functioning

Salmond, Menon, Chatfield, Pickard, and Sahakian (2005) examined how an individual’s ability to make/not make decisions is compromised following an acquired brain injury. After receiving a brain injury, increased impulsivity, and a lack of insight and judgement may ensue, and affect an individual’s ability to form and maintain appropriate decisions. A computerised betting task was utilised, whereby participants with a brain injury and impulsivity issues made greater incorrect / poorer quality decisions then controls – hence indicating impulsivity in particular can affect the ability to make a decision.

It has also been discovered that within a population with an acquired brain injury (with dysexecutive syndrome), not only are decisions made inconsistently to the same tasks / questions, but also that the quality of the decision is poor and would not necessarily benefit the individual in the long-term (Schlund, Pace & McGready, 2001; Schlund, 2002).

Memory and emotion are also thought to play a role in decision making – again impairment to these can lead to poor decisions being made (Bateman & Evans, 2005). An individual’s memory can help with the decision making process by allowing the individual to think of similar events where a decision was required, right through to allowing the individual to remember that information which is important when making the decision. Impairment to memory can lead to inappropriate choices being made, even after a lengthy time of consideration (Malojcic, Mubrin, Coric, Susnic, & Spilich, 2008). If an individual with a brain injuries ability to attend to information is impaired due to attentional issues, the individual may not take on all of the information being offered, which could also impact on the decision making process. In terms of emotion (i.e. how will the outcome of my decision make me feel?), if an individual is unable to monitor their own emotions, again, this could lead to impairments in the decisions being made – after all, some decisions in life are made on ‘gut instinct’ which in turn is affected by emotions (Bechara, 2004).

In essence, the Mental Capacity Act is based on the concept of decision-making, which is fundamentally one of the concepts under the umbrella term of executive function. Therefore, in line with current developments and research, it could be said that an issue with executive function, could lead to an inability to make appropriate decisions, regardless of how the information is presented. In order to understand the elements of capacity, it is important to first consider each element and how it relates to models of executive functioning, and second both functional and formal psychometric tests that could be used to assess each element.

ASSESSING CAPACITY

Understanding Information Relevant to the Decision

Understanding information also translates to understanding the likely consequences of making, or not making the decision. When providing information pertinent to making a decision, the information should be presented in such a way that the individual understands. For example, an individual with a brain injury may not be able to understand verbal information, but could clearly understand pictures that provide the same information.

In order understand information coming in to the senses, an individual first has to be able to recognise what the information is by using information already stored within the brain. For example, if the following description was given, ‘I have four legs, a tail that wags, ears and a long nose, and my favourite hobby is chasing sticks’, one would guess that the item is a dog from all of the previous knowledge of the subject. Therefore, some of the processes involved are first understanding and remembering the information, second using the information by manipulating it so that pros and cons of each action can be decided, and third, being able to show logic in the thinking process.

Wittrock (1989) also examined processes involved in comprehension. It was found that generation of the information, motivation to understand the information, the ability to attend to the information, and the ability to remember the information were core cognitive processes involved in fully understanding information.

The working memory (Baddeley, 1974) also plays a role in understanding information as the individual must keep the intention of attending to the information in their working memory, whilst also attending to, and doing other things, such as keeping note of the time, and not being distracted by other things (Insel, Morrow, Brewer, & Figueredo, 2006). In line with this, understanding information and what it means for the individual would also require encoding and storage of the information about content, and relevance to that person. Psychometric measures here should take into account an individuals ability to understand information (regardless of how it is presented), and also to be able to understand the likely consequences of making, or not making a decision.

Formal assessment of understanding of information should first assess whether there are any sensory deficits that impede the reception of the information (for example, impairments of auditory/visual acuity or of the visual field (e.g., Bells Cancellation Test (Gauthier, DeHaut, & Joanette, 1989)). If such deficits are identified information should be either provided via another modality or structured in such a way as to minimise the impact of the sensory disability.

The next stage of assessment of understanding involves the examination of factors that might mediate the perception of information. In the first instance this involves the assessment of whether the patient presents with limitations in the complexity with which the information is presented. Factors that may influence understanding include the speed of processing, syntactical and semantic complexity. With regard to speed of processing, tests of speed of reading comprehension (e.g., the Speed and Capacity of Language Processing Test (Strauss, Sherman, & Spreen, 2006)) provide useful measures for understanding written language. Information should be tailored to match the limitations of processing speed.

The Token Test provides useful measures of limitations on syntactical complexity of language. In this task, tokens of different sizes, shapes and colours are presented to individuals in a specified order. Complex instructions on what to do with the tokens are also given, and depending upon the level, instruction can / not be repeated, hence becoming more complex.

Finally, assessment of semantic understanding should be related to the semantic categories pertinent to the particular capacity being assessed. For example, to decide whether an individual has capacity to administer small amounts of money, it may be necessary to ensure that she can distinguish and comprehend differences in coinage and small notes (i.e., that her semantic understanding of coins is intact). However, it may not be relevant to assess whether or not the patient has an understanding of complex financial concepts (e.g., compound interest); which might be salient if the assessment were undertaken to assess whether the patient has capacity to administer larger sums of money (e.g., following remuneration after litigation). In addition, an individual with executive dysfunction may focus of tangential or irrelevant aspects of the information and consequently form decisions based upon a semantically biased understanding of the problem. Accordingly, psychometric tests that assess the ability to identify salient information (e.g., WCST) and inhibit irrelevant information (e.g., Stroop) may be of relevance.

In terms of an individual's ability to understand information, this is somewhat dependent on executive function being intact, and co-ordinating the various elements that are involved in understanding and utilising information. In order to understand information, it must first be assessed what type of information the individual best understands and would be able to encode and store – be this verbal, written, pictorial, and so on.

As could be expected, testing for an individual's ability to understand information could be a lengthy process, especially if the individual seems to already have made their mind up about a situation, or if they are not interested in the topic at hand (Rocchio, 1999). A comprehensive test would assess for an individual's ability to understand information in different formats, whilst being quick and easy to administer so as to not cause fatigue in the individual the test is being carried out on – it would also assess for processing speed, attention and consistency in performance (Stuss, Stethem, Hugenholtz, Picton, Pivik, & Richard, 1989). Combined tests could assess for all these issues, however, at present, a single test assessing for all these things does not exist.

Retaining Information

With respect to the retention of information, neuropsychological assessment should focus upon the retention of information over relatively short periods of time, the ability to retain information over longer periods of time and the ability to retrieve information from long-term memory when required.

Retaining information over relatively short periods of time relies on the cognitive processes of either short-term or working memory (Baddeley, 1974) being in tact. Short-term / working memory allows information to be held in the memory, just long enough for it to be utilised. For example, remembering a phone number just long enough to use it involves short-term memory processes. Hence, formal psychometric tests assessing short term memory include both forward and backward digit span (WMS-III, Wechsler, 1997), and sub-tests such as Logical Memory whereby individuals are required to recall details in a story as soon as it is told.

Further assessment should ascertain an individual's ability to retain information over longer periods of time. This process involves the ability of the individual to consolidate information from short, to long-term memory. In order for memories to be as accurate as possible, the individual needs to possess the ability to consolidate the appropriate information. Psychometric testing for consolidation of information from short to long term memory consists of word lists whereby individuals are repeatedly given words to learn, and also in visual format as pictures of faces, and auditory form of remembering details of a story after a period of time (WMS-III, Wechsler, 1997).

Finally, the ability to retrieve information from long-term memory should be assessed as most decisions require the problem at hand to be dealt with over a period of time. It is thought that memories can become de-contextualised with executive function disorders. Here, retrieval cues simply are not strong enough in order to allow the memory to be recalled from where it has been stored. Therefore, deficits are evident in retrieval strategies (Vanderploeg, Crowell, & Curtiss, 2001). This can occur due to frontal amnesia. Memory here can be consolidated, but is done so with poor contextual association, which in turn leads to the individual being unable to remember the information. Also, after sustaining a brain injury, if temporal amnesia occurs, the individual at hand would be unable to consolidate new information, hence meaning that the information would not be stored and remembered (Squire, 1986).

Psychometric tests assessing for ability to retrieve information are well documented within the Wechsler Memory Scale – Third Edition (WMS-III, Wechsler, 1997) – This whole battery assesses auditory and visual memory retrieval, on both a short and long term memory basis. Furthermore, learning slopes are calculated which would be useful in deciding approximately how many times information needs to be presented before it is stored in memory.

Many psychometric tests for assessing memory exist – too numerous to discuss them all. As could be expected, testing for different types of memory is a lengthy process – although the WMS-III has an official administration time of 30 minutes per subtest (Strauss, Sherman & Spreen, 2006), this is optimistic when testing individuals with a brain injury; administration actually takes approximately 42 minutes per subtest (Axelrod, 2001). In turn, such a lengthy test would undoubtedly lead to fatigue, especially if attention tests were also required. A comprehensive test for the retention of information would assess for both short and long-term memory, as well as assessing for different types of memory and attention.

Finally, when assessing for memory, it would also be important to assess for attention to ensure that the individual is able to sustain attention for long enough to understand the information at hand. The Test of Everyday Attention (Robertson, Ward, Ridgewat, & Nimmo-Smith, 1994) – includes eight subtests that examine selective, sustained, working memory, attentional switching, and divided attention, which could assess concentration.

Using/Weighing the Information as Part of the Process of Making the Decision

The ability to use/weigh information implies that once the information is stored in memory, it is perhaps manipulated and made sense of by the individual in order to come to some conclusion about a greater question. This also implies that the individual is able to recognise what is important and what is not from the environment.

The process of using/weighing information first involves goal selection (what is trying to be achieved), then some elements of planning (what needs to happen in order for the goal to be completed successfully), and finally monitoring (is everything going to plan, or do revisions need to be made in order for the final goal to be reached?) (Stuss & Benson, 1986). Evidence for the contribution of working memory to weighing up information in order to make a decision has been scarce. Studies that exist dissociate working memory from the decision making processes (Bechara, Damasio, Tranel, & Anderson, 1998), but do recognise decisions are made based on immediate gains as opposed to thinking about future losses (being impulsive – which is evident within individuals with a brain injury) (Bechara, Tranel, & Damasio, 2000).

Individually, the concepts of goal selection, planning and monitoring may be difficult to assess for. In terms of goal selection, unless a goal is specified, or an individual is directly asked what their goal is, it would be hard to assess for. Within certain psychometric measures, such as the Zoo Map from the BADS, planning time is allowed, however, the cognitive processes of planning the individual goes through are not vocalised. Monitoring again is another concept, which alone is hard to assess for. One attempt at assessing the concept of monitoring is the Six Elements Test, again from the BADS. Individuals are required to monitor how much time is spent on each of the six tasks so that all are attempted, and that specific rules are not broken.

Formal psychometric measures that involve the use of information being weighed up often require some element of using existing knowledge to help arrive at the ‘right’ decision. Such a measure that exists, and also relies on goal selection, planning and monitoring (Stuss & Benson, 1986) is the Wisconsin Card Sorting Test (WCST, Berg & Grant, 1948). This task involves planning and the ability to utilise environmental feedback in order to shift a pattern of thinking to complete a goal. It also monitors goal orientated behaviour and an individual's ability to control impulsivity and perseverance. Furthermore, the Tower of London / Hanoi work on the same principles as the WCST.

To conclude, in terms of an individual's ability to use/weigh information, again this is somewhat dependent on their executive function being intact, and co-ordinating the various elements that are involved in understanding and utilising information. In order to use the information, it must first be assessed for relevance in helping to solve the problem at hand. For this to happen, it needs to be coded and stored correctly, so that with cues, the right information can be accessed quickly.

The WCST appears to be the only formal test taking into account environmental factors and providing participants with cues in the hope that they shift the way in which they are thinking, which in turn should be reflected in how the task is completed. Therefore, there is room within this particular remit for new tests to be developed.

Communicating a Decision

When communicating a decision, this can be in a number of ways. It is acceptable for decisions to be communicated verbally, pictorially, by pointing, with the blinking of eyes, via sign language, and so on. In the case of an individual with a brain injury, sometimes people have such a severe injury that they are unable to communicate appropriately due to inhibition issues. Also, when asked to communicate the response more then once, answers can change which can lead to confusion (Richardson, 2001).

In order to communicate a decision, it is important that the decision is first held in the individual's memory, and then that it can be communicated in such a way that it is made clear to others. In turn, this means that potentially the language area of the brain must be utilised, and then either the words must be spoken, or provided in a different way. Attention, working memory and reasoning are also deemed as being important mechanisms when communicating a decision (Azuma, Daily, & Furmanski, 2006), as together they would allow the individual to put forward a coherent decision.

The ability to communicate a decision utilises a combination of the models of executive function. First, the working memory (Baddeley, 1974) is an important concept as it allows for the decision to be held in the mind. Grafmans model (1995) of Structured Event Complexes, could hold the hierarchical system for actually communicating and delivering the decision that has been made via the managerial knowledge units.

Within psychometric testing, all of the tests known involve a decision being communicated, be this via verbal communication, pointing, a nodding of the head, or via a drawing. The decision can be related to a question being asked, the next in a series of pictures being decided, or faces being recognised. In order to produce a comprehensive assessment of an individual's ability to communicate their decision, it would be useful to pick a variety of subtests that required responses being communicated in different ways. These subtests could be chosen at the clinician's discretion to suit the situation at hand. Useful resources exist listing various formal psychometric tests in order of what they are assessing for, which could be useful when attempting to pick the best test for the job (see Strauss, Sherman, & Spreen, 2006).

Neuropsychological measures can be useful when initially assessing for an impairment/disturbance of the mind. For example, after acquiring a brain injury, it may be useful for the clinician to find out the extent of the damage via assessing for disturbance of executive functioning, memory, attention, etc., before assessing for capacity (as this will allow the clinician to be aware of the impact the impairment may have on capacity).

Capacity is defined as being situation specific within the Mental Capacity Act (2007). Although neuropsychological assessment may not directly relate to the specific situation, results will provide some overview of the difficulties the individual may face in making a decision due to their particular impairment (for example, for an individual with memory problems due to an acquired brain injury, verbal information may not be remembered, and may potentially be better written and given to the individual so they can re-refer to it if necessary).

It is clear that neuropsychological assessment can potentially be useful in assessing for disorders that may contribute to an impairment of the mind (e.g. an acquired brain injury, psychosis), and hence leading to the individual lacking capacity to make decisions. However, results of these tests should be used in conjunction with information gained from a clinical interview, and hence, the clinicians judgement (Church & Watts, 2007) in order for an informed decision to be made.

SUMMARY AND CONCLUSION

Difficulties in assessing for executive function disabilities can be frustrating for the neuropsychologist. Even at the basic level of description, executive function defies a simple definition being observed due to the fact it is an umbrella term encompassing many sub-components. Numerous theories of executive function have been proposed which are successful at an intuitive level, but fail to indicate how the complex mental activity is organised. However, having said this, the sheer complex nature of executive function may never be amenable to one theory only.

Due to the issues surrounding conceptualising executive function, it is not surprising that the measurement of executive function has also proven to be problematic. Initially the key difficulty may have been the desire for executive functions to be associated with one particular part of the brain (i.e. the frontal lobes). However, now the difficulty with the assessment exists in the form that psychometric tests are novel, and therefore are not amenable to the test-retest situation, which is important for assessing cognitive change.

With the introduction of the Mental Capacity Act (2007) - assessing for an individual’s ability to make his or her own decisions - the assessment of executive function has never been more important. Dysexecutive syndrome can affect an individual’s ability to attend to important information, to keep a goal in mind, to monitor progress, and to make a consistent and high quality decision.

In order to observe whether or not an individual’s capacity to make decisions, and inadvertently their executive function abilities, is deemed as being sound, it is important for a psychometric test to exist in parallel forms. Parallel forms would allow for the task to look different, but to still allow the same aspects of executive functioning to be measured – hence allowing the test-retest principles to take place. In turn, this would allow the neuropsychologist to note any improvement or deterioration within the executive functioning of an individual. At present, a psychometric test that has parallel forms does not exist, indicating a gap within the battery of psychometric tests.

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EMPIRICAL PAPER

THE DEVELOPMENT AND PSYCHOMETRIC PROPERTIES OF A NEW TEST OF DECISION-MAKING FOR USE IN PEOPLE WITH ACQUIRED BRAIN INJURY

ABSTRACT

After sustaining a brain injury, severe disabilities in daily activities such as the ability to make decisions can occur. The aims of this study were to develop a test of decision-making that was sensitive to assessing for an acquired brain injury. The Escape Task was based on the executive function principle of ‘task setting and rule governed behaviour’, which monitored both spontaneous (uncued version of the task) and inductive (cued version of the task) reasoning in order for the task to be completed. The execution of the Escape Task was studied in 38 participants – 19 with an acquired brain injury, and 19 neurologically healthy controls. In the uncued version of the Escape Test, performance did not differentiate between those with a brain injury and neurologically healthy control participants. However, the cued version of the task did discriminate well between those with a brain injury and neurologically healthy controls. Task performance was found to not be particularly well associated with performance on an established measure of executive function (BADS), but was found to be relatively independent of general intellectual functioning and memory (i.e. these did not influence task performance). Preliminary findings have identified two error-making styles that could be associated with brain injury (Impulsivity Index, and Total Error Index). The overall results demonstrated the clinical utility of the test when assessing for whether an individual belongs to a healthy or brain injured group, and whether spontaneous or inductive reasoning was superior.

INTRODUCTION

There is general agreement that rehabilitation services should be targeted to the individual needs of the patient. Accordingly, a thorough assessment of impairments, disabilities and social participation is required prior to goal planning (World Health Organisation, 2001). The assessment of impairment and disability presents ongoing challenges to the neuropsychologist, of which the assessment of executive functioning continues to present particular difficulties. Executive functioning is difficult to operationalise due the inherent, abstract and multimodal nature of executive functions and the lack of agreement in the theoretical descriptions of component processes. Often the tests of executive function are based on a patient's performance in novel situations and thus are not suitable for use on a test/retest basis as the second administration of the test loses the novel aspect of the task. Therefore, there is a need for additional tests of executive functioning, which are less susceptible to practice effects and which, ideally, should be amenable to parallel versions.

The Assessment of Traumatic Brain Injury

After receiving a brain injury, numerous cognitive, behavioural and somatic complaints can occur (Ashman, Gordon, Cantor, & Hibbard, 2006). Neuropsychological assessment, in combination with information from neuro-imaging tests such as a functional Magnetic Resonance Imaging scans, are employed to assess the severity of cognitive impairment consequent to the brain injury (Wilson, Wiedmann, Hadley, Condon, Teasdale, & Brooks, 1988). In terms of assessment, objective psychological tests can provide professionals with an individual's functional strengths and weaknesses in order to aid with diagnosis, identify treatment goals and to select the most appropriate treatment methods (Lezak, Howieson, & Loring, 2004).

A thorough neuropsychological assessment should assess multiple domains of cognitive ability; a minimum assessment should include (a) measures of pre-morbid ability to act as a reference standard for the estimation of relative impairment, (b) measures of current cognitive performance (emphasising those domains of functioning that are reported as impaired by the patient and/or in the empirical literature), (c) measures of emotional impairment, (d) measures of other pertinent syndromes (e.g., PCS), and (e) a least two symptom validity tests (Moss, Jones, Fokias, & Quinn, 2003).

What Is Executive Function?

Existing definitions portray executive function as ‘higher level’ cognitive processes that coordinate and control the processing of posterior sensory/motor processing. These cognitive processes allow thoughts to be organised, the execution of tasks to planned, time to be managed, and problems to be solved (Lezak, 1995) – although this is not an exhaustive list. Hence, sustaining a brain injury can lead to dis-inhibition, perseveration, and deficits around self-awareness. Within the literature, often the concepts of executive function and frontal lobes are used interchangeably, yet the link between these terms remains unclear (Stuss & Alexander, 2000).

Although many frameworks and concepts have been put forward in order to explain executive function, ranging from basic single system theories (e.g. Norman and Shallices’

Supervisory Attentional System, 1986; Graffman, Structured Event Complex Theory, 1995, 2002), through to construct led (e.g. Baddeley and Hitchs' Working Memory Model, 1974), and the more complex multiple process theories (e.g. Stuss, Shallice, Alexander, & Picton, 1995)), at present the consensus is the executive system is fractionated (Fournier-Vicente, 2008). Accordingly, the term "executive function" refers to a variety of functionally discrete processes (Lezak, 1983; Lafleche and Albert, 1995; Banich, 2004). Although differences in terminology may exist, there remains considerable commonality in the various conceptual articulations of executive functioning. It still remains for a theory to be developed that encapsulates the full range of functioning articulated across different theoretical descriptions of executive function. Figure 6 provides a heuristic aggregate of the discrete processes that have been included in the descriptions of executive functioning (Evans, 2009).

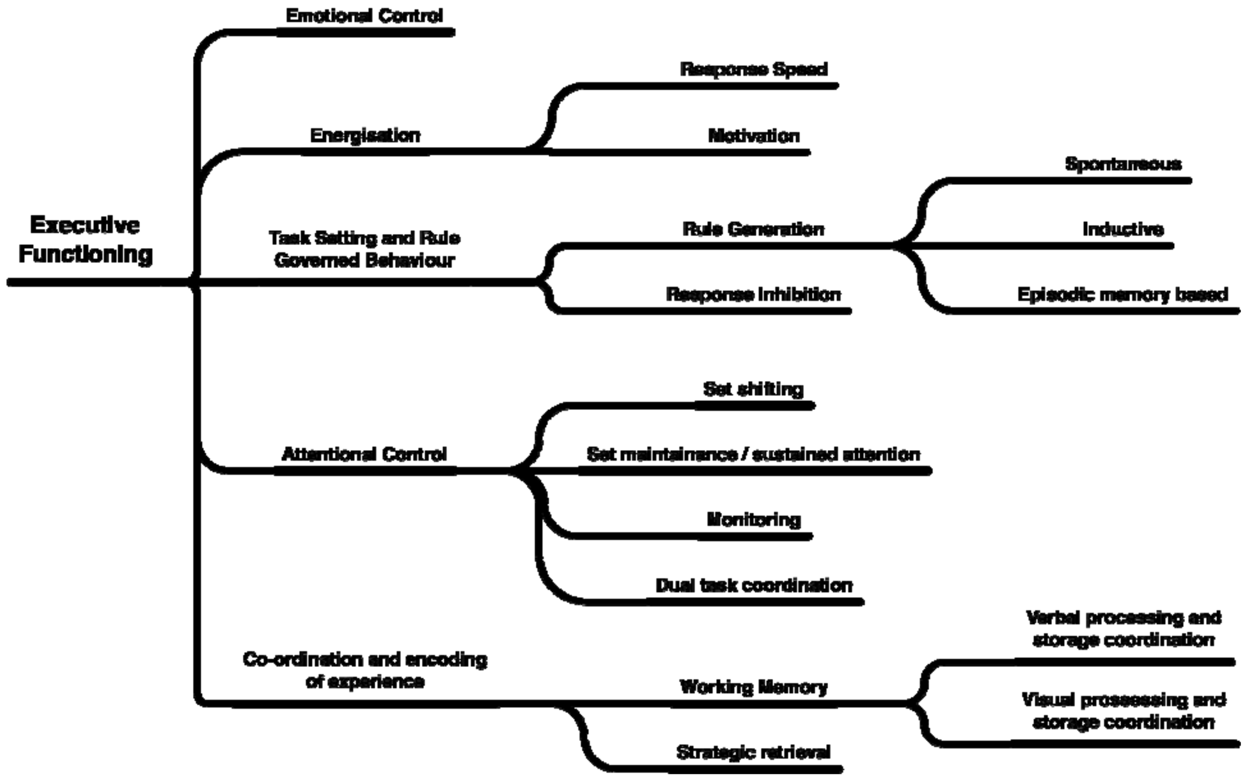


Figure 6: Heuristic aggregate of the discrete processes that have been included in the descriptions of executive functioning.

Shallice and Burgess (1996) proposed a model of particular interest on executive functioning, which emphasized the role of the executive systems in problem solving. The Shallice and Burgess model (1996) proposes three main stages in problem solving. The first stage involves the construction of a temporary new schema on the basis of induction, recall of previous solutions or a spontaneous (novel) solution. These processes are dependent upon the individual's abilities to set goals and strategies (from utilising episodic memory, inductive reasoning or novel schema generation). The second stage involves implementing the selected strategy over time and is dependent upon working memory. The third stage involves the assessment of the success of the strategy. This stage involves the monitoring of environmental feedback in terms of goal relevance. Accordingly, the

Shallice and Burgess (1996) model implies specific roles for working memory and attentional control systems (i.e., supervising the engaging, monitoring and disengaging of attentional resources).

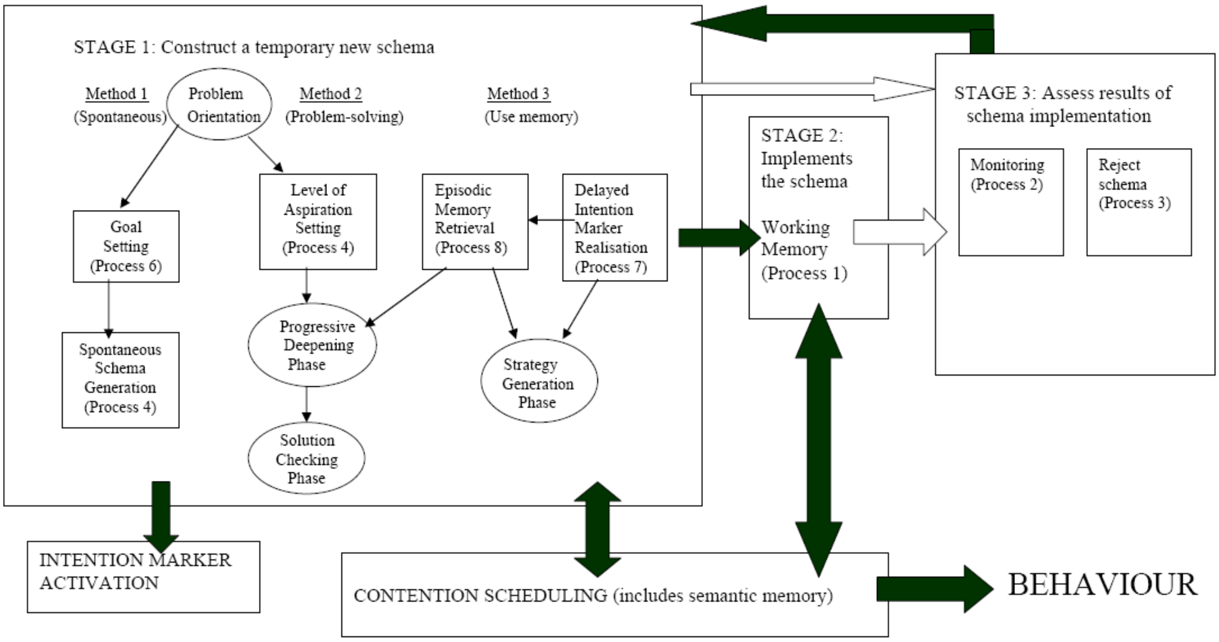


Figure 7: Shallice and Burgess Model of Executive Functioning

Given the diversity of abilities that have been described under the rubric of "executive function" it is perhaps unsurprising that multiple psychometric tests are required to adequately assess executive functioning following brain injury. It is also evident that failure on a test of executive function may result from insult to both anterior and posterior processing systems, as opposed to simply being associated with frontal lobe injury (Stuss & Benson, 1986).

Executive Dysfunction and the Challenge of Assessment

Frequently, neuropsychological assessment of executive function is achieved by placing the respondent into novel problem environments that require the respondent to generate novel solutions in which new solutions have to be generated, and prepotent responses inhibited (Wilson, Alderman, Burgess, Emslie, & Evans, 1996). Commonly cited examples of standardised neuropsychological measures of executive function include the Wisconsin Card Sorting Test (WCST), the Stroop Test, and Tower of Hanoi (Strauss, Sherman, & Spreen, 2006).

Principle amongst the requirements of an adequate psychometric test is the sensitivity of the test to detect impairment in the target population and the specificity of the test to the cognitive process of interest. Measures of executive function have therefore traditionally been expected to be sensitive to impairment to the frontal lobes. However, recent imaging studies of performance on executive tasks have implicated a range of anterior and posterior cortical regions. For example, the WCST was originally though to detect frontal lesions and executive dysfunction. However, newer evidence suggests that scores can also be affected by those with damage to non-frontal regions such as the anterior temporal lobe (see Anderson, Bigler, & Blatter, 1995). Further, evidence also exists whereby individual's with frontal damage have performed 'within normal limits' on psychometric tests claiming to examine the frontal lobes (see Saver & Damasio, 1991).

Finally, difficulties in the assessment of executive functioning also occur due to the fact that performance on standardised measures are not predictive of everyday difficulties that arise from having dysexecutive syndrome (e.g. Gioia & Isquith, 2004; Shallice & Burgess, 1991; Eslinger & Damasio, 1985). Everyday problem solving is often associated with poorly defined problem parameters and “cognitively noisy” and distracting environments. Such environments are in stark contrast to the well-defined, boundaried problems often used in clinical psychometric assessment.

Many of the component stages from the Shallice and Burgess (1996) model are already well represented in the cannon of neuropsychological measures. For example, the working memory is included in the WAIS-III and WMS-III, and can also be assessed independently using the PASAT. Less well represented in the battery of tests are measures of rule generation, whether that is spontaneous or inductive generation of rules, and the monitoring of rule governed behaviour. It may be possible to assess the generation of rules by providing unstructured versions of tasks in which solutions need to be generated from past experience. Performance can then be compared with structured versions of tasks, which reduce inductive reasoning.

To summarise, taking into account the Shallice and Burgess Model (1996), three core aspects exist when assessing executive function as related to problem solving. An adequate psychometric test should require individual’s to construct new schema, implementing the strategy that is derived, and finally assess the success of the strategy being employed. Although this is the ideal, current tests of executive function may achieve this, but can also be defined as being ‘one shot’, in that they require the respondent to solve novel problems. Repeat testing to establish change in cognitive status may not be appropriate as the task is no longer novel at the time of the second administration, resulting in an artifactual inflation of performance parameters and the consequent appearance of improved performance. One response to this difficulty might be to develop tests with parallel forms. In order to achieve parallel forms on a measure of executive functioning, the description of the elements of the problem should be varied (i.e., so that the problems are experienced as novel), but the component cognitive processes required for completion of the task should remain identical in both versions.

Regardless of the flaws within standardised measures of executive function, assessments are still useful in order to provide a gross measure of executive functioning difficulties. Standardised tests such as the Behavioural Assessment of Dysexecutive Syndrome (BADS; Burgess, Alderman, Wilson, Evans, & Emslie, 1996) may further improve on results, as neuropsychological measures with multiple sub-tests appear to tap in to several areas related to executive functioning. In summary, there is a current need for new tests of executive function that have the capacity for parallel forms and are sensitive and specific to executive dysfunction.

A new test of executive functioning - The Escape Task - that emphasises rule generation and response inhibition was created. The Escape Task was based on the problem of the Farmer that needs to get his chicken, fox and corn to the other side of a river, but the boat can only carry two objects including himself. The rules are ‘the fox can not be left with the chicken as it will eat it, and the chicken will do the same with the corn’. In the case of the Escape Task, neutral and non-offensive characters were established, along with a scenario, and finally the optimum amount of characters and moves needed were worked out by trial and error.

Relating the Escape Task to the Heuristic Aggregate of discrete processes (Evans, 2009), the task directly relates to the ‘arm’ entitled ‘Task Setting and Rule Governed Behaviour’ in that responses may be developed spontaneously or inducted from the available rules. The appropriateness of the response must be evaluated it terms of whether the individual moves the problem space toward the goal and inhibits the response if it does not.

The Escape Task was also developed with the premise that parallel forms could be created in order to assist test-retest reliability. Also change in cognitive status could be monitored without the individual’s performance being affected by practice effects.

To complete the task the respondent is required to complete a series of seventeen rule-governed moves without error. The task is presented in two conditions. In the uncued, or unstructured, condition the respondent is required to generate moves without prompts. Therefore, this condition emphasises spontaneous and inductive rule generation. In the cued, or structured condition, the respondent is required to select a response from four suggested responses, three of which contain rule violations. The difference between uncued and cued performance provides a measure of how well the respondent is able to utilise the additional structure inherent in the cued version of the task. The Escape Task has four general performance parameters (total completion time in the uncued and cued conditions, and the mean time to move in the uncued and cued conditions) and three executive functioning indices (Impulsivity Index, Total Error Index and Sequence Failure Index).

Aims

The aim of the current study is to assess the performance on the Escape Task of participants with a brain injury and neurologically healthy controls. Specifically, it is hypothesised that;

- Neurologically healthy controls will be able to complete the task
- Individual's with a brain injury will perform more poorly on the task then neurologically healthy controls
- The executive function indices will be able to differentiate participants from the neurologically healthy control group, and participants from the brain injury group, with sufficient sensitivity and specificity to allow clinical inferences to be made regarding individual assessments
- The indices of executive function from the Escape Task will show convergent validity with existing measures of executive function
- The indices of executive function from the Escape Task will show divergent validity with psychometric tests of other domains (i.e. General intellectual functioning and memory).

METHOD

Participants

Two groups of participants were included; a neurologically healthy control group, and a patient group of individuals with a brain injury. Nineteen participants volunteered for each of the two groups. The participants within the acquired brain injury group comprised of patients who were admitted to the Kemsley Division (a neurorehabilitation service), St. Andrews Healthcare, Northampton. The neurologically health group comprised of 19 individuals, with no history of a head injury requiring treatment, and were recruited from the student population at the University of Birmingham.

Measures

In addition to completing the Escape Task (described below), participants completed a number of neuropsychological and psychometric measures. For participants within the brain-injured group, this information was collected as part of their routine clinical examination. The neurologically healthy control group completed measures prior to testing with the Escape Task.

<u>Measures completed by participants with a brain injury and neurological healthy controls</u>

Wechsler Test of Adults Reading (WTAR, The Psychological Corporation, 2001). The WTAR provided a measure of pre-morbid IQ within the brain injured group, and for the neurologically healthy control group it provided a gross measure of current cognitive functioning. The WTAR was utilised as reading recognition is usually not affected by cognitive declines associated with both normal aging and brain injury. All participants were given the list of fifty words to read out aloud, and the same clinician administered the WTAR to the 38 participants.

Hospital Anxiety and Depression Scale (HADS, Zigmond & Snaith, 1993). Mood was rated by using the HADS – a self report measure giving separate anxiety and depression scores. In order to obtain each individual's emotional status at testing, the HADS was administered just prior to the task being administered. The HADS was included within the testing due to the fact that increased anxiety and depression can be associated with traumatic brain injury, and may impair cognitive functions further (Bowen, Neuman, Conner, Tennant, & Chamberlain, 1998) and may in turn act as a confounding variable.

<u>Measures completed by participants with a brain injury</u>

Behavioural Assessment of Dysexecutive Syndrome (BADS, Wilson et al., 1996). The BADS was chosen as the measure for assessing for dysexecutive syndrome as it has high ecological validity and is widely used in clinical practice. The BADS consists of six subtests and a questionnaire (Rule Shift Cards Test, Action Programme Test, Key Search, Temporal Judgment, Zoo Map Test, Modified Six Elements Test, and finally the Dysexecutive Questionnaire – DEX). The BADS authors reported profile scores are correlated with the DEX, suggesting the test is predictive of executive problems.

Wechsler Adult Intelligence Scale Third Edition (WAIS-III, Wechsler, 1999). The WAIS-III was chosen to assess the current level of cognitive functioning (in particular IQ), as again, it is high in validity and is widely used in clinical practices. Although norms for the WAIS-III have been established on an American population, due to similarities between populations in the United Kingdom and the United States of America, the test is renowned for being the most appropriate for assessing IQ.

Wechsler Memory Scale Third Edition (WMS-III, Wechsler, 1997). As with the WAIS-III, the WMS-II was chosen due to its common use within the United Kingdom. Although other measures of assessing memory exist, e.g. AMIPB, it is understood that the WMS-III still provides a more comprehensive assessment of an individual's memory (Franzen, 2000). A further reason for the choice of the WMS-III is that it is also well integrated with the WAIS-III, hence digit span, and letter number span (contained in both) need only be administered once.

The Escape Task. The task itself consisted of two versions – one requiring participants to attempt it on their own (uncued version), the other requiring it be attempted with multiple choice answers for each move (cued version). The task was made up of an A3 laminated sheet displaying what the task was, rules that would have to be followed, a picture of two rooms (one on-top of the other – making it look like two floors), eight characters (attached and movable via Velcro), and finally a task hints booklet (containing the task, the rules, and the multiple choice answers). Appendix 2 contains illustrations of all the Escape Tasks stimuli and a description of the sequence of legal moves.

Participants are instructed that a new test will be placed in front of them, and in order to complete the task, it is important that the rules are both read and understood. The Escape

Task is set in a Vets waiting room and is then placed before the participant (an A3 laminated copy, with characters). The principle investigator then reads out what exactly the task is - “There is a fire on the first floor and you need to get everyone to the safety of the floor below”, and then reads aloud the instructions. In order to reduce ambiguity and simplify task demands the rules are made explicit and are clearly stated on the task, and are visible to the participant at all times. The principle investigator also points towards each character, and states who they are so that the participant cannot confuse the characters. Participants are all asked to summarise the Escape Tasks details in order to establish they have understood what is necessary to complete the task. The uncued version of the Escape Task is then started with the words “Begin the exercise”. The principle investigator makes notes regarding moves taken, time taken to each move, the direction of the move (either up or down) and rule violations.

Once completed, the principle investigator then states “I am now going to give you the task again, but this time as well as having the rules, you will also be given a multiple choice for each move, one of which will be the correct answer, hence providing you with the correct move”. The cued version of the exercise is again commenced with “Begin the exercise”, and the principle investigator is responsible for not only reading aloud the clues, but for also turning over the page to reveal the next clue. Time taken to move is commenced after the four statements have been read. Again, moves taken, time taken to each move, direction of the move (either up or down), and rule violations are noted by the principle investigator. Once completed, all task materials are removed, and participants are asked to recall the rules, those that cannot be remembered will have cues provided. Care is taken to ensure none of the test items are in the participants' view, as this could potentially facilitate responses. Figure 8 displays how the opening board for the Escape Task should look.

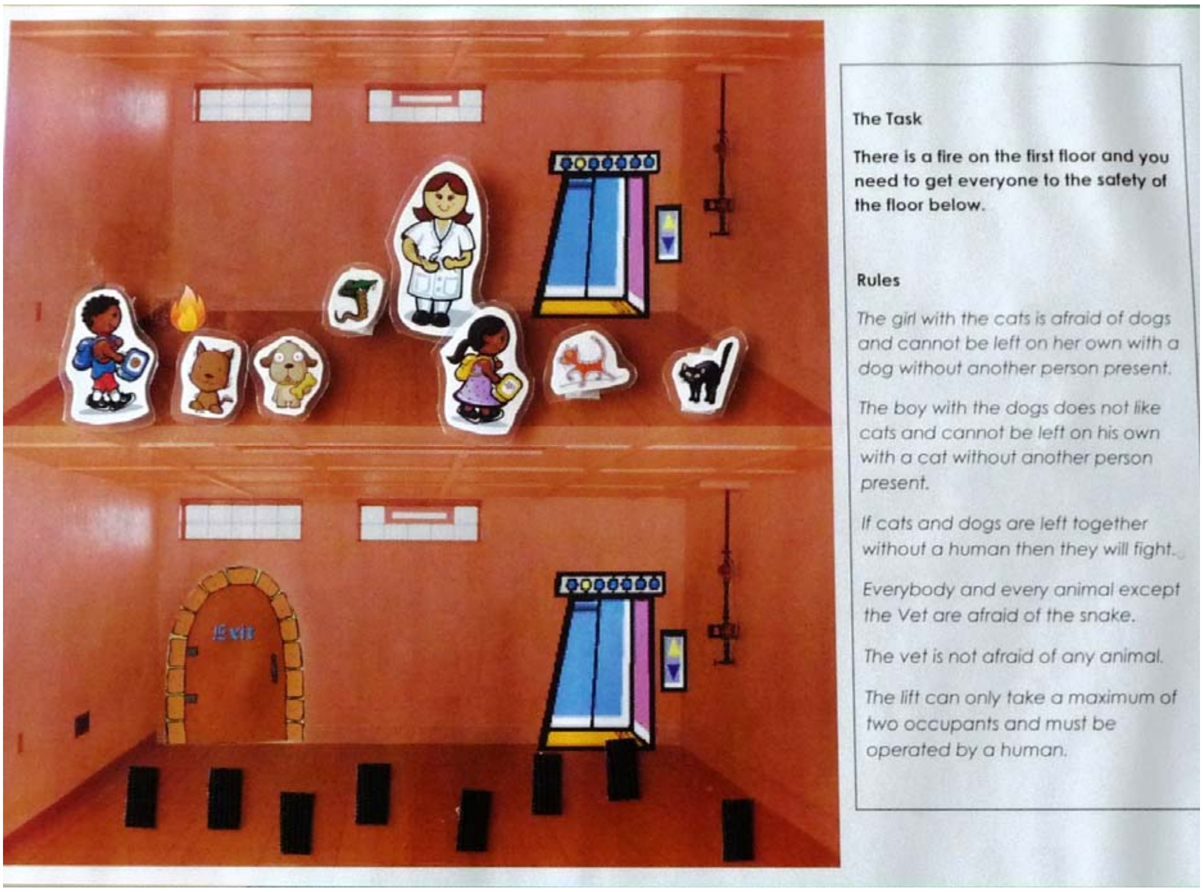


Figure 8: Opening board for the uncued and cued versions of the Escape Task.

The indices of executive functioning from the Escape Task, and how they were calculated are as follows:

- Impulsivity Index (mean time to move uncued – mean time to move cued) - examining how quickly participants responded to the information and moved the characters

- Total Error Index - (Number of sequencing errors uncued/total items completed uncued)-(Number of sequencing error cued/total number of items completed cued) indicating the number of total errors made across the two parts of the task
- Sequence Failure Index – (sequencing error score / total number of items completed) – depicting how many times only downward or upward moves were made as opposed to the down, up, down, up motion.

(In order to work out the above indices, the completion time for the uncued and cued versions of the task were recorded, the number of moves to completion was recorded, and the mean time to move (completion time / number of moves completed) was calculated).

Procedure

Neurologically Healthy Control Group

Individuals initially expressed an interest in participating in the study via contacting the principle investigator for more information from a poster (see Appendix 3). Once the individual had agreed to take part in the study, a testing time was established. Upon meeting, a brief screening interview took place, in which participants were asked to disclose if they had a history of neurocognitive risk factors (e.g. a brain injury) or developmental difficulties (e.g. dyslexia), as well as details such as age and marital status, and to sign the consent form (Appendix 4). Participants were then required to do the WTAR in order to establish IQ, and complete the HADS in order to rate mood at the time of testing. Finally the participant was required to undertake the Escape Task.

Participants in the Brain Injury Group

Individuals were identified via consent from the named Responsible Medical Officer (Appendix 5). Ward staff were then informed of the study, and finally participants themselves were approached. Participants were given twenty-four hours in order to make a decision as to whether they wanted to participate, and if so, that they should let their named nurse know. Participants were required to complete the WTAR, WAIS-III, WMS-III, BADS and HADS. Finally the participant was required to undertake the Escape Task.

Analysis of Individual Participant Performance

After both the uncued and cued versions of the task had been completed, the principle investigator reviewed the record forms (Appendix 6) in order to determine the error categories. The information was categorised according to the following – 1) the number of moves taken to complete the task (both uncued / cued), 2) number of moves taken to complete the task (both uncued / cued), 3) mean time to move (both uncued / cued), 4) *impulsivity index* – (mean time to move (uncued) minus the mean time to move (cued)) examining how quickly participants responded to the information and moved the characters, 5) *sequence failure* – (sequencing error score / total number of items completed) whereby a participant did not make moves in a down, up, down, up motion, 6) *error frequency* – how many wrong characters were moved, and finally, 7) *total error index* - (Number of sequencing errors uncued/total items completed uncued)-(Number of sequencing error cued/total number of items completed cued).

RESULTS

Participant Demographics

A total of 38 participants entered the study – 19 participants with a brain injury and 19 neurologically healthy participants. The participants in the brain injured group consisted of 13 males and six females. The age range of this sample was 18 to 53 years (M = 36.5; SD = 11). Time post-injury ranged from 10 to 252 months. Types of acquired brain injury within the sample included traumatic brain injury (n=10), hypoxia (n=4), other (n=4), and infection (n=1). Glasgow Coma Scale scores for the participants in the brain injury group ranged from 2 to 4, with post-traumatic amnesia ranging from 1 to 56 days.

The neurologically healthy control group consisted of nine males and nine females. The age range of this sample was 18 to 36 years (M = 22; SD = 5.2). An independent t-test revealed a significant difference between the ages of brain injured and neurologically healthy participants ($t[25.7]= 5.22$; $p = .000$). Table 1 depicts the last full qualification level, marital status, and occupations of the two groups. As can be seen, most demographics are well spread across the various areas, apart from the occupation of the neurologically healthy control group – which was expected to be solely students.

		Neurologically Healthy Control		Patients With A Brain Injury	
Qualification		N	%	N	%
	None	0	0	4	21.1
	GCSEs	0	0	4	21.1
	A Level	13	68.4	4	21.1
	HND	0	0	2	10.5
	Degree	6	31.6	3	15.7
	Higher Degree	0	0	2	10.5
Marital Status					
	Single	11	57.8	9	47.3
	Partner	6	31.6	1	5.3
	Widow	0	0	0	0
	Married	1	5.3	3	15.8
	Separated	0	0	2	10.5
	Divorced	1	5.3	4	21.1
Occupation					
	Professional	0	0	4	21.1
	Company Director	0	0	0	0
	Skilled	0	0	2	10.5
	Manual	0	0	5	26.2
	Clerical	0	0	1	5.3
	Customer Services	0	0	0	0
	HM Forces	0	0	0	0
	Housewife/husband	0	0	0	0
	Student	19	100	6	31.6
	Retired	0	0	0	0
	Unemployed	0	0	1	5.3

Table 1: Last full qualification, marital status and occupation of individuals with a brain injury and neurologically healthy participants.

For the participants in the brain injury group, further analysis was also carried out on how the brain injury occurred, pre-morbid and current functioning, memory levels, and whether executive function was in tact or not (see Table 2). Estimates of pre-morbid cognitive ability using the WTAR gave a range of 89 to 115 for individuals within the brain-injured group (mean = 102.5; SD = 8.1, cf neurologically healthy controls, mean = 110.3; SD = 5).

Current levels of ability, assessed via the WAIS-III were somewhat lower, with the FSIQ falling between 59 to 112 (mean = 79.6; SD = 12.8).

As mentioned, pre-morbid function was assessed via the WTAR. A between groups t-test revealed a significant difference between neurologically healthy participants and participants with a brain injuries WTAR FSIQ scores (t[30.1] = -3.57; p = .001). Upon further investigation, between groups t-tests also revealed significant differences between neurologically healthy and participants with a brain injuries WTAR VIQ scores (t[30] = -3.54; p = .001), and WTAR PIQ scores (t[29.5] = -3.55; p = .001).

Table 2: Details of Brain Injury, Age, Gender, Levels of General Ability (Pre-morbid and Current), Memory, and Executive Function Status

Participant	Description of Brain Injury	Age (at test)	Gender	WTAR FSIQ	WAIS-III FSIQ	General Memory	BADS Score
1	Hypoxic brain injury secondary to a tetanus infection and subsequent muscle spasm. GCS 4. PTA 11 days.	53	M	113	112	117	Average
2	Suffered from a subarachnoid haemorrhage. Middle cerebral artery was clipped. GCS 3. PTA 14 days.	53	M	106	71	49	Impaired
3	RTA – Frontal lobe contusions. Left hemisphere paralysis, temporary loss of vision. MRI scan indicates increased lateral ventricles CSF space widening and white matter loss. GCS 5. PTA 8 days.	32	M	89	68	59	Low Average
4	RTA – Right spastic paraparesis. GCS 7. PTA 7 days.	27	F	109	89	98	Low Average
5	Sexually and physically assaulted. Left unconscious. Sustained frontal-parietal subdural haematoma. GCS 4. PTA 7 days.	47	F	95	59	69	Impaired
6	Three month history of headaches. Post operative surgery complicated by hypopituitarism and meningitis. Underwent a right fronto-temporal craniotomy and total macroscopic excision of a craniopharyngioma. GCS 9. PTA 14 days.	34	F	103	86	49	Impaired
7	Overdosed on insulin and crack cocaine leading to hypoxia. GCS 7. PTA 3 days.	32	F	98	75	86	Low Average
8	Brain injury secondary to multiple cardiac arrests leading to hypoxia. Duration of anoxia unknown. GCS 6. PTA 21 days.	51	M	93	70	51	Impaired
9	RTA caused brain injury. Violent and aggressive behaviour. GCS 4. PTA 14 days.	41	M	109	79	45	Impaired

Participant	Description of Brain Injury	Age (at test)	Gender	WTAR FSIQ	WAIS-III FSIQ	General Memory	Executive Function
10	Suffered hypoxia following a suicide attempt. GCS 5. PTA 35 days.	42	M	115	84	45	Impaired
11	RTA – struck by a car. CT scan indicated right fronto-temporal skull fracture bones around the eye. Extradural haematoma of right frontal area of the brain. GCS 3. PTA 1 day	29	M	112	76	87	Low Average
12	Fell climbing a fire escape. Depressed skull fracture. Blood clot and portion of left frontal lobe removed. Hydrocephalus and atrophy of fronto-temporal region. GCS 2. PTA 56 days.	25	M	101	94	108	Average
13	RTA – stuck by a car. CT scan indicated structural damage to basal Ganglia (related to movement and emotional processing). GCS 3. PTA 28.	22	M	99	85	92	Low Average
14	Collapsed from ventricular fibrillation and cardiac arrest leading to hypoxia. GCS 5. PTA 21 days.	18	M	99	67	49	Impaired
15	RTA – CT scan indicated right parietal contusions with a brain stem haemorrhage. Low densities in the right external capsular and Cerebellum atrophy. GCS 4. PTA 21 days.	27	M	99	71	63	Impaired
16	Brain injury sustained after suffering a fall. GCS 4. PTA 7 days.	49	M	94	75	63	Impaired
17	Fell under the influence of alcohol and struck head. CT scan revealed Fronto-temporal subdural haematoma and a small extra-dural haematoma. Had a craniectomy. GCS 3. PTA 18 days.	33	M	95	69	82	Impaired
18	Overdose of alcohol and drugs leading to hypoxia. GCS 5. PTA 7 days.	32	F	110	84	57	Impaired
19	Suicide attempts leading to hypoxia. CT scan indicated ‘numerous subcortical lesions’. GCS 4. PTA 8 days.	47	F	112	87	88	Low Average

WAIS-III and WMS-III information presented in Table 2 was interpreted via the following descriptions – a score less than or equal to 69 was interpreted as ‘Extremely Low’; 70 – 79 as ‘Borderline’; 80 – 89 as ‘Low Average’; 90 – 109 as ‘Average’; 110 – 119 as ‘High Average’; 120 – 129 as ‘Superior’; and finally a score equal to or greater than 130 as ‘Very Superior’. WAIS-III full scale IQ scores for the brain injured participants indicated 21% of brain injured participants (n = 4) fell into the ‘extremely low’ category, 37% into the ‘borderline’ category (n = 7), 32% into the ‘low average’ category (n = 6), and 5% fell into both the ‘average’ and ‘high average’ categories (n = 1 respectively). WMS-III general memory scores for participants with a brain injury indicated 58% (n = 11) fell into the ‘extremely low’ category, 21% into the ‘low average’ category (n = 4), 16% into the ‘average’ category (n = 3), and 5% fell into the ‘high average’ range (n = 1). BADS overall profile scares indicate 58% (n = 11) of participants with a brain injury were ‘impaired’, 32% (n = 6) were ‘low average’, and 10% (n = 2) were ‘average’.

Regarding emotional status at the time of testing, HADS scores indicated participants with a brain injury scored a mean of 6.84 (4.32) for anxiety, compared with 2.95 (2.72) for neurologically healthy control participants, and 7.11 (4.97) for depression, again compared with 1.42 (1.54) for neurologically healthy controls (SD in parenthesis). A between groups t-test indicated significant differences between the two groups for both anxiety ($t[30.3] = 3.32$; $p = .002$), and depression ($t[21.4] = 4.77$; $p = .000$).

Performance of Neurologically Healthy Control Participants on the Escape Task

The question as to whether age and HADS scores correlate with the measures of executive function were assessed by calculating the Pearsons correlation between performance and executive indices, and HADS depression and anxiety, and age. Table 3 depicts the results.

	Age		HADS Anxiety		HADS Depression	
	NHG	BI	NHG	BI	NHG	BI
	r	r	r	r	r	r
Performance Parameters						
Completion time/uncued	0.13	0.05	0.56**	0.47*	0.43	0.50*
Completion time/cued	-0.14	0.20	0.50*	-0.29	0.45*	0.15
Mean time to move uncued	-0.03	0.30	0.45	0.40	0.44	0.60**
Mean time to move cued	-0.14	0.21	0.50*	-0.28	0.45*	0.18
Executive Functioning Indices						
Impulsivity Index	0.10	-0.04	0.28	0.55**	0.33	0.19
Error frequency without cues	-0.02	-0.21	0.34	-0.06	0.06	-0.31
Error Frequency with cues	-	0.31	-	-0.07	-	0.10
Total Error Index	-0.14	-0.11	0.25	-0.40	0.22	-0.36
Sequence Failure without cues	-0.36	0.19	-0.12	0.15	0.05	0.41
Sequence Failure with cues	-	-0.26	-	0.42	-	0.06
Sequence Failure Index	-0.36	0.43	-0.22	-0.15	-0.05	0.29

(*=significant at 0.05, ** = significant at 0.01)

Table 3: The correlation between Age, HADS Anxiety and HADS Depression and the indices of executive functioning in normal healthy controls and participants from the brain injury groups.

As can be seen from the table above, participants from the neurologically healthy control group did not make any errors or sequence failures when the Escape Task was presented with cues – hence correlations for those could not be calculated. Those calculations that appeared as significant (according to the p value) have been highlighted. In terms of performance parameters age was not correlated, however, anxiety and depression were. For the executive functioning indices, for the brain injured group, there was a significant correlation between anxiety and the impulsivity index (r [19] = 0.55; p = 0.01).

The mean, SD and percentile cut-offs for the performance and executive functioning measures of the neurologically healthy control group are presented in Table 4. Neurologically healthy control participants presented with both total errors and sequence errors during the uncued version of the Escape Task. However, during the cued version, healthy control participants did not present with any total errors or sequence errors.

	Mean	Std.Dev.	Percentiles					
			Impaired (5%)	Borderline (9%)	Low Average (25%)	Average (50%)	High Average (75%)	Superior (91%)
Performance Parameters								
Completion time/uncued	105.84	57.67	196	141	81	68	36	34
Completion time/cued	203.68	98.54	388	301	156	144	112	86
Mean time to move uncued	15.74	9.82	33	20.14	11.14	7.71	6.00	5.14
Mean time to move cued	11.98	5.80	22.82	17.71	9.18	8.47	6.59	5.06
Executive Functioning Indices								
Impulsivity Index	3.75	5.29	-3.18	-2.23	-0.03	2.44	7.38	13.53
Error frequency without cues	5.63	2.34	9	7	6	4	3	1
Error Frequency with cues	0.00	0.00	-	-	-	-	-	-
Total Error Index	0.79	0.23	0.036	0.086	0.286	0.555	0.800	1.000
Sequence Failure without cues	35.06	31.56	80.00	75.00	28.60	7.10	0.00	0.00
Sequence Failure with cues	0.00	0.00	-	-	-	-	-	-
Sequence Failure Index	6.94	7.50	0	0	2.90	9.38	16.00	18.75

Table 4**:** Performance of Normal Health Controls on the Indices of executive performance

All of the healthy control participants successfully completed the task in the cued condition.

Performance of Participants with a Brain Injury on the Escape Task

Task Performance Parameters

The performance of participants with a brain injury and healthy control participants on the performance, and executive functioning parameters of the Escape Task was compared using a one-way ANOVA (Table 5).

	Control		BI			
	Mean	SD	Mean	SD	F	p
Performance Parameters						
Completion time/uncued	105.84	57.67	94.26	41.78	0.50	0.48
Completion time/cued	203.68	98.54	317.26	164.88	6.64	0.01
Mean time to move uncued	15.74	9.82	18.30	8.34	0.75	0.39
Mean time to move cued	11.98	5.80	31.26	13.96	30.91	0.00
Executive Functioning Indices						
Impulsivity Index	3.75	5.29	-12.96	13.05	26.78	0.00
Error frequency without cues	5.63	2.34	4.68	1.25	2.43	0.13
Error Frequency with cues	0.00	0.00	5.95	2.66	95.29	0.00
Total Error Index	0.79	0.23	0.30	0.19	51.81	0.00
Sequence Failure without cues	35.06	31.56	65.17	24.27	10.87	0.00
Sequence Failure with cues	0.00	0.00	15.42	14.24	22.27	0.00
Sequence Failure Index	6.94	7.50	11.57	6.05	4.38	0.04

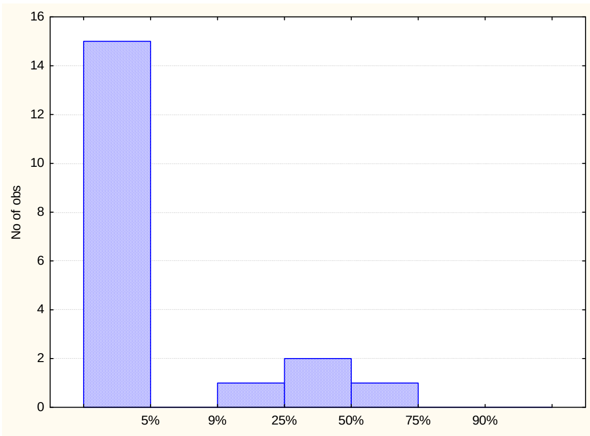
Table 5**:** Performance of participants with a brain injury and healthy control participants on performance and executive functioning parameters of the Escape Task

As can be seen from Table 5, on the performance parameters of the Escape Task neither overall completion time ($F = 0.50$, $p = 0.48$) nor mean time to move ($F = 0.75$, $p = 0.13$) evidenced a significant difference between the healthy control group and the participants in the brain injury group in the uncued condition. However, both overall completion time ($F = 6.64$, $p = 0.01$) and mean time to move ($F = 30.91$, $p < 0.01$) evidenced significantly quicker completion times in the healthy control participants during the cued condition.

Performance on the Indices of Executive functioning

With regards to the executive functioning indices, Error Frequency without cues did not reveal any significant differences between participants with a brain injury and the neurologically healthy control participants ($F = 2.43$, $p = 0.13$). However, the Impulsivity index evidenced a significant difference between the neurologically healthy controls and the participants from the brain injured group ($F = 26.78$, $p < 0.01$), which remained significant when the effect for HADS Anxiety was covaried out ($F=45.48$; $p<0.01$) suggesting that the difference between the groups was not an artefact of anxiety.

On average, the neurologically healthy control group evidenced a quicker mean time to move in the cued condition relative to the uncued condition, such that an Impulsivity Score of less than -3 is indicative of impaired performance in the neurologically healthy control group. As can be seen from Figure 9, 15 (80%) of the participants in the brain injured group scored in the impaired range on the Impulsivity Index. Indeed, only 3 (16%) of the participants from the brain injured group received a positive Impulsivity Index compared to 14 (74%) of the health control participants.



Percentiles

Figure 9: Distribution of Impulsivity Index scores for the participants from the brain injured group relative to the percentile cut-offs for the healthy control group

In order to identify the optimum cut-off for the Impulsivity Index a Response Operator Characteristics (ROC) analysis was undertaken. The area under the ROC curve for the Impulsivity Index was 0.928 (95% CI 0.795 to 0.985; $z = 9.54$, $p < 0.01$). The sensitivity and specificity of the Impulsivity Index at different cut-off criterion are presented in Table 6. If the Impulsivity Index was to be used as a screening test of cognitive impairment then the optimal cut-off was calculated as -2.23 (which provided a sensitivity of 0.78 and a specificity of 0.89). An Impulsivity Index score less than -2.23 would suggest that the individual responding is 7.5 times more likely to have been from the brain injury group.

Criterion	Sensitivity	95% CI	Specificity	95% CI	+LR	95% CI	-LR	95% CI
< -50.5179	0.00	0.0 - 17.8	100.00	82.2 - 100.0			1.00	
<=-3.4	78.95	54.4 - 93.8	100.00	82.2 - 100.0			0.21	
<=-2.2294 *	78.95*	54.4 - 93.8	89.47*	66.8 - 98.4	7.50	5.7 - 9.9	0.24	0.05 - 1.1
<=-2.2222	84.21	60.4 - 96.4	89.47	66.8 - 98.4	8.00	6.2 - 10.3	0.18	0.03 - 0.9
<=-0.0294	84.21	60.4 - 96.4	73.68	48.8 - 90.8	3.20	2.3 - 4.5	0.21	0.06 - 0.8
<=0.1786	89.47	66.8 - 98.4	73.68	48.8 - 90.8	3.40	2.5 - 4.6	0.14	0.03 - 0.6
<=0.6765	89.47	66.8 - 98.4	68.42	43.5 - 87.3	2.83	2.0 - 4.0	0.15	0.04 - 0.7
<=1.0286	94.74	73.9 - 99.1	68.42	43.5 - 87.3	3.00	2.2 - 4.1	0.077	0.01 - 0.6
<=4.9412	94.74	73.9 - 99.1	31.58	12.7 - 56.5	1.38	0.7 - 2.7	0.17	0.02 - 1.2
<=5.1	100.00	82.2 - 100.0	31.58	12.7 - 56.5	1.46	0.8 - 2.8	0.00	
<=16.7882	100.00	82.2 - 100.0	0.00	0.0 - 17.8	1.00			

Table 6**:** Criterion values and coordinates of the ROC curve for the Impulsivity Index

The participants from the brain injured group made significantly more errors in the cued version of the Escape Task than did the healthy control participants ($F = 95.29$, $p < 0.01$). None of the neurologically healthy control participants made errors during the cued condition, whereas all of the participants from the brain injured group made at least two or more errors. The distribution of cued error scores in the participants with a brain injury is shown in Figure 10.

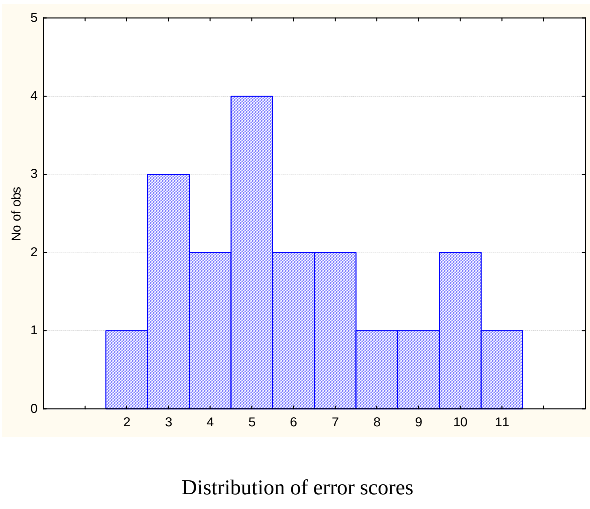


Figure 10**:** The distribution of cued error scores in the participants with a brain injury

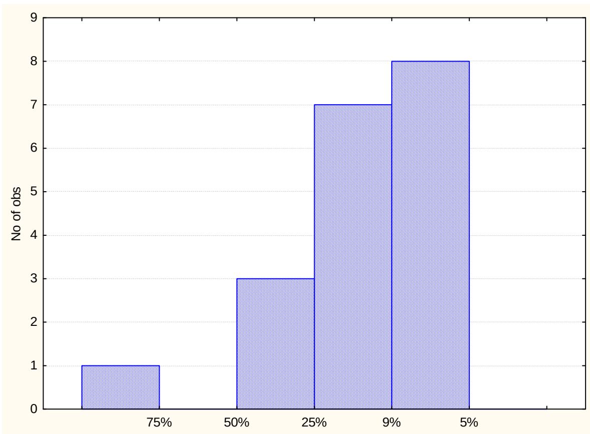
The Total Error Index evidenced a significant difference between the neurologically healthy controls and participants from the brain injured group (F = 51.81, p < 0.01). On average, the neurologically healthy control group evidence evidenced a higher Total Error Index suggesting that they made fewer errors in the cued condition than they did in the uncued version of the task.

In order to identify the optimum cut-off for the Total Error Index a Response Operator Characteristics (ROC) analysis was undertaken. The area under the ROC curve for the Total Error Index was 0.943 (95% CI 0. 0.816 to 0.99; z = 11.21, p < 0.01). The sensitivity and specificity of the Total Error index at different cut-off criterion are presented in Table 7. If the Total Error Index were to be used as a screening test of cognitive impairment then the optimal cut-off was calculated as -0.5 (which provided a sensitivity of 0.89 and a specificity of 0.95). A Total Error Index score less than 0.5 would suggest that the responded is 17 times more likely to have been from the brain injury group.

	Sensitivity	95% CI	Specificity	95% CI	+LR	95% CI	-LR	95% CI
<=0	5.26	0.9 - 26.1	100.00	82.2 - 100.0			0.95	
<=0.0357	10.53	1.6 - 33.2	100.00	82.2 - 100.0			0.89	
<=0.0714	10.53	1.6 - 33.2	94.74	73.9 - 99.1	2.00	0.5 - 7.5	0.94	0.1 - 6.4
<=0.0857	15.79	3.6 - 39.6	94.74	73.9 - 99.1	3.00	1.1 - 8.5	0.89	0.1 - 6.0
<=0.1058	21.05	6.2 - 45.6	94.74	73.9 - 99.1	4.00	1.7 - 9.6	0.83	0.1 - 5.7
<=0.1333	31.58	12.7 - 56.5	94.74	73.9 - 99.1	6.00	3.1 - 11.7	0.72	0.1 - 5.0
<=0.1618	36.84	16.4 - 61.6	94.74	73.9 - 99.1	7.00	3.8 - 12.7	0.67	0.1 - 4.6
<=0.25	42.11	20.3 - 66.5	94.74	73.9 - 99.1	8.00	4.7 - 13.7	0.61	0.09 - 4.3
<=0.2857	47.37	24.5 - 71.1	94.74	73.9 - 99.1	9.00	5.5 - 14.6	0.56	0.08 - 3.9
<=0.3077	52.63	28.9 - 75.5	94.74	73.9 - 99.1	10.00	6.4 - 15.5	0.50	0.07 - 3.6
<=0.4	68.42	43.5 - 87.3	94.74	73.9 - 99.1	13.00	9.4 - 18.0	0.33	0.04 - 2.5
<=0.4545	78.95	54.4 - 93.8	94.74	73.9 - 99.1	15.00	11.6 - 19.4	0.22	0.03 - 1.8
<=0.5 *	89.47*	66.8 - 98.4	94.74*	73.9 - 99.1	17.00	14.1 - 20.5	0.11	0.01 - 1.1
<=0.5714	94.74	73.9 - 99.1	84.21	60.4 - 96.4	6.00	4.8 - 7.5	0.063	0.007 - 0.5
<=0.6071	100.00	82.2 - 100.0	84.21	60.4 - 96.4	6.33	5.2 - 7.7	0.00	
<=0.75	100.00	82.2 - 100.0	57.89	33.5 - 79.7	2.37	1.6 - 3.5	0.00	
<=0.8	100.00	82.2 - 100.0	47.37	24.5 - 71.1	1.90	1.2 - 3.1	0.00	
<=0.8571	100.00	82.2 - 100.0	36.84	16.4 - 61.6	1.58	0.9 - 2.9	0.00	
<=1	100.00	82.2 - 100.0	0.00	0.0 - 17.8	1.00			

Table 7**:** Criterion values and coordinates of the ROC curve for the Total Error Index

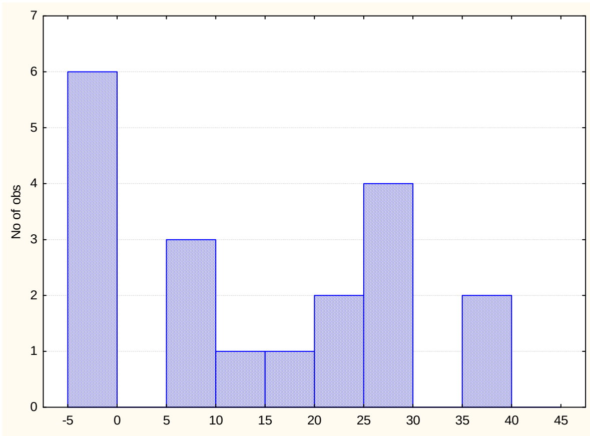
Similarly, significantly more Sequencing Failures were made by participants from the brain injury group than by the neurologically healthy control participants in both the cued (F = 22.27, p < 0.01) and the uncued (F = 22.27, p < 0.01) versions of the Escape Task. The distribution of uncued sequencing errors in the participants with a brain injury group, relative to the percentile cut-off points as derived from the neurologically healthy control participants is presented in Figure 11. This index of executive functioning did not provide a clear separation of participants with a brain injury and neurologically healthy control participants. However, 15 (78%) of the participants in the brain injury group performed in the borderline impairment and low average classification ranges, whereas only 4 (21%) of the participants with a brain injury showed a normal range of uncued sequencing scores.



Distribution of sequence errors

Figure 11**:** The distribution of sequencing errors for participants in the brain injury group relative to the percentile cut-off points.

None of the neurologically healthy control participants made any sequencing errors in the cued version of the Escape Task. The distribution of cued sequencing errors in participants with a brain injury are shown in Figure 12. Thirteen (68%) of the participants from the brain injury group performed in the impaired range for cue sequence errors.



Distribution of cued sequencing errors

Figure 12**:** The distribution of cued sequencing errors in participants with a brain injury

The Sequence Failure Error Index evidenced a significant difference between the neurologically healthy controls and the participants from the brain injured group (F = 4.38, p = 0.04). On average, the neurologically healthy control group evidenced a higher Sequence Failure Index suggesting that they made fewer sequence errors in the cued condition than they did in the uncued version of the Escape Task.

In order to identify the optimum cut-off for the Sequence Failure Index a ROC analysis was undertaken. The area under the ROC curve for the Sequence Failure Index was 0.657 (95% CI 0.485 to 0.802; z = 1.76, p = 0.08). The sensitivity and specificity of the Sequence Failure Index at different cut-off criterion are presented in Table 8. If the Sequence Failure Index were to be used as a screening test of cognitive impairment then the optimal cut-off was calculated as 4.09 (which provided a sensitivity of 0.79 and a specificity of 0.68). A Sequence Failure Index score of 4.9 would suggest that the responded is 2.5 times more likely to have been from the brain injury group. Given the relative poor sensitivity and specificity of the Sequence Failure Index, this index, in isolation, may be inappropriate as a method of classifying respondents as impaired unless the respondent is presenting with Sequence Failure Index scores in the extreme range (i.e., a negative value).

Criterion	Sensitivity	95% CI	Specificity	95% CI	+LR	95% CI	-LR	95% CI
>=-0.5071	100.00	82.2 - 100.0	0.00	0.0 - 17.8	1.00			
>-0.5071	94.74	73.9 - 99.1	0.00	0.0 - 17.8	0.95			
>1.5625	94.74	73.9 - 99.1	36.84	16.4 - 61.6	1.50	0.8 - 2.7	0.14	0.02 - 1.0
>2.9011	84.21	60.4 - 96.4	36.84	16.4 - 61.6	1.33	0.7 - 2.5	0.43	0.1 - 1.3
>4.0857 *	78.95*	54.4 - 93.8	68.42*	43.5 - 87.3	2.50	1.7 - 3.7	0.31	0.1 - 0.9
>15	31.58	12.7 - 56.5	68.42	43.5 - 87.3	1.00	0.5 - 2.1	1.00	0.5 - 2.1
>16	21.05	6.2 - 45.6	84.21	60.4 - 96.4	1.33	0.5 - 3.3	0.94	0.3 - 2.7
>18.25	10.53	1.6 - 33.2	84.21	60.4 - 96.4	0.67	0.2 - 2.5	1.06	0.4 - 3.0
>18.75	0.00	0.0 - 17.8	100.00	82.2 - 100.0			1.00	

Table 8**:** Criterion values and coordinates of the ROC curve for the Sequence Failure Index

In order to establish the utility of the Impulsivity, Total Error and Sequence Failure indices in the classification of participants as brain injured, a backwards elimination discriminant function analysis was undertaken. The discriminant function analysis converged on a model including the Impulsivity and Total Error indices. Significant univariate effects were observed for both the Impulsivity Index (Lambda = 0.41, $p < 0.01$) and the Total Error Index (Lambda = 0.57, $p < 0.01$), suggesting that these indices are providing unique contributions to the classification function.

The classification function for the prediction of brain injury was CF = (-0.095 * Impulsivity Index) + (5.27 * Total Error Index). A CF >=0.5 would classify the respondent as brain injured with a sensitivity of 0.95 and a specificity of 0.95. The classification function resulted in an overall correct classification rate of 94.73%, with one false positive and one false negative classification.

Does the Escape Task Measure Executive Functioning?

In order to assess whether the task actually measures executive functioning, Pearsons correlation were carried out between the task and the subtests of the BADS (in order to establish convergent validity). The results are shown in Table 9.

	Impulsivity Index	Total Error Index	Sequence Failure Index
Rule Shift	-.0108	.007	-.410
	p=.965	p=.979	p=.081
ActionProg	.1317	.126	-.447
	p=.591	p=.607	p=.055
Key Search	-.2802	.293	-.366
	p=.245	p=.223	p=.124
TemporalJudg	.6600	-.514	-.157
	p=.002	p=.024	p=.520
Zoo Map	.0171	-.113	-.140
	p=.945	p=.644	p=.568
SixElem	-.3074	.486	-.383
	p=.200	p=.035	p=.106
Total Score	-.1065	.143	-.550
	p=.664	p=.559	p=.015
DEXSelf	.0898	-.185	-.244
	p=.715	p=.449	p=.314
DEXOthers	-.2448	.050	-.426
	p=.312	p=.839	p=.069

Table 9: Convergent validity of the task with the BADS

As can be seen from the table above, there was a significant correlation between the Impulsivity Index and Temporal Judgment (*r* [19] = .6600; *p*=.002), the Total Error Index and Temporal Judgment (r [19] = -.514; *p* =.024) and the Six Elements Test (*r*[19] = .486; *p* = .035), and the Sequence Failure Index and the Total Score (*r*[19] = -.550; *p* = .015). Overall, it could be said that the Escape Task was not significantly correlated with the BADS.

Does the Escape Tasks Executive Function Indices Correlate With Other Cognitive Domains?

The Escape Tasks executive function indices were correlated with both indices from the WAIS-III and the WMS-III in order to look for any connections between the Sequence Failure Index, the Total Error Index, and the Impulsivity Index and them. Table 10 shows correlations between the Escape Tasks indices, and the WAIS-III indices, whilst Table 11 shows correlations between the Escape Tasks indices and the WMS-III.

	Sequence Failure Index	Total Error Index	Impulsivity Index
FSIQ	-.340 p=.154	.055 p=.823	.218 .370
VIQ	-.480 p=.038	.054 p=.827	.268 p=.267
PIQ	-.302 p=.209	-.116 p=.637	.332 p=.165
VCI	-.525 p=.025	.363 p=.139	-.075 p=.767
POI	-.485 p=0.41	.269 p=280	-.058 p=.820
WMI	-.392 p=.097	.158 p=.517	.067 p=.786
PSI	-.418 p=.085	.270 p=.278	-.078 p=.760

Table 10: The Escape Tasks correlation with the WAIS-III indices

As can be seen from the table above, the only significant correlations between the task indices and indices from the WAIS-III were between the Sequence Failure Index and the VIQ (*r*[19] = -.480; *p*=.038), the VCI (*r*[19] = -.525; *p*=.025), and the POI (*r*[19] = -.485; *p*=0.41). All correlations were significant at the 0.05 level. However, as the Total Error Index and the Impulsivity Index did not show association with general intellectual functioning, then it may be concluded that these scales and the discriminant function indices are resistant to the effects of intellectual functioning.

	Sequence Failure Index	Total Error Index	Impulsivity Index
AudRecDelTotScore	-.189 p=.439	-.177 p=.469	.205 p=.400
Auditory Immediate	-.359 p=.131	-158 p=.519	.127 p=.606
Visual Immediate	-.466 p=.045	.087 p=.724	.025 p=.919
Immediate	-.407 p=.084	.118 p=.630	.089 p=.717
Working Memory	-.211 p=.386	.204 p=.402	.005 p=.985
Auditory Delayed	-.542 p=.017	.152 p=.533	.107 p=.664
Visual Delayed	-.481 p=.037	.210 p=.389	-.241 p=.321
AudRec Delayed	-.514 p=.024	.160 p=.514	-.047 p=.848
General Memory	-.541 p=.017	-187 p=.443	-.089 p=.717

Table 11: The Escape Tasks correlation with the WMS-III indices

As can be seen from the table above, the task indices do not correlate well with indices from the WMS-III. Where correlations do occur, they are within the Sequence Failure Index of the task providing significant negative correlation with visual immediate memory (*r*[19] = -.466; *p*=.045), auditory delayed memory (*r*[19] = -.542; *p*=.017), visual delayed memory (*r*[19] = -.481; *p*=.037), auditory recognition delayed (*r*[19] = -.514; *p*=.024), and general memory (*r*[19] = -.541; *p*=.017). Once again, as per IQ, the Total Error Index and the Impulsivity Index did not show association with memory functioning, hence it may be concluded that these scales and the discriminant function indices are resistant to the effects of memory functioning.

DISCUSSION

In this study a test of executive function, which examines the principles of task setting and rule governed behaviour (particularly spontaneous and inductive rule generation, and response inhibition), was described, and its psychometric properties were examined with regards to its role within a clinical assessment. The performance of individuals from within the brain injured group showed evidence of problems of inductive reasoning, in that there was a failure to show the performance advantage in the cued condition of the task (as did the neurologically intact). In addition, the low scores obtained by the individuals with a brain injury on the Impulsivity Index is suggestive of difficulties of response inhibition. Both of these areas of impairment are incorporated within the Task Setting and Rule Governed behaviour" arm of the heuristic aggregate (Evans, 2009) depicted in figure 6.

Provisional results from the limited data collected indicate that the Escape Task does differentiate between the performance of neurologically healthy controls and those individuals with an acquired brain injury. The results indicate that the Escape Task does not correlate with memory (by excluding the Sequence Failure Index) and general intellectual functioning regarding the two indices of particular interest – the Total Error Index and Impulsivity Index. The Escape task did not correlate with the BADS, which does put into question whether the Escape Task is sensitive to executive function. However, the sensitivity and specificity of the task in assessing for brain injury, does provide promising outcomes.

Is the Escape Task sensitive to impairments in cognitive function?

Individuals with an acquired brain injury were found to make significantly more errors than neurologically healthy controls on the cued version of the Escape Task. A classification rate of 94.73%, with one false positive and one false negative classification, yielding sensitivity and specificity of 0.95. Such a degree of sensitivity and specificity is notable, and would afford a high degree of diagnostic accuracy as both a screening task, and as a measure of individual performance. Such high sensitivity and specificity is also particularly important, as it has been recognised that existing tests of frontal lobe and executive functioning appear to lack sensitivity in discriminating people with a brain injury from neurologically healthy individuals (see Alderman, Burgess, Knight & Henman, 2003).

The two indices from the Escape Task that contributed the most to the assessment of an acquired brain injury were the Total Error, and Impulsivity Indices. Results indicated the Sequence Failure Index did not contribute to the discriminate function any more then the other two indices. Also worthy of note is the Sequence Failure Index was correlated with other aspects of cognitive function (IQ and memory), potentially indicating little relationship to executive function. The Sequence Failure Index also had the poorest sensitivity and specificity as an individual index, indicating alone, this index would not be reliable in assessing for acquired brain injury group membership unless accompanied by information from other sources (e.g. the other two indices, or another test of executive function). On this basis, the Sequence Failure Index does not possess the requisite psychometric properties for inclusion as an index of executive function.

How does the task compare with other measures of executive function?

It was anticipated that the Escape Task would correlate with the BADS, an established measure of executive functioning. Upon attempting to ascertain the convergent validity with the BADS, it was found that only several significant correlations existed between the two indices of particular interest (Impulsivity and Total Error Index) and the BADS sub-tests (Temporal Judgement and the Six Elements Test), which together were unable to establish convergent validity. In terms of what the Escape Task actually shows us then, it is clear to say that it can distinguish between an individual with a brain injury or one without, but it does not clearly indicate a link between the Escape Task and executive functioning. Further research would have to take place in order to establish the Escape Tasks link with executive functioning.

Although it was hoped that the Escape Task would be highly correlated with the BADS, research has shown that executive function tests such as the Delis-Kaplin Executive Function Scale may be a more useful tool when attempting to examine for executive functioning difficulties (Manchester, Priestley, & Jackson, 2004).

It has also been documented that there are several issues arising with the use of the BADS to assess for executive function difficulties (Strauss et al., 2006). As of yet, there are no age-based norms available for each sub-test of the BADS, even though the overall score is based on the participant's age. Also, subtest performance is calculated on a crude 1-4 scale, hence making it insensitive. Finally, it has still not been established whether all of the subtests are useful in identifying dysexecutive syndrome, and evidence exists suggesting that one or two of the sub-tests are just as useful in establishing dysexecutive syndrome as the whole test (Bennett, Ong, & Ponsford, 2005).

It has been suggested that the Action Programme and Six Elements tests from the BADS are predictive of dysexecutive syndrome (Bennett, Ong, & Ponsford, 2005). If this is the case the Escape Task could be useful in testing for executive function difficulties as the the Total Error Index from the task correlated to the Six Elements Test, and the Impulsivity Index correlated to Temporal Judgment.

Is there a relationship between the Escape Task, and other cognitive function measures?

In terms of the Escape Tasks correlation with other cognitive domains (i.e. IQ), the results indicated that the two indices of particular interest (Impulsivity and Total Error Index) did not show any association with general intellectual functioning. In turn this could indicate that the Escape Task is robust to the effects of intellectual functioning. It was also established that the Impulsivity and Total Error Indices did not show any association with memory functioning – again allowing the conclusion to be made that the discriminant function indices are resistant to the effects of memory functioning. This was however expected, due to the fact that participants had the rules in front of them at all times, hence reducing the load on the working memory. In both the cases of IQ and memory correlations, the Sequence Failure Index showed significant correlations, and was hence excluded when reporting the findings. This particular index was also excluded from aiding a participant's group membership due to the fact that formal statistical analysis indicated it did not add anything more to the other two indices.

Ardila, Pineda, & Rosselli (2000) suggest that executive function may be dissociable from other cognitive functions. The present study seemed to support the assumptions of Ardila et al. (2000) in that no significant relationship between the Escape Tasks executive function indices and the WAIS-III were identified. This suggests that the indices of the Escape Task, and the IQ and consequent indices were sensitive to different aspects of the individual's performance.

The WMS-III has been correlated with the WCST, and was found to have a high correlation with working memory, which one would expect as working memory has traditionally been depicted as a part of executive function (Strauss et al., 2006). However, excluding the Sequence Failure Index the present study found no significant relationship between the tasks indices and the WMS-III. The independence of the executive function indices and memory function was partially expected as participants explicitly had all rules and the purpose of the Escape Task in front of them so that the task would not be overcomplicated and demand that participants remember all of the information. However, this result must be considered with caution as further exploration is required between tests of executive function and their relationship to memory (Strauss et al., 2006).

Implications

A new test of executive functioning has been described and examined with regards to the sensitivity and validity of the task. The Impulsivity Index and the Total Error Index have been shown to be sensitive to brain injury, insensitive to general intellectual function and memory, and to provide information on different aspects of the performance data. Accordingly, these indices fulfill the psychometric criteria for clinical interpretation.

The main implication of the Escape Task is after further data collection, results permitting, a new test of executive function could be published. The present study potentially provided insight into decision-making processes, planning, problem solving, and rule-governed behaviour. Although sample sizes were limited, it was still adequate enough to accommodate comparisons between participants from the brain injured and neurologically healthy control groups.

Limitations of the Study

The interpretation of participant's performance on the Escape Task is ambiguated by the relatively small sample sizes employed in the study. However, it should be noted that significant discrimination between the participants in the brain injury group, and neurologically healthy controls was achieved regardless of limitations to the sample size. Nevertheless, further investigation of these performance parameters is required in a larger and appropriately stratified population, especially in terms of providing normative data for the Escape Task.

From the two groups the data was collected from, it is clear that the groups were not well matched. In turn, the data should be treated with caution as the two groups did consist of totally independent people. Had time not been of the essence, matched pairs would have been the preferred method of collecting data as it would have allowed for some extraneous variables to be controlled for (e.g. educational level). Using a single participant design could potentially mean without extra research, it would not be viable to generalise the results to other people, as the individuals used could have been classified as a group of over performers, and therefore outliers.

Furthermore, the participants comprising the brain injury sample presented with mixed posterior and anterior brain injuries. Accordingly, it is not possible to empirically demonstrate from this data that performance on the Escape Task is sensitive to anterior insult alone. The correlations between the Escape Task and measures of intellectual and memory function suggest that the Escape Task may be sensitive to executive dysfunction, and consequently to anterior brain injury. However, this hypothesis would require more stringent evaluation in a sample of identified unique anterior and posterior brain injuries.

Although the neurologically healthy control percentile ranking (Table 4) adds to the evidence base for the Escape Task, the information has to be considered with caution. The percentile ranks are based on 19 individuals from a student population, which in turn itself may have skewed the data, leading to skewed percentile ranks. This leads to inconsistency between the means for the indices and the average percentiles being present (e.g. mean for impulsivity index is 3.75, and the Average (50%) percentile falls at 2.44). In line with this, any associated histograms would also need to be treated with caution. In order to gain a more conclusive and established percentile ranking, significantly more neurologically healthy control participants would have to be tested, with an emphasis upon testing individuals from a variety of ages, educational backgrounds, religions, etc. In turn this would allow for more reliable norms and percentile ranks to be established, leading to higher reliability and validity rates.

Finally, the Escape task presented in this study was a paper and pen task. Time permitting, it would have been interesting to establish whether the scenario in the Escape Task could be altered, without actually changing the task parameters (making parallel forms of the task). In turn this would increase the test-retest reliability co-efficient. I.e. the task would remain the same, and simply the scenario and characters would change giving the Escape Task a novel feel. The complexity of the task could also be altered by increasing and decreasing the number of characters, which in turn would directly impact upon the number of moves required to complete the task. A computer version of the task would be beneficial as the time to move would be recorded more accurately, and the package could also calculate the index scores for the clinician. This would also free up the clinicians time in order to make behavioural observations of participants whilst doing the task.

CONCLUSIONS

In conclusion, this preliminary study regarding the utility of the Escape Task, which is simple and robust enough for it to be used in clinical practice, and normative data has been collected on an appropriately large sample. It would in deed appear that the task can offer a quick and sensitive measure of whether an individual has a brain injury (the Escape Task takes approximately 15 minutes to administer).

Clearly, the development of the Escape Task is still only in a preliminary stage. There is much to be gained from continued investigation of the tasks methodology – both in the context of assessing within the remit of brain injury, and other areas where executive function can be temporarily disabled due to ill health, such as in the area of mental health – and its contribution to assessing executive function.

There is a continuing need for reliable and valid measures of executive function, especially with regard to assessment of decision-making. Statutory regulations regarding the assessment of capacity may necessitate assessment of problem solving abilities, ability to inhibit prepotent responses, and the individual's ability to understand and implement instructions. The Escape Task may be a useful addition to the cannon of psychometric tests assessing such issues.

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APPENDIX 1

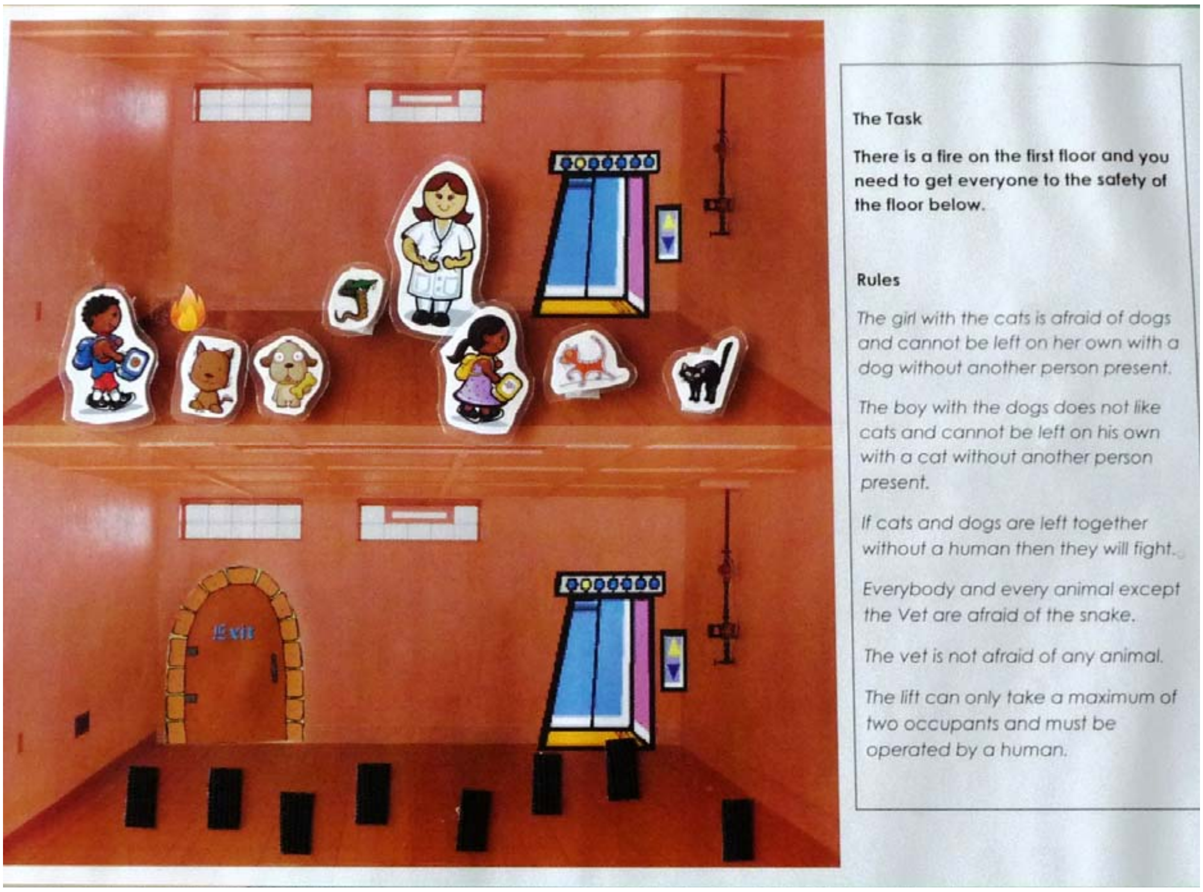
LITERATURE REVIEW SEARCH CRITERIA

The literature search was conducted using the PUBMED and PsychInfo databases. The initial search utilised the terms “traumatic brain injury”, “frontal lobes”, “executive function” and “implications”. After ascertaining the search was too broad due to the fact that hundreds of articles were available, the search was further refined with the key words “decision making” and “capacity”. This search located 137 articles, of which 29 were of direct use. Further articles were located via references within the selected articles, which led to a further 10 articles being of use.

Information with regards to the Capacity Act was obtained from current government and legislative documents (such as the executive summary, and lay copies of the Act), which were readily available both on the Department of Health website, and from copies located within the Kemsley Unit (St Andrews Healthcare, Northampton).

The Escape Task - APPENDIX 2

Opening board of the Escape Task – Both uncued and cued versions



<u>DESCRIPTION OF THE TASK</u> Version 01102008

1. Before being given the task, consent will be sought from participants, and their right to stop or withdraw from the experiment will be explained.
2. Once consent has been granted, participants will be given a brief introduction to the test – test will still not be in sight. Participants will be told:
   "I am going to put in front of you a new test that looks at decision making. It is important that you read the rules in order to be able to complete the task. Just try your hardest. If you are unsure of what to do, please re-read the rules".
3. The test will then be placed in front of the participant.
4. The researcher will then point out to the participant the rules, the characters, and how the figures are to be moved between the floors.
5. If the participant asks for help, the researcher must point out the rules only.
6. Once the participant is finished, or if they are unable to finish after trying, they will be given a second chance to complete the task.
7. The researcher will say something along the lines of:

"I am now going to give you the task again, but this time as well as having the rules, you will also be given a multiple choice for each move, one of which will be the correct answer, hence providing you with the correct move".

8. The multiple choices will then be placed in front of the participant. As the Participant makes each move, the researcher will produce the next set of answers.
9. Once the test has been completed, the participant will be given a 5 minute break, and then the (cued) recall items will be asked.
10. "I am now going to ask you to recall the rules you had. Can you remember them and tell me. Do not worry if you cannot remember them, I will give you a clue".
11. Once this has been done, the participant will be thanked for their time, with a view of being informed of the outcome of the research.

Task Hints

There is a fire on the first floor and you need to get everyone to the safety of the floor below.

Rules

The girl with the cats is afraid of dogs and cannot be left on her own with a dog without another person present.
The boy with the dogs does not like cats and cannot be left on his own with a cat without another person present.
If cats and dogs are left together without a human then they will fight.
Everybody and every animal except the Vet are afraid of the snake.
The vet is not afraid of any animal.
The lift can only take a maximum of two occupants and most be operated by a human.

Move Rules

1 Down The girl could go down with the snake
The vet could go with a cat and dog
The vet could go with the snake
The boy could go down with the snake

1 Up *Vet could go up*
Snake could go up

2 Down *The vet could take one of the cats*
Two cats could go together
The two dogs could go together
One cat and one dog could go together

2 Up The vet could go back up with the cat
The snake could go back up with the cat
The snake could go up on its own
The vet and the snake could go back up

3 Down The snake could take a dog down
The girl could take a cat down
The snake could go down
The dogs could take each other down

3 Up *The girl could go up on her own*
The two cats could go up together
The girl could take up one cat
The girl could take up both cats

4 Down The vet could take the girl down
The two dogs could go down together
The boy and girl could go down together
The snake could take a dog down

4 Up The girl could come back up
The boy could go back up
The two cats could go up together
The boy could take up a cat

5 Down The two dogs could go down together
The vet could take a dog down
The boy could take the snake down
The vet and snake could go down together

5 Up The vet could bring the girl up
The girl could take the snake up
The girl could go up on her own
One cat could go up

6 Down *The boy and girl could go down*
The girl could take a dog down
One dog could go down
Two dogs could go down with the girl

6 Up The girl could go back up
The boy could go back up
The vet could go back up
The snake could go back up

7 Down One dog could go down on its own
Two dogs could go together
The boy could take down one of his dogs
The boy could go down on his own

7 Up *The vet could take the snake up*
The boy could take a cat up
The girl could take the dog up
The snake could take a cat up

8 Down The snake could take a dog down
The snake could go down on its own
The vet could go down on her own
The vet could take the dog down

8 Up The two cats could go up together
The vet could go up on her own
The two dogs could go up together
No body could go up

9 Down Only the vet and snake left to come down!!!!
(correct moves are in italics)

(Cued) Recall for Decision Making Task (response sheet)

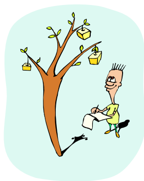
Version 01102008

Rule	Recall Y/N	Cued Recall	Recall Y/N
The woman with the cats is afraid of dogs and cannot be left on her own with a dog without another person present.		There was a rule about **the woman being afraid of something.** Do you remember what that rule was?	
The man with the dogs does not like cats and cannot be left on his own with a cat without another person present.		There was a rule about **the man not liking something.** Do you remember what that rule was?	
If cats and dogs are left together without a human then they will fight.		There was a rule about **cats and dogs being left together.** Do you remember what that rule was?	
Everybody and every animal except the Vet are afraid of the snake.		There was a rule about **who was afraid of the snake.** Do you remember what that rule was?	
The vet is not afraid of any animal.		There was a rule about the **vet and her animal fears.** Do you remember what that rule was?	
The lift can only take a maximum of two occupants and most be operated by a human.		There was a rule about **the lift and who could operate it, and how many could go in it.** Do you remember what that rule was?	

Recruitment poster for neurologically healthy control participants - APPENDIX 3

UNIVERSITY OF BIRMINGHAM

Interested in taking part in research?



Looking for healthy volunteers to participate in research to understand the difficulties faced by people living with brain injury.

Medical professionals need to understand these difficulties in order to develop better ways of assisting people with brain injury in managing their daily lives, and decision making. One way of doing this is through the use of *neuropsychological* tests, which look at how well people cope with decision making, planning, solving problems, and remembering things.

A new neuropsychological test has been designed, and healthy volunteers are being sought to find out how useful this test would be if it were to be used in clinical practice.

The test involves making decisions based on information given, in order to solve a problem. In addition, volunteers will be asked to complete a short reading test, and fill in two very brief questionnaires. The whole process will take <u>less than half an hour</u>.

If you are interested in volunteering, all that we ask is that you please check that you fulfil all of the following requirements:

- Aged 18 years or over
- Have <u>never had a head injury</u> (requiring treatment)
- Have no diagnosed medical conditions involving the brain, e.g. stroke
- Have half an hour your time that you are willing to use to take part in research

To find out more information and/or to arrange an appointment, please contact:
Jyoti Kainth Evans on **07967 568701** or **jke606@bham.ac.uk**

Neurologically healthy control letter, information sheet and consent form – APPENDIX 4

UNIVERSITY OF BIRMINGHAM

School of Clinical Psychology
Edgbaston
Birmingham
B15 2TT

Tel: 0121 414 7124
Fax: 0121 414 4897

<Date>

Dear <name >,

Re: The Development and Psychometric Properties of A New Test of Decision Making

Thank you for your interest in participating in this study, which I will be conducting at the University of Birmingham.

Further details about the study are provided in the information sheet accompanying this letter.

If you decide that you would like to participate, please contact me on <telephone> or <email> to arrange a convenient appointment.

Yours sincerely,

Jyoti Kainth Evans
Clinical Psychologist in Training

UNIVERSITY OF BIRMINGHAM

Participant Information Sheet

Development of a New Test to Examine Decision Making
Principle Investigator – Jyoti Kainth Evans

You may contact Jyoti Kainth Evans at
The University of Birmingham, Department of Clinical Psychology, Tel: 0121 414 7124
Or Kemsley Division, St Andrews Hospital Tel: 01604 616000

What is the purpose of the study?

Some people who have suffered damage to the brain experience difficulties with making decisions, plans and solving problems. Medical professionals often group these skills together using the term *Executive Functioning.* People who experience problems with these skills often find it more difficult to manage everyday life. I am carrying out this research to understand how these difficulties affect the daily lives of people living with brain injury. I hope that this information will help develop better ways of assisting people to cope with their difficulties in making decisions in particular.

In order to assess whether my neuropsychological test would be useful in clinical practice, a neurologically healthy participants group is needed to be compared against a brain injured participants group. This allows us to see if the test can differentiate between those who have a brain injury, and those who do not.

Who Has Reviewed The Study?

This study has been reviewed by lecturers, clinicians and the Research and Enterprise Director at the University of Birmingham. It has also been reviewed and approved by Leicestershire, Northampton & Rutland Research Ethics Committee 2.

What will be involved if you choose to take part in the study

If you agree to participate in this research, you will be asked to carry out a test that involves decision making, planning, problem-solving and memory. The test involves you carrying out a task at the University of Birmingham. In addition, you will be asked to complete a short reading test and fill-in two short questionnaires. The tests are not unpleasant to perform. You will not be asked to do anything that causes you either pain or discomfort, or puts you at a risk greater than you would face in your everyday life. If you agree to help me, you will be seen once for about an half an hour.

One of the questionnaires assesses for anxiety and depression. If your scores on this questionnaire are ok, then you will be able to take part in the study. If your scores are high on this questionnaire you will not be able to take part in this study, as research suggests that if an individual is anxious or depressed, it can impair their performance on neuropsychological tests. At this point, the researcher will be able to sign-post you to services which you may find useful (such as your GP, student support services, or voluntary services) for support or help.

What is the purpose of the study?

Some people who have had a brain injury find it hard to make decisions after looking at all of the options available. I am carrying out research to see how this difficulty can affect people's lives.

The purpose of the study is to see if the test of decision making can actually show that an individual has difficulties when making a decision. In turn, perhaps new methods could be looked at to aid with the decision making process.

What will happen to the information that you provide

The information collected will be kept securely under lock and key. It will also be treated with confidentiality under the data protection act. The information will be used only for the purposes of this research and it will not be shared with outside agencies. If the research findings are eventually published, I will make sure that there are no personal details that could identify you.

Your rights as a participant

You should understand that you do not have to take part in this research. No-one will mind if you chose not to take part and you do not have to offer an explanation. You may also leave the study at any time you wish, and you may do so without saying the reasons why.

Medical research is covered for mishaps in the same way as for patients undergoing treatment in hospital, which means that compensation is only available if negligence occurs. In other words, you may have grounds for legal action if you are harmed by someone's actions.

If you wish to complain, or are unhappy about the way that you have been treated during the course of this study, the normal National Health Service complaints mechanisms will be available to you.

If you have any further questions, please feel free to ask me.

Thank you
Jyoti Kainth Evans

Version 2 06/12/2008

UNIVERSITY OF BIRMINGHAM

CONSENT FORM

Development of a New Test to Examine Decision Making

Principal Investigator **Jyoti Kainth Evans**

This form should be read in conjunction with the Participant Information Sheet, version no. **2** dated **06/12/2008**

Please Tick:

1. I confirm that I have read and understand the information sheet dated 06/12/2008 (version 2) for the above study. I have had the opportunity to consider the information, ask questions, and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that information collected during the study may be looked at by individuals from St Andrews Healthcare and the University of Birmingham. I give permission for these individuals to access my information related to the study. ☐

4. I agree to take part in the above study. ☐

Signature of participant ……………………………….. Date ………………………..
(Name in BLOCK LETTERS)

I confirm that I have explained the nature of the tests, as detailed in the Information Sheet, in terms which in my judgement have been understood by the participant.

Signature of Investigator ……………………………… Date ……………………….
(Name in BLOCK LETTERS)

Signature of Witness ………………………………….. Date ……………………….
(Name in BLOCK LETTERS)

Relationship to participant: ……………………………

When completed, 1 for participant, 1 for researcher site file

Brain injury participants letters, information sheet and consent form – APPENDIX 5

St Andrew's Healthcare
Northamptonshire . Essex . Middlesex

<Date>

Dear <name of patient>,

Re: The Development and Psychometric Properties of A New Test of Decision Making

I am writing to tell you about some research that will be taking place at the Kemsley Division. The research considers how decision making abilities are affected by having a brain injury. It is hoped that this information will help develop better ways of assisting people to make decisions.

The research will be conducted by Jyoti Kainth Evans, Clinical Psychologist in Training, from the University of Birmingham.

Further details about the study are provided in the information sheet accompanying this letter.

Jyoti Kainth Evans is currently looking for people who are willing to take part in the research. If you are interested in taking part, please inform <Named nurse/Keyworker> who will then contact her.

Yours sincerely,

Prof. Nick Alderman
Consultant Clinical Neuropsychologist

UNIVERSITY OF BIRMINGHAM

Participant Information Sheet

Development of a new test to examine decision making
Principle Investigator – Jyoti Kainth Evans

You may contact Jyoti Kainth Evans at
The University of Birmingham, Department of Clinical Psychology, Tel: 0121 414 7124
Or Kemsley Division, St Andrews Hospital Tel: 01604 616000

What is the purpose of the study?

Some people who have had a brain injury find it hard to make decisions after looking at all of the options available. I am carrying out research to see how this difficulty can affect people's lives.

The purpose of the study is to see if the test of decision making can actually show that an individual has difficulties when making a decision. In turn, perhaps new methods could be looked at to aid with the decision making process.

Who Has Reviewed The Study?

This study has been reviewed by lecturers, clinicians and the Research and Enterprise Director at the University of Birmingham. It has also been reviewed and approved by Leicestershire, Northampton & Rutland Research Ethics Committee 2.

What will be involved you choose to take part in the study

If you agree to take part in the study, I will come and visit you to make sure you understand what the test is about, and will be glad to answer any questions you may have. Once you are sure you want to take part, I will ask you to sign a consent form, and will then arrange a time with you to meet again so we can do the test.

· If you agree to take part in this research, you will be asked to carry out a test that involves decision making, planning, problem-solving and memory. The test involves you carrying out a task in your hospital ward. You will also be asked to fill in two short questionnaires.

· The tasks comprise: reading some information in order to help you solve a task, to have a go at the paper task on your own, and then to have a go at the task with multiple choice answers.

· The test is not unpleasant to perform. You will not be asked to do anything that causes you either pain or discomfort, and you will not be asked to do anything that is riskier than the things that you do in your everyday life.

· If you agree to help me, you will be seen once for about an hour. I will make sure that the time you are seen will not interfere with your daily ward activities.

· With your permission, I will also access information that has been collected during your routine clinical examination. The information that I will be looking at concerns the details of your brain injury and the results of psychological tests.

What will happen to the information that you provide

· The information collected will be kept securely under lock and key. It will also be treated with confidentiality under the data protection act. The information will be used only for the purposes of this research and it will not be shared with other people.

· If the research findings are eventually published, I will make sure that there are no personal details that could identify you.

Your rights as a participant

· You should understand that you do not have to take part in this research. No-one will mind if you chose not to take part and you do not have to offer an explanation. You may also leave the study at any time you wish, and you may do so without saying the reasons why.

· If you do not wish to take part, or if you wish to leave the study, this will not affect your normal care or future treatment.

· Medical research is covered for mishaps in the same way as for patients undergoing treatment in hospital, which means that compensation is only available if negligence occurs. In other words, you may have grounds for legal action if you are harmed by someone’s actions.

· If you wish to complain, or are unhappy about the way that you have been treated during the course of this study, the normal National Health Service complaints mechanisms will be available to you.

If you have any further questions, please feel free to ask me.

Thank you
Jyoti Kainth Evans

PATIENT CONSENT FORM

Development of a New Test to Examine Decision Making

Principal Investigator **Jyoti Kainth Evans**

This form should be read in conjunction with the Patient Information Sheet, version no. **2** dated **06/12/2008**

Please Tick:

1. I confirm that I have read and understand the information sheet dated 06/12/2008 (version 2) for the above study. I have had the opportunity to consider the information, ask questions, and have had these answered satisfactorily. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time without giving any reason, without my medical care or legal rights being affected. ☐

3. I understand that relevant sections of my medical notes and data collected during the study may be looked at by individuals from St Andrews Healthcare and the University of Birmingham. I give permission for these individuals to access my records. ☐

4. I agree to my RMO doctor being informed of my participation in this study. ☐

5. I agree to take part in the above study. ☐

Signature of participant ……………………………….. Date ………………………..
(Name in BLOCK LETTERS)

I confirm that I have explained the nature of the tests, as detailed in the Information Sheet, in terms which in my judgement have been understood by the participant.

Signature of Investigator ……………………………… Date ……………………….
(Name in BLOCK LETTERS)

Signature of Witness ………………………………….. Date ……………………….
(Name in BLOCK LETTERS)

Relationship to participant: ……………………………

When completed, 1 for participant, 1 for researcher site file, 1 (original) to be kept in medical notes.

Memorandum to be signed by Responsible Medical Officer

MEMORANDUM

Kemsley Division

To: <NAME OF RMO>

From: Jyoti Kainth Evans

Date:

CC:

Re : Development and Psychometric Properties of a New Test of Decision Making

---

Following our earlier conversation, I would like to reiterate formally our discussion.

As the Responsible Medical Officer, it is your belief that
<NAME OF SERVICE USER>

Is in a position to consent, and will therefore be invited to participate in the study as we agreed

Please sign this memo to confirm this is your position. Thank you for your time and assistance.

Kind regards,

<SIGNATURE OF RESEARCHER>

<SIGNATURE OF RMO>

Information recording forms for the Escape Task - APPENDIX 6

TASK RECORDING SHEET WITHOUT CHOICES (1)

- Please note down all moves made, indicating whether the move is down (D) or up (U) in the Move Made section. Please also note the characters that are moved.
- A 'rule break' is classified as a move that violates once of the rules, with or without the participant realising.
- If a participant corrects his/her move please note this down.
- Please score an 'interpretation failure' only if the participant asks you to help them. This is because all rules are written in front of them.
- Please record task failure only if the individual is unable to complete the task.
- Place totals at the bottom of the page.

Participant Number………………………………………………

Move made (write characters)	**Correct? Y/N**	**Error- Rule break (a rule has been broken)**	**Error – Interpretation Failure (task is misunderstood)**	**Error – Task Failure (task has not been completed)**	**Time taken to move (to nearest second)**

Total:

Incorrect Moves

Rule breaks

Interpretation Failure

Task Failure

Time Taken

Version 01102008

TASK RECORDING SHEET WITH CHOICES (2)

- Please note down all moves made, indicating whether the move is down (D) or up (U) in the Move Made section. Please also note the characters that are moved.
- A ‘rule break’ is classified as a move that violates once of the rules, with or without the participant realising.
- If a participant corrects his/her move please note this down.
- Please score an ‘interpretation failure’ only if the participant asks you to help them. This is because all rules and clues are written in front of them.
- Please record ‘task failure’ only if the individual is unable to complete the task.
- Place totals at the bottom of the page.

Participant Number……………………………………………

Move made (write characters)	**Correct? Y/N**	**Error- Rule break (a rule has been broken)**	**Error – Interpretation Failure (task is misunderstood)**	**Error – Task Failure (task has not been completed)**	**Time taken to move (to nearest second)**

Total:

Incorrect Moves

Rule breaks

Interpretation Failure

Task Failure

Time Taken

Ethics Approval – APPENDIX 7

Leicestershire, Northamptonshire & Rutland Research Ethics Committee 2
1 Standard Court
Park Row
Nottingham
NG1 6GN

Telephone: 0115 8839428
Facsimile: 0115 9123300

18 December 2008

Mrs Jyoti K. Evans
Trainee Clinical Psychologist
University of Birmingham
School of Psychology - Clinical Section
Edgbaston
Birmingham
B15 2TT

Dear Mrs Evans

Full title of study: **Development and Psychometric Properties of A New Test of Decision Making**
REC reference number: **08/H0402/146**

Thank you for your letter of 10 December 2008, 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 and Vice-Chair.

Confirmation of ethical opinion

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

Ethical review of research sites

The Committee has designated this study as exempt from site-specific assessment (SSA). The favourable opinion for the study applies to all sites involved in the research. There is no requirement for other Local Research Ethics Committees to be informed or SSA to be carried out at each site.

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 at NHS sites ("R&D approval") should be obtained from the relevant care organisation(s) in accordance with NHS research governance arrangements. Guidance on applying for NHS permission is available in the Integrated Research Application System or at http://www.rdforum.nhs.uk.

Approved documents

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

Document	*Version*	*Date*	
Covering Letter		07 November 2008	
Protocol	Delegated 1	01 October 2008	
Investigator CV			
Application	AB/143329/1	05 November 2008	
Letter of invitation to participant – Patient	1	01 October 2008	
Investigator CV: Dr C Jones			
Letter of invitation to participant - Neurologically Healthy Group	1	01 October 2008	
Task Description	Delegated 1	01 October 2008	
RMO Memorandum		01 October 2008	
Interview Schedules/Topic Guides	Delegated 1	01 October 2008	
Compensation Arrangements		01 August 2008	
Task Sheet	Delegated 1	01 October 2008	
Peer Review		24 September 2008	
(Cued) Recall for Decision Making Task (Response Sheet)	Delegated 1	01 October 2008	
Task Recording Sheet With Choices	Delegated 1	01 October 2008	
Task Choices	Delegated 1	01 October 2008	
Task Recording Sheet Without Choices	Delegated 1	01 October 2008	
Recording Sheet for Patient Biographical Information	Delegated 1	01 October 2008	
Protocol for healthy volunteers with a positive HADS score	1	06 December 2008	
Response to Request for Further Information		10 December 2008	
Participant Consent Form: Neurologically Healthy Group	2	06 December 2008	
Participant Consent Form: Patient	2	06 December 2008	

Participant Information Sheet: Neurologically Healthy Group	2	06 December 2008	
Participant Information Sheet: Patient	2	06 December 2008	
Advertisement	2	06 December 2008	

Statement of compliance

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

After ethical review

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

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

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

- Notifying substantial amendments
- Progress and safety reports
- Notifying the end of the study

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

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

08/H0402/146	**Please quote this number on all correspondence**

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

Yours sincerely

Mr Ken Willis / Miss Jeannie D McKie
Chair / Committee Coordinator

Email: jeannie.mckie@nottspct.nhs.uk

Enclosures: "After ethical review – guidance for researchers" *SL- AR2 for other studies*

Copy to: *Mr Brian Berry*
R&D office for care organisation at lead site – St Andrew's

Notes to authors (Neuropsychological Rehabilitation) – APPENDIX 8

INSTRUCTIONS FOR AUTHORS

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Your covering email must include full contact details (including email), the title of the journal to which you are submitting, and the title of your article.

All manuscripts must be accompanied by a statement confirming that it has not been previously published elsewhere and that it has not been submitted simultaneously for publication elsewhere.

All manuscripts should be submitted in American Psychological Association (APA) format following the latest edition of *Publication Manual of the APA* (currently 5th edition).

Authors will normally receive a decision on their papers within three months of receipt, and if accepted they will normally be published six to nine months later. The date of receipt of the manuscript will be printed. Where minor revision of a paper is requested the original date of receipt will appear, provided that a satisfactory revision is received within one month of the request. Otherwise it will bear the revised version date.

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FORMAT

Typescripts. The style and format of the typescripts should conform to the specifications given in the *Publication Manual of the American Psychological Association* (5th ed.). Typescripts should be **double spaced** with adequate margins, and numbered throughout. The title page of an article should contain only:

(1) the title of the paper, the name(s) and address(es) of the author(s);
(2) a short title not exceeding 40 letters and spaces, which will be used for page headlines;
(3) name and address of the author to whom correspondence and proofs should be sent;
(4) your telephone, fax and e-mail numbers, as this helps speed of processing considerably.
(5) 3-5 keywords

Abstract. An abstract of 50-200 words should follow the title page on a separate page.

Headings. Indicate headings and subheadings for different sections of the paper clearly. Do not number headings.

Acknowledgements. These should be as brief as possible and typed on a separate page at the beginning of the text.

Permission to quote. Any direct quotation, regardless of length, must be accompanied by a reference citation that includes a page number. Any quote over six manuscript lines should have formal written permission to quote from the copyright owner. It is the author's responsibility to determine whether permission is required from the copyright owner and, if so, to obtain it. (See the bottom of the page for a template of a letter seeking copyright permission.)

Footnotes. These should be avoided unless absolutely necessary. Essential footnotes should be indicated by superscript figures in the text and collected on a separate page at the end of the manuscript.

Reference citations within the text. Use authors' last names, with the year of publication in parentheses after the last author's name, e.g., "Jones and Smith (1987)"; alternatively, "(Brown, 1982; Jones & Smith, 1987; White, Johnson, & Thomas, 1990)". On first citation of references with three to six authors, give all names in full, thereafter use first author "et al.". If more than one article by the same author(s) in the same year is cited, the letters a, b, c etc. should follow the year.

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

Books:

Baddeley, A. D. (1999). *Essentials of human memory*. Hove, UK: Psychology Press.

Chapter in an edited book:

Plomin, R., & Dale, P. S. (2000). Genetics and early language development: A UK study of twins. In D. V. M. Bishop & L. B. Leonard (Eds.), *Speech and language impairments in children: Causes, characteristics, intervention and outcome* (pp. 35-51). Hove, UK: Psychology Press.

Journal article:

Schwartz, M. F., & Hodgson, C. (2002). A new multiword naming deficit: Evidence and interpretation. *Cognitive Neuropsychology, 19*, 263-288.

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

Figures. Figures should only be used when essential. The same data should not be presented both as a figure and in a table. Where possible, related diagrams should be grouped together to form a single figure. Figures should be drawn to professional standards and it is recommended that the linear dimensions of figures be approximately twice those intended for the final printed version. Each of these should be on a separate page, not integrated with the text. Figures will be reproduced directly from originals supplied by the author(s). These must be of good quality, clearly and completely lettered. Make sure that axes of graphs are properly labelled, and that appropriate units are given. Photocopies will reproduce poorly, as will pale or broken originals. Dense tones should be avoided, and never combined with lettering. Half-tone figures should be clear, highly-contrasted black and white glossy prints.

Black and white figures are included free of charge. Colour figures are not normally acceptable for publication in print -- however, it may be possible both to **print** in black and white and to **publish online** in colour. Colour figures will only be printed by prior arrangement between the editor(s), publisher and author(s); and authors may be asked to share the costs of inclusion of such figures.

The figure captions should be typed in a separate section, headed, e.g., "Figure 2", in Arabic numerals. Instructions for placing the figure should be given in parentheses in the text, e.g., "(Figure 2 about here)". More detailed *Guidelines for the Preparation of Figure Artwork* are available from the publisher: Psychology Press Ltd, 27 Church Road, Hove, East Sussex BN3 2FA, UK (Email: authorqueries@tandf.co.uk).

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

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

Other tests should be reported in a similar manner to the above example of an *F* -ratio. For a fuller explanation of statistical presentation, see pages 136-147 of the *APA Publication Manual* (5th ed.). For guidelines on presenting statistical significance, see pages 24-25.

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

AFTER ACCEPTANCE OF PUBLICATION IN THE JOURNAL

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Your prompt consideration of this request would be greatly appreciated.

Yours faithfully

Volume contents and author index. The list of contents and the author index for the whole of the year's issues are published in the last issue of the year of each journal. For ***Neuropsychological Rehabilitation***, this is issue 6 (December).

EXECUTIVE SUMMARY

THE DEVELOPMENT AND PSYCHOMETRIC PROPERTIES OF A NEW TEST OF DECISION-MAKING FOR USE IN PEOPLE WITH ACQUIRED BRAIN INJURY

Overview

This study was conducted by Jyoti Kainth Evans in partial fulfilment of the requirements for the Doctorate in Clinical Psychology, at the University of Birmingham. The research was supervised academically by Dr Christopher Jones, and clinically by Professor Nick Alderman.

Background

The incidence of people receiving a traumatic brain injury is on the increase. This in turn has led to government guidelines being issued in order to provide both families and medical staff with guidance on the matter (Department of Health, 2005). The biggest issues with sustaining a traumatic brain injury are initially the mortality and morbidity rates, and consequently if the individual does survive, the fact that there is no specific treatment route – each case has to be treated as a unique case (Moppett, 2007).

In order to get to the point of a clear rehabilitation goal, comprehensive neuropsychological assessment is needed to indicate where the rehabilitation is needed and whether the individual themselves can be a part of the decision-making process. In particular, the issue of decision making has come to the forefront with the introduction of the Mental Capacity Act (2007), which states that an individual should be presumed to have the capacity to make decisions, unless it is proven otherwise. However, 'proving' whether someone has capacity or not is a lengthy and potentially complicated process.

Literature Review

Executive function is an 'umbrella' term for higher levels of cognitive functioning such as decision making, planning, monitoring, inhibition, and working memory, but to name a few. This literature review examines theories of executive functioning and the associated assessment instruments. The review of theories allowed for a heuristic aggregate of discrete processes to be established, acting as a thesaurus for the term executive function. In addition, the review examined how current measures of executive function might be able to help with the assessment of an individuals level of capacity to make decisions; based on the principle of understanding the information relevant to the decision, retaining the information, using/weighing the information as part of the decision making process, and communicating the decision (Department of Health, 2007). It was concluded that one test of executive function alone would not allow a clinician to conclusively establish that an individual either lacked or had the capacity to make decisions, due to the one-shot nature of current tests.

Instead it was found that it would be beneficial for a test to exist that is available in parallel forms in order to allow test and retest to take place in a short place of time, to be used in conjunction with information from a clinical interview and the clinician's clinical judgement.

Research Paper

Carrying out a battery of neuropsychological tests in order to assess for an individuals executive function ability, especially within a brain injured population, could lead to fatigue, the individual withdrawing from the process totally, or non-compliance – all of which would affect the outcome for the individual. Therefore, a niche exists within this area of assessment, which would benefit from a neuropsychological assessment that assesses the core issues of executive (dys)function, whilst taking minimal amount of time to complete.

Aims. The aims of this study were to develop a test of decision making that was sensitive to assessing for an acquired brain injury. The Escape Task was based on the executive function principle of 'task setting and rule governed behaviour', which monitored both spontaneous (uncued version of the task) and inductive (cued version of the task) reasoning in order for the task to be completed. The study also aimed to explore the following - Is the Escape Task sensitive to impairments in cognitive function?; How does the Escape Task compare with other tests of executive function?; and is there a relationship between the Escape Task, and other cognitive function measures?

Method. Nineteen individuals with an acquired brain injury and nineteen neurologically healthy individuals participated in the study. For participants with an acquired brain injury, WTAR, WAIS-III, WMS-III, BADS, and HADS scores were collected. For neurologically healthy controls, WTAR and HADS scores were collected. All participants carried out the two sections of the Escape Task – first without cues, and then with cues. Ethical approval was gained from Leicestershire, Northamptonshire and Rutland NHS Research Ethics Committee 2.

Results. In the uncued version of the Escape Test, performance did not differentiate between those with a brain injury and neurologically healthy control participants. However, the cued version of the task did discriminate well between those with a brain injury and neurologically healthy controls. Task performance was found to not be particularly well associated with performance on an established measure of executive function (BADS), but was found to be relatively independent of general intellectual functioning and memory (i.e. these did not influence task performance).

Conclusions. Preliminary findings have identified two error making styles that could be associated with brain injury (Impulsivity Index, and Total Error Index). The overall results demonstrated the clinical utility of the test when assessing for whether an individual belongs to a healthy or brain injured group, and whether spontaneous or inductive reasoning was superior. This preliminary study regarding the utility of the Escape Task, which is simple and robust enough for it to be used in clinical practice, with a range of individuals with a brain injury is indeed, encouraging (a classification rate of 94.73%, with one false positive and one false negative classification, yielding a sensitivity and specificity of 0.95 was particularly worthy of note). Clearly, the study is still only preliminary, and there is much to be gained from continued investigation of the tasks methodology.

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